# ELEMENTARY
# TEXT-BOOK OF ZOOLOGY.

# PREFACE TO SECOND EDITION.

IN this Edition it has been made possible to add about 50 new Figures as well as a short description of a type of *Rotifera*. On the other hand, a careful revision of the text and former figures has enabled me to keep the volume to practically the same bulk as before without the loss of any essential parts.

I have freely availed myself of the numerous criticisms which have been offered, and desire to thank many friends for their valuable aid in this respect, among whom I would specially mention Professor W. C. McIntosh, Professor Marcus Hartog, Dr H. Gadow, Dr Fraser Harris, Dr E. W. G. Masterman, and Mr F. H. Marshall: to Professor Cossar Ewart I am indebted for permission to reproduce a figure (Fig. 330) from his work on the "Development of the Horse": lastly, I have to thank my wife for the preparation of a comprehensive Index.

A word of explanation upon the arrangement of the subject-matter may be found useful. Part I. deals in separate chapters with the general facts and principles of the subject and its relationship to kindred sciences: in Part II. the student is expected to study the types of each group in the museum, or in the laboratory, as the case may be, and then to proceed to the generalisations under each phylum or class. This must ever be the natural way of learning the subject, and has therefore been adopted here.

ARTHUR T. MASTERMAN.

NEW SCHOOL, SCHOOL OF MEDICINE,
EDINBURGH.

# PREFACE TO FIRST EDITION.

IF we may accept the hypothesis, generally acknowledged, that efficiency of the few is attained only under the stimulas of the inefficient many, no apology is needed for another addition to the already numerous text-books in existence. It is questionable whether it is possible to provide the student with a book which can entirely take the place of oral instruction, but it is intended in the present work to provide the necessary accompaniment to a well-ordered course of lectures and practical work. Although there are still science "Schools" in existence in which practical instruction is entirely neglected or relegated to unqualified teachers, the importance of this branch of education is being generally recognised: hence I have written the discriptions of the types in this book, and in the majority of cases have drawn the figures, with the animals (or the parts of them) before me, in order that the work may be found an aid to dissection as well as a preparation for written examinations.

So far as is possible the scope of the work has been largely modelled on the subject "Natural History," as interpreted in our Scottish Universities, and the method of instruction by types has been adhered to as conducing to the best results.

In a volume of this kind which must necessarily hold in view the necessities of examinations, there is a very definite limit to the introduction of new features of classification or even of new types, and a continual check has to be applied to the inclination to add this or that new result, For example, the temptation to partition such time-honoured institutions as the *Ganoidei* and some of the Orders of Insects is almost irresistible. However, our whole system of Zoological Classification is in such confusion that the adoption of any particular scheme appears at present to be purely arbitrary.

The thanks of the publishers and myself are due to Messrs A. & C. Black, Messrs Cassell & Co., and Messrs Methven & Co., to whom we are indebted for the use of a number of the illustrations. I have also to record my indebtedness to my friend and assistant, Mr R. A. Staig; he has not only contributed several of the illustrations, but, in addition, his lengthy experience of zoological teaching in the Edinburgh Medical School has been productive of some valuable hints and suggestions. To Dr Ashworth I am also under an obligation for kindly reading over the portion relating to the Lobworm, which is largely illustrated from his original work.

I have also to thank Dr Traquair, F.R.S., for kind permission to reproduce certain of the specimens in the Edinburgh Museum of Science and Art.

Finally, I must express my thanks to Messrs E. & S. Livingstone, who have met my wishes with respect to illustrations and to the general scope of the work with a rare liberality.

ARTHUR T. MASTERMAN.

NEW SCHOOL,
SCHOOL OF MEDICINE.

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# ZOOLOGY.

## INTRODUCTION.

ZOOLOGY means, in its widest sense, the study of animals. For the sake of convenience we may take as our unit of study either the whole animal kingdom, a single animal, or any intermediate group between these two extremes. Let us first take the animal, or individual organism, and notice how its study may be approached. We can inquire into the manner in which the organism is put together or constructed by an examination of its external appearance and by a dissection of its interior. This study of structure is called MORPHOLOGY. It is often, though somewhat unnaturally, divided into ANATOMY or morphology of organs, and HISTOLOGY or morphology of cells and tissues. Our real knowledge of an organism would, however, be very limited if we did not go on to inquire the meaning of its structure and how it works. This study of function is called PHYSIOLOGY. Structure and function go hand in hand throughout the constitution of the organism, and it is impossible to study the one without due consideration of the other.

The next important fact about an organism is its *inconstancy* in structure and function. The organism passes through a definite sequence of changes from birth to death. The greatest and most obvious changes are those which occur during early life called *development*, and the study of these is termed EMBRYOLOGY.

Embryology includes morphology and physiology of the young, or more rapidly changing, organism.

In morphology, parts of an organism which have a similar structure and structural relationship to other parts are called *homologous*, whilst in physiology those parts which perform a similar function are termed *analogous*. In many cases one part may be both analogous and homologous with another.

Again, if we take a number of structural characters in an organism, these can be divided into *inherited* and *acquired*. In the former case, the structure is such because of the tendency in all organisms to resemble their parents; in the latter it is such because of the capacity of an organism to adapt itself to its surroundings.

Hence the study of an organism resolves itself into the following:—

1. MORPHOLOGY or study of form. < ANATOMY. / HISTOLOGY.
   (Homology = similarity in structure.)
2. PHYSIOLOGY or study of function.
   (Analogy = similarity in function.)
3. EMBRYOLOGY or study of the early history of an organism.

We now have to consider the relationship of an organism to other organisms. The comparison of structure, function and development can obviously be called Comparative Anatomy, Comparative Physiology, and Comparative Embryology respectively, but there are one or two other points to notice.

If we take two closely allied organisms their structure will show a certain degree of similarity or homology. This similarity must in each case be due to one of two causes. It is either due to the fact that the two organisms are descended from a common ancestor, and therefore *inherited*, or it is due to the two organisms having lived in a similar environment, and thus *acquired*. The form of homology in the first instance is termed *homogeny*, and that in the latter *homoplasy*.*

Two brothers owe their similarity to homogenetic or inherited homology, and two sailors owe their similarity in uniform, gait and habits to homoplastic or acquired homology. The distinction is clear when such a crude example is given, but, if we assume the sailors to be brothers, one would be in great doubt whether to ascribe some similarities to one or to the other kind of homology.

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* The terms *Palingenetic* and *Cænogenetic* are often used in much the same sense as homogenetic and homoplastic.

Let us now pass to the consideration of the animal kingdom as an organic whole. We may here discern a certain parallel to the organism. The study of the structure of the animal kingdom as such means the arrangement or distribution of animals on the world's surface, or, as it is usually termed, GEOGRAPHICAL DISTRIBUTION. The past history of animal life is in a similar manner called GEOLOGICAL DISTRIBUTION, whilst physiology finds its parallel in the relationship of the animal kingdom to the inorganic world, for which there is no inclusive term.

We can at least see this structural parallelism :—

| *ORGANISM.—* | *ANIMAL KINGDOM.—* |
|---|---|
| Morphology. | Geographical Distribution. |
| Embryology. | Geological Distribution. |

By keeping this clearly in mind we are assisted in a consideration of Distribution.

# Part I.

# GENERAL ZOOLOGY.

◆

## CHAPTER I.

### *LIVING MATTER.*

RETURNING to the animal kingdom, we find that there runs throughout it a presence of the primary basis of life called *protoplasm*. The living part of all organisms (animals and plants) consists of this substance. So far as we know, protoplasm cannot, at least under present conditions of the earth's surface, arise spontaneously from less highly organised materials, although it is one of the primary properties of protoplasm that it can add to its bulk or *grow* by the aggregation to itself of non-living materials.*

According to present views, the whole animal world owes its origin to growth of some primeval protoplasm, and the constituent organisms owe their being to the fact that this growth is discontinuous.

The moving, thinking organism which we call a man differs only in degree and not in kind from the isolated and undifferentiated mass of protoplasm known as *Amœba*. Hence it is of primary importance that we should get a clear idea of the physical, chemical and physiological properties of this basis of life, living protoplasm.

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* This statement does not preclude the possibility of living matter having been in the past evolved from non-living matter; but of this *we know absolutely nothing*.

**Physical Properties of Protoplasm.**—Protoplasm, or living matter, is in itself usually colourless and transparent. Its consistency varies considerably according to the amount of contained water. There can be little doubt that it is a physical as well as a chemical complex. Differential staining and other methods reveal the existence of a meshwork of more stable and less fluid substance, sometimes termed *spongioplasm*, and a more mobile and less easily stained substance, sometimes termed *hyaloplasm*, which permeates the interstices of the spongioplasm. Scattered throughout the hyaloplasm is a number of minute bodies, readily stained and of unknown composition. They are called *microsomata* and may be connected with the nutrition of the more essential living parts of the protoplasm, as they decrease and are absorbed when the protoplasm is starved. This idea is often extended to include the hyaloplasm, which is thus regarded as merely a nutrient fluid bathing the primary living spongioplasm, but there is little certainty regarding these points. It is important to notice that at least three physical constituents of protoplasm can be discerned, and that its mobility, fluidity and reactivity are directly related to the amount of contained water. A number of the physical phenomena of protoplasm, such as its mobile movements and change of shape, can be closely imitated by small isolated oil drops and other devices.

**Chemical Properties of Protoplasm.**—It is very generally accepted that protoplasm is not a definite chemical substance but a complex of several. If it be a single substance it must be of so great instability as to break up into its constituents as soon as it is formed. Analysis shows that protoplasm consists of a number of substances called *proteids*, which are sufficiently definite to come within the power of chemical manipulation. They may be the first decomposition-products of protoplasm itself, or they may be the actual constituents of protoplasm. In other words, protoplasm is either a physical or a chemical aggregate of proteids.

Proteids are of very complex molecular composition, and are known by definite chemical tests (such as the production of a violet colour with copper sulphate and sodium hydrate, and a pink precipitate on boiling with Millon's reagent). They are divided into groups according to their degrees of solubility. Common proteids are albumens, albuminoids, and peptones. The essential constituents of proteids are the elements carbon, oxygen, nitrogen, hydrogen and sulphur, the average percentage composition of albumen being—

| | | | |
|---|---|---|---|
| Carbon | about | 53 | per cent. |
| Oxygen | " | 23 | " |
| Nitrogen | " | 15 | " |
| Hydrogen | " | 7 | " |
| Sulphur | " | 2 | " |

Thus the physical and chemical evidence is in favour of regarding living matter or protoplasm as an aggregate of substances of high chemical constitution and of an unstable nature.

## Primary Vital Functions of Protoplasm.

1. ALIMENTATION.—Living matter has always, if in suitable surroundings, the property of aggregating to itself foreign substances which are termed *foods*, and thereby increasing in bulk. The food is by necessity of an insoluble or non-diffusible kind, and it has, before it is available for *absorption* into the substance of the protoplasm, to undergo a process of reduction to a soluble condition. This process is known as *digestion* and has, by its nature, to be conducted in the body of the organism.

2. MOVEMENT.—Living protoplasm exhibits the power to move, owing to its contractility. A drop of oil moves according to the forces of gravity and capillarity, but an organism can move in a definite direction in response to other stimuli. The movement is essentially the same throughout and consists of shortening of the organism, or part of the organism, in one or more directions and a corresponding lengthening in others. The movement implies a loss of kinetic energy and the setting free of heat.

3. SENSATION.—Protoplasm is *irritable* or capable of responding to certain stimuli. The demonstration of this fact lies in the preceding property of movement, for outside our own consciousness we have no means of recognising the effect of a stimulus except by its result in movement.

4. EXCRETION.—Movement implies a loss or expenditure of energy which is furnished by the chemical decomposition of protoplasm or its constituents, resulting in its turn in the formation of waste products or *excreta*. These products have to be removed, and, in the simplest organisms, they are extruded at the limiting surface. The carbon of proteids is removed in combination with oxygen, as carbonic acid gas, and the hydrogen and oxygen as water. For this purpose oxygen is taken into the interior of the body. This form of excretion is often called *Respiration*. It involves the introduction of oxygen and the extrusion of carbonic acid gas. In addition, the nitrogen and sulphur of the proteids leave the body, in combination with other elements, as complex nitrogenous compounds, such as urea. Thus the waste products are of two kinds, non-nitrogenous and nitrogenous, removed by *Respiration* and *Nitrogenous Excretion* respectively.

The taking-in of oxygen during respiration should be carefully distinguished from the ingestion of "food," as also should excretion from the egestion of waste residue or fæces. Ingestion and egestion are processes of alimentation, which itself is part of the building-up of fresh protoplasm, whereas respiration and excretion are processes essentially connected with the breaking-down or consumption of protoplasm. A starving man will, unfortunately for himself, continue to respire and excrete though the alimentary function be in abeyance.

## Secondary Vital Functions of Protoplasm.

1. GROWTH.—It is quite conceivable that protoplasm might carry on the above functions in such a manner that the waste and repair were exactly balanced, in which case the original protoplasm would remain the same in size and other relations. This, however, is not the natural state of matters. Given suitable conditions, an organism will acquire a credit account with nature, and the result is a continued production of fresh protoplasm and increase in bulk or *growth*. In the case of living organisms growth takes place by addition throughout the bulk of the body, and is called growth by *intussusception* to distinguish it

from increase in size of a non-living body (*e.g.*, a crystal), which is merely an addition to the surface and is called growth by *accretion*. We have seen that efficiency of the vital functions depends upon the relationship of surface to bulk in the organism, for alimentation and excretion depend upon this proportion. But increase in bulk involves a reduction of the proportion between surface and bulk to the detriment of the former. Here we have a definite limit to the bulk of an organism beyond which it cannot go without further differentiation.

2. REPRODUCTION.—Further growth necessitates an increase of surface by division of the organism. Division results in the production of two organisms from the former one, usually termed *Reproduction.* Reproduction alternating with growth are the two vital phenomena which result in life on this earth presenting itself as a series of organisms or individuals, which have a common origin in primeval protoplasm. This perpetual organic continuity of protoplasm throughout the animal kingdom is a most important principle in connection with the problems of heredity and descent.

**Food of Animals.**—The foods of animals and their nature have an important bearing on structure and function. We may distinguish four kinds :—

1. PROTEIDS.—These form the most important foods. We have already seen that they are highly organised, that they contain carbon, hydrogen, oxygen, nitrogen and sulphur, and enter into the very composition of protoplasm. White-of-egg or albumen is a common example.

2. CARBOHYDRATES.—Carbohydrates differ in many respects from proteids. Not the least is their chemical composition, into which carbon, hydrogen and oxygen alone enter. Starches and sugars are familiar examples.

3. FATS.—Fats are complex compounds of glycerine and some fatty acid. They contain only carbon, oxygen and hydrogen. Dilute alkalies decompose them into glycerine and soap.

4. MINERALS.—The minerals include water and numerous mineral salts in solution, such as common salt and phosphates of lime.

The three first kinds of food are mostly, by the very nature of things, insoluble, and the process of digestion consists essentially in reducing them to a soluble state. If this occurred at the surface of the organism the soluble substances would be largely lost, hence the insoluble food has to be taken within the organism. Here we may say in a very general way that the insoluble proteids are converted into soluble peptones, insoluble carbohydrates into sugars, and fats into soaps and glycerine, though in some cases the fats are emulsified or broken into minute particles which are then carried into the organism.

The next important point to notice is the constitution of foods. Leaving out of consideration the minerals, which are only of secondary importance, we find that the simplest animal-foods are complex compounds of carbon, hydrogen and oxygen, and that others have these elements with the addition of nitrogen, sulphur and phosphorus. An animal is incapable of building up its protoplasm from any simpler products. It would be easy to supply an animal with mineral salts alone, such as nitrates, sulphates and carbonates, containing all the chemical elements in protoplasm, but they would be of no practical use to the animal in the formation of fresh protoplasm.

**Plants and Animals.**—On the other hand, it is typical of plants that they can build up protoplasm from such simple compounds as carbonic acid, water and mineral salts, all of which are soluble and diffusible, either as gas or liquid.

Hence the primary distinction between a plant and an animal rests in the power of the former to perform the synthesis of compounds containing carbon, hydrogen and oxygen from carbonic acid and water. This power resides in the presence of *chlorophyll*, a green colouring matter, which under suitable conditions of warmth and sunlight can effect the important synthesis. From this we can derive the other differences between animals and plants. The food of animals being solid, they require digestive organs to bring it into a condition suitable for absorption. Again, they require motor organs, for solids of this nature are in isolated masses (plants and other animals) and must be sought for.

The liquid and gaseous food of plants being already in a condition for absorption (or assimilation) no alimentary organs are required, and, being universally distributed, there is no necessity for movement; the absence of movement implies a low condition of the function of sensation.

We have already referred to the relationship between the surface and the bulk of an animal, and in a typical animal the demands of locomotion and alimentation are best satisfied by a maximum bulk with minimum surface, whereas in a plant the absorptive area, being mainly co-extensive with the surface, the typical plant tends to attain minimum bulk with maximum surface. With such a large proportion of surface there is no necessity for excretory organs.

Lastly, from the difference in food it follows that a plant can, from the simplest to the highest, protect its body in a supporting membrane, usually of cellulose, whereas an animal must always have a certain part of its surface exposed to form an ingestive and egestive area. When, as in low types, the ingestive area is co-extensive with the surface (*cf. Amœba*), the difference in this respect from a plant is very marked. We may tabulate these differences as follows:—

| *PLANT.** | *ANIMAL.** |
|---|---|
| 1. Protoplasm has chlorophyll. | 1. No chlorophyll. |
| 2. Food liquid or gaseous. | 2. Food solid, and mostly insoluble. |
| 3. No alimentary organs nor excretory; motor and sensory organs little developed. | 3. Alimentary and excretory; motor and sensory organs highly developed. |
| 4. Form tending to maximum surface with minimum bulk. | 4. Form tending to maximum bulk with minimum surface. |
| 5. Body completely clothed in coat (cellulose). | 5. Body naked in lowest types, partially enveloped in exoskeleton in higher. |
| 6. Are dependent on salts, carbonic acid gas, water and sunlight. | 6. Live only upon plants or other animals (highly organised food), and do not require sunlight or carbonic acid. |

The plant-nutrition is sometimes termed *holophytic* and animal-nutrition is then known as *holozoic*.

**Transfer of Energy.**—The movements of animals, and the maintenance of a high temperature in the higher

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* *Fungi* form an exception to 1 and 6 in the "*Plant*" column, whilst *Hydra* and a few other animals form an exception to 1 in the "*Animal*" column. One or two plants are partial exceptions to 3.

animals, mean an enormous and ceaseless expenditure of energy, and the question naturally arises, Whence is this energy obtained?

We find that the chemical decomposition of the constituents of protoplasm, such as proteids, results in a setting free of chemical energy. We have seen that proteids and less complex carbohydrates are brought directly into the body of the animal as food, so we are forced to look beyond the animal itself for the source of energy.

On the other hand, these complex carbon compounds are built up or manufactured by the plant from simple constituents within it. In this building-up the same amount of energy has to be supplied as is again set free in movement and heat in the subsequent decomposition. This building-up, or the chief part of it, is effected in the plant by a process not fully understood, but certainly requiring a supply of radiant energy from the sun's rays.

Hence we are led to two important conclusions:—

1. The animal kingdom is entirely dependent (or parasitic) upon the vegetable kingdom for all its energy.
2. The vegetable kingdom accumulates vast stores of energy in the formation of complex chemical compounds, derived from the radiant energy of the sun.

Organisms may be regarded as complex machines for transmutation of energy. The work of plants is the transmutation of kinetic (radiant) into chemical energy, and that of animals is (like that of steam-engines) the transmutation of chemical into kinetic energy.

We must therefore look to the sun as the sole source of every movement, thought or impulse of the animal creation. Plants and animals have the same essential living matter or protoplasm, but with certain marked differences in form and function. These are more pronounced in the higher types, but when the simplest living organisms are studied the distinctions break down. Supposing the two kingdoms are of common descent this state of affairs is to be expected.

We have thus passed in review the various physical, chemical and vital properties of living matter, as found in the organic world, and have noticed the main underlying distinctions between the vital functions of plants and animals.

The vital functions of organisms are :—

*Primary.* — 1. Alimentation.
2. Movement.
3. Sensation.
4. Excretion (and Secretion).

*Secondary.*—1. Growth.
2. Reproduction.

It cannot be too much insisted upon that these vital functions are all exhibited by all living organisms from highest to lowest.

If the secret of vital phenomena ever be revealed to the future scientific investigator, the steps from *Amœba* to man will appear as a mere nothing compared to the immeasurable difference between living protoplasm and its non-living constituent proteids.

We know life only by its effects, not in itself, and the student should ever bear in mind that just as the physicist has to assume the fundamental conceptions of matter and motion, so the zoologist, the biologist and the physiologist have to start with the assumption of life and its vital phenomena. The attempt to explain these premises in each case is mere speculation.

# CHAPTER II.

## *COMPARATIVE PHYSIOLOGY.*

WE have seen that every animal organism exhibits the four primary functions of alimentation, movement, sensation and excretion. In the lowest types these functions are performed indifferently by all parts of the body, but in all the higher types we find that one part of the body becomes specially concerned with one function, another part with another function, and so on. In every case all the functions are represented in the single organism and each part becomes dependent on the others for the execution of the other functions. The parts concerned with each function are usually called *systems* and the subsidiary parts of these systems are termed *organs*. The following systems are connected with the primary functions:—

Alimentation...(1) *Alimentary system.*
Movement......(2) *Motor system* (usually *muscular system*).
Sensation ......(3) *Sense-organs.*
Excretion ...{ (4) *Respiratory system.*
(5) *Excretory system.*

Inter-communication between the various parts is established by the (6) *Nervous system* and (7) *Circulatory system*, whilst the function of reproduction demands a separate (8) *Reproductive system.* Lastly, the body is often supported and strengthened by the (9) *Skeletal system.*

The principle of gradual relegation of certain functions to certain parts of the body is termed *physiological division of labour* and proceeds hand in hand, throughout the animal kingdom, with growing complexity of structure. This principle can be best understood by a simile. In a primitive human community each man hunts for himself, each builds his fire, makes the clothes and weapons he may require, and so on. In more advanced communities, however, there occurs a *division* of labour. One man does nothing but make weapons whilst another perhaps builds houses, and each of these depends upon the rest of the community for his other necessities. The result is increased efficiency of the whole at the expense of the individuality of each unit, for the tailor soon loses the art of making weapons, and *vice versa*. The greater the extent to which the division of labour is carried the more pronounced will be the individuality of the community. In a similar manner it will be seen that the lower animal types with little physiological division of labour have little individuality and portions of them can survive when separated from the parent, but the higher types have pronounced individuality and death ensues upon the disturbance of a finely-balanced equilibrium of the parts.

1. **The Alimentary System** is perhaps the most fundamental; the parts of which may be divided into:—

(1) INGESTIVE SYSTEM.—The ingestive organs are those connected with the seizure of food and its introduction into the body. As the essential purpose of locomotion is the obtaining of food they are closely allied to motor organs and are often modified from them. The ingestive aperture is the *mouth*, usually surrounded by organs for seizing or preparing the food, *e.g.*, jaws, teeth, tentacles, &c.

(2) DIGESTIVE SYSTEM.—Digestive organs are more directly concerned with the reduction of food into a soluble and diffusible condition. There is usually a cavity, the *enteron* or gastric cavity, in which digestion is effected, and there are often digestive glands which secrete a digestive fluid. This cavity is part of the *alimentary canal*, occupying the interior of the animal and opening to the exterior by the mouth, or by mouth and anus.

(3) EGESTIVE SYSTEM.—Egestive organs are concerned with the removal of waste residue of the food. The egestive aperture when present is called the *anus*; in higher types it is usually at the posterior end of the body.

2. **Motor System.**—In a motor system the property of contractility is especially concentrated. The primary object of movement is the obtaining of food, and in the case of sedentary (fixed) animals the motor organs are employed, not to move the animal to its food, but the food to the animal.

The two principal organs of movement are:—

(1) CILIA AND FLAGELLA.—These are vibratile processes of protoplasm which, by striking the water or surrounding fluid medium, cause either motion of the medium or that of

the animal as well. Cilia usually occur in great numbers and are short. Flagella occur singly, or at most two or three to each cell, and they not only lash the water in a definite direction but often have a spiral motion.

In the lower animals, such as *Protozoa*, *Porifera* and *Cœlenterata*, these organs usually act as motor organs or for the purpose of obtaining food. In the higher animals these functions are performed by muscles.

(2) MUSCLES.—A muscle is a specially contractile organ which is either in the form of a straight line or a circle. In the former the muscle, upon contracting, reduces the length between the points; in the latter, contraction results in a reduction of the diameter. Nearly all the lower *Metazoa*, sometimes called "worms," move by a system of circular and longitudinal muscles and their alternate action upon the fluids of the body, as more fully explained later (see Lobworm). Above these, the other *Metazoa* have the circular principle mainly confined to the *sphincter* muscles, which close up certain apertures, and to the muscles of the alimentary canal. The great majority of their muscles are of the "long" or straight-line type, which extend from one fixed point, called the *origin*, to another attached to the part intended to be moved and called the *insertion*. These muscles move a definite system of levers and we can observe two great types. In the one form (throughout the *Arthropoda*) the lever is hollow and contains the muscle, and in the other (in the *Vertebrata*) the lever is solid and the muscle is placed outside it. The former conduces to greater actual mechanical advantage, but the latter has infinitely greater possibilities in complexity and nicety of movement.

3. **Sense - Organs.** — Sense-organs are parts of an organism in which is specially concentrated the property of irritability. Quite far down in the animal scale, these sense-organs become distinguished among themselves for response to vibrations of a special wave-length. It is difficult for us to appreciate any kind of senses other than our own. Our eyes are sensitive to vibrations varying from λ760 to λ390*

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* λ = A millionth of a millimetre. The higher wave-length vibrations give us the sensation which we call "violet," and the lowest we call "red"; between them lie all the colours of the spectrum. A mixture of all these wave-lengths we term light.

wave-length and the sensation so imparted we call *sight.* Lower vibrations than this we call heat, and we have, probably, sense-organs for the discernment of heat. Vibrations of a still lower grade (from 40,000 to 30 per second) we perceive by our ears and the sensation we term *sound.* Lastly, the actual contact of particles upon a specially sensitive surface gives us the closely allied senses of smell and taste.

Sight involves the perception of light or shade and also, as a higher faculty, the discernment of actual images. The former alone exists in a number of low animals and the latter is only added when the organ of sight has the addition of an optical apparatus, known as the dioptric mechanism. It is highly probable that many animals have organs for the perception of vibrations higher or lower than those of sight and the "sense" thus produced is quite inconceivable to us. It may differ from our senses as widely as sight from hearing.

In the case of hearing much the same remarks hold. There is little question that many aquatic animals have *organs* of *equilibrium* or of motion which render them cognisant of low mechanical vibrations of water produced by the approach or proximity of a foreign object. In certain land-animals (*e.g.*, Bats) there appears to be much the same kind of faculty, which enables their possessors to avoid objects without the aid of eye, ear or nose.

We may therefore divide sense-organs into three arbitrary groups, as follows :—

1. High-vibration organs.—
    - (1) Possible organs for perception of vibrations above λ760 wave-length.
    - (2) Eyes for perceptions of vibration λ760 to λ390 wave-length.
    - (3) Possible heat-organs for vibrations of lower frequency.
2. Low-vibration organs.—
    - (1) "Auditory" organs for perception of vibrations above 40,000 per second.
    - (2) Auditory organs for perception of vibrations 40,000 to 30 per second.
    - (3) Motion-organs for perception of vibrations 30 per second to a single vibration.
3. Contact-organs —
    - (1) Olfactory organs for finely divided particles.
    - (2) Taste-organs for food.
    - (3) Touch-organs for mechanical contact.

The structure of these sense-organs will be dealt with in each type, but we may here note that they resemble each other in consisting essentially of (1) *a modified sensory epithelium* or layer of cells, to which is added (2) *a more or less complex accessory apparatus.* The epithelium is in every case directly connected with part of the nervous system, when this is present.

**Excretory System.**—Excretory organs are of several types. We can usually recognise (1) an excretory surface which by its secretory activity produces the waste products, (2) a duct to the exterior often endowed with motor cells to carry the waste products to the surface of the body, (3) a reservoir for the accumulation of the waste products before ejection. All these parts can be distinguished in the series from the simple contractile vacuole to the flame-cell organs, the nephridia and the kidneys.

The Respiratory organs are late in development. In the lower animals, the surfaces of the body serve to effect the interchange of oxygen and carbonic acid, but respiratory organs, in the form of gills, arise from the worms onwards. These *gills* are formed on the "plant" principle of maximum (respiratory) surface and minimum bulk and are usually formed from the outer surface of the body. They are replaced in land-animals by air-breathing organs of quite another type. Air is usually taken into the body *towards* the respiratory surface and pulmonary organs do not protrude from the body. Air is so much more mobile than water that the greatest economy is effected in this way.

**Correlative Systems.**—These four primary systems are in intimate contact and relation with each other in the lower types in which the functions are co-extensive with the protoplasm of the body, but in the higher types the systems, developed in each case in the most suitable parts of the body, become removed from each other and systems of correlation are necessary. The two most important of these are the *nervous* and *vascular* systems. The former is a system of correlation between the sense-organs and the motor system, whereas the vascular system connects all the others.

**Vascular Systems.**—The vascular system in the higher animals is usually of two kinds—(1) the BLOOD VASCULAR

SYSTEM, which carries blood and is primarily a correlative system between the motor and alimentary on the one hand, and the respiratory and excretory on the other. Hence the *blood is primarily a respiratory and excretory fluid.*

In most higher animals this system has a central organ of propulsion, the *heart*, to ensure proper circulation. In some cases, the heart drives the blood over the system, when it is called *systemic*, whereas in the others it propels the blood directly to the respiratory organs, when it is known as a *respiratory* heart. Occasionally we find that the heart alternates in its action and it is then called *reversible.* The blood-system arises as a system of sinuses or spaces between the organs, in which condition it remains in the lower types; in higher types definite walls are formed and produce vessels. In those animals which possess a heart or central circulatory organ, the vessels carrying blood away from the heart are called *arteries*, those bringing blood to the heart are *veins.*

(2) THE CŒLOMIC SYSTEM, which usually carries a cœlomic fluid. This fluid is primarily *nutritive* in function but this function is often usurped by the blood-vascular system.

In the forms with a nutritive cœlom the fluid bathes the muscles, gonads and skeletal system, and even in those cases in which the nutritive function is largely transferred to the blood, as in vertebrates, the cœlomic fluid (lymph) still acts largely as a medium of exchange between the tissues and the blood. Cœlomic hearts are not common, as the circulation of the fluid is usually assured by the movements of the body, but "lymph-hearts" are observable in the frog.

**Nervous System.**—In the lowest types, the protoplasm of the body is alike irritable and contractile; but in the higher organisms, as seen above, the property of contractility becomes concentrated in a motor system, and that of power of transmitting impulses in the sense-organs. The latter are, from their nature, bound to be situated peripherally, whilst the position of the former is determined by the mechanical principles of the body. Hence the necessity for a special means of direct communication between the two systems. The system which fulfils this condition is called the NERVOUS SYSTEM. It first appears as connecting strands or nerves running direct from sense-organs to muscles (or the motor organs). In higher types, there appear nerve-cells with connecting nerve-fibres, and the nerve-cells become aggregated into masses called *ganglia.* The nerves become differentiated into *afferent* (*sensory*) nerves, or those which carry impulses to the ganglia, and *efferent* (*motor*) nerves, which carry impulses from the ganglia to the muscles. The brain is a specially differentiated mass of nerve-cells often composed of several ganglia aggregated together. It is usually at the anterior end in close contiguity to the main sense-organs.

**Skeletal System.**—The skeletal system consists of certain parts of the body which are formed by the secretory activity of the protoplasm. These may be of three principal kinds according to the material of which they are composed :—

1. In a number of the lowest types *silica* is employed in the formation of a skeletal system, but this substance is confined to the *Protozoa* and *Cœlenterata.*

2. *Calcareous matter* is a very common skeletal material. It occurs throughout the animal phyla, and is specially important in the *Vertebrata* in which it enters into the constitution of bone.

3. Horny matter or *keratin* is also very widespread. Keratin is a complex nitrogenous chemical substance, thus differing from the two former materials. Keratin, or its allies, forms the main constituent of cuticles, horns, nails, hair, hoofs, &c.

Morphologically, these various skeletons may be divided into *exoskeletons* and *endoskeletons.* The exoskeleton is formed on the outside of the body and belongs to the so-called *integumentary system.* The endoskeleton is produced in the deeper tissues, usually in the middle layer or mesoderm.

Lastly, a more or less consistent skeleton is composed of certain modified tissues, such as cartilage or connective tissue (see Chapter IV.).

It is not uncommon for many animals to employ foreing bodies for protection, such as grains of sand or shells of other animals.

In a general way, a skeleton performs three functions. Firstly, it gives a general firmness or consistence to the whole body which from its protoplasmic nature would otherwise be mobile. Secondly, it protects the body from enemies, physical or organic, and, thirdly, it provides a mechanical system of levers through which the muscles can operate.

**Reproductive System.**—The vital phenomenon of GROWTH does not become concentrated in one special system of organs, though there are striking cases of differential growth in many animals. In the case of REPRODUCTION it is different, and a special reproductive system appears very early in the animal kingdom. The subject of reproduction is dealt with under Embryology, but we may note here that reproductive organs usually have:—

1. The primary *gonad*, producing the germ-cells. The male organ is called the *testis*, the female the *ovary*.

2. Ducts leading to the exterior. The male duct is called the *vas deferens*, the female the *oviduct*.

Further differentiations ensue as development becomes more complex. Firstly, the eggs are supplied with yolk and yolk-glands are often required. Secondly, the eggs require protecting shells or capsules produced by *shell-glands*. Thirdly, these additions require internal fertilisation, within the oviduct, before the shell is added. This means copulation and a copulatory organ in the male, whilst there may be a receptacle for the semen (*receptaculum seminis*) in the female. Lastly, the eggs and young may be retained for some time within the oviduct of the female, in which case the portion of the oviduct adapted for this purpose is the *uterus*. Various accessory glands may become superadded. We may tabulate the reproductive organs as follows:—

| | | | |
|---|---|---|---|
| *Male* | 1. | Production of spermatozoa | Testis. |
| | 2. | Transportation to exterior | Vas deferens. |
| | 3. | Introduction of same into female, | Penis. |
| *Female* | 1. | Production of eggs | Ovary. |
| | 2. | Transportation of eggs to exterior, | Oviduct. |
| | 3. | Production of yolk and shell | Yolk-glands and shell-glands. |
| | 4. | Reception of sperms | Receptaculum seminis. |
| | 5. | Retention of egg and embryo | Uterus. |

# CHAPTER III.

## COMPARATIVE MORPHOLOGY.

IN studying the structure of an organism, we can recognise two departments of morphology. In the first we have to deal with the form assumed by the organism or "body-form," the study of which is sometimes termed *Pro-morphology*, and in the second we investigate the internal construction of organisms. On a first inspection of typical examples of animals their body-form does not appear to be referable to any definite plan. They do not assume geometrical shapes, like a cube, or a cylinder, and so on. Yet we can, especially by a study of the lower types, find geometrical principles underlying their construction. A like environment produces a similarity of structure in response to it. For example, if an animal exposes two sides to a similar environment, the structure of these two sides will tend to be similar.

The manner in which the similar parts of an organism are arranged is termed its symmetry.

**Animal Symmetry.**—Animals may be divided into three groups according to the symmetry of their body:—

1. Centro-symmetric } (often termed radially symmetrical).
2. Axo-symmetric }
3. Plano-symmetric (bilaterally symmetrical).

1. CENTRO-SYMMETRIC animals have all their parts arranged about a *point* in the centre of the body, hence they are usually spherical or stellate. The only parts to be distinguished are *central* and *peripheral*. This form of symmetry is only found in the lowest aquatic animals (*e.g.*, *Radiolaria*, *Foraminifera*, &c., and many eggs).

2. AXO-SYMMETRIC animals have their organs arranged about an *axis* down the centre of the body and hence they

tend to a cylindrical form. In this type we can distinguish *axial* and *peripheral* parts and the two ends of the main axis can usually be recognised as the *apex* and the *base*. The mouth is situated at the one end or apex often termed the *oral* end, the base being known as the *aboral* end. Examples are found among the lowest animals (*Protozoa*, *Porifera* and *Cœlenterata*) which are either sedentary (fixed by the aboral end) or pelagic.

3. PLANO-SYMMETRIC (bilaterally symmetric) animals have their parts arranged about a central *plane*, which usually lies in the long axis of the body. In these we can determine an *anterior* and a *posterior* end, a *dorsal* and a *ventral* surface, and a *right* and *left* side. The parts are either *median* or *lateral*. Nearly all the members of the animal kingdom above the *Cœlenterata* conform more or less closely to this type.

Certain organisms do not appear to conform to any of these types. *Amœba* and some other low organisms have no definite shape of body since they change their shape at every moment. They really belong to the centro-symmetric, because, when encysted or subjected to a stimulus, they assume the spherical shape. Other higher types, such as the snail, show a distortion which destroys to some extent the plano-symmetry underlying their general body-form.

The locomotion of animals usually conforms to their symmetry. Most centro-symmetric animals rotate freely about the centre, but do not move in a definite direction. Axo-symmetric animals, if not sedentary, usually move in the direction of the axis of symmetry, and plano-symmetric animals usually move in the direction of the plane of symmetry, with the anterior end forwards and usually with the plane of symmetry vertical.

**Morphological Units.**—If we next proceed to investigate the actual constituent elements of organisms we can discern a very definite unit which occurs throughout. This unit is called a *cell*. It is impossible to define a cell in such a way as to include all the numerous forms and modifications, but for our present purpose we must regard it as a definite mass of protoplasm containing a nucleus, and usually having more or less of a limiting cell-membrane.

The members of the lowest group or phylum, called *Protozoa*, consist of single cells, or colonies of single cells, whereas all the higher animals are multicellular or consist of cell-aggregates. The study of cell-structure is Histology (see Chapter IV.).

The second structural unit is the *epithelium* (derm) or layer of cells. A number of cells are aggregated together and all perform the same common function. No animal organism is entirely of this form, but many organs show this stage very clearly.

The third unit is the *tome* or sac-like form in which the layer of cells surrounds a common space (or *cœle*) and forms a complete organ separated from the parent-layer.

These three stages can be traced more or less clearly in most organs and organisms. Their mutual relationship may be made more clear by a comparison with a brick, a wall, and a room, respectively.

Amongst multicellular animals we can distinguish three important types according to their construction. The simplest are those with a single layer or epithelium of cells, called *monodermic* (or monoblastic).

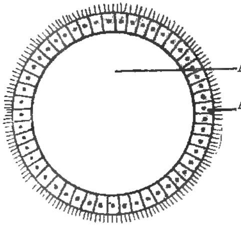

Fig. 1.—Diagram of a Monodermic Organism.

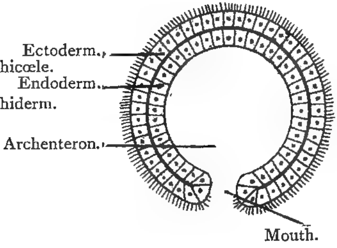

Fig. 2.—Diagram of a Didermic Organism.

This is a very simple condition found in only a few types, such as the blastula larva and *Volvox.*[*] The single epithelium of cells is called the *archiderm*, and may surround a cavity called the *archicœle.* In the second type the body is formed of two epithelia, when it is known as

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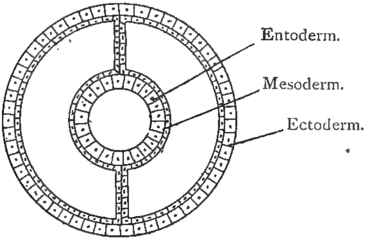
[*] A low colonial protozoan belonging to the *Mastigophora.*

*didermic* (or *diploblastic*). The large phylum of *Cœlenterata* is didermic. The outer layer is known as *ectoderm*, the inner as *endoderm*, and the space enclosed by them is the *archenteron*. The space between the layers is usually filled with a jelly-like substance called the *mesoglœa*. The third type is the *tridermic* (or *triploblastic*). In it there can be discerned, at least in early stages, three distinct primary layers or epithelia. Nearly all the higher animals are tridermic. In tridermic forms, the outer and inner layers are called the *ectoderm* and *entoderm*, whilst the middle layer is the *mesoderm*. The space in the *entoderm* is now called the *mesenteron*. The ectoderm and entoderm are not in contiguity, but there is always a more or less spacious *body-cavity* or cavity of the body, which is the primary body-cavity or *archicœle* (*cf.* monoblastic types). In this archicœle is arranged the third layer or element. It may consist (in the *Archicœla* or *Acœlomata*) of a mass of connective tissue, muscle-cells and gonads formed of more or less isolated cells (cystic) or layers (dermic). In this type the excretory organs are of the type called *flame-cell tubules* (see *Platyhelminthes*) which end internally in blind tubes or sacs. In the second type (the *Cœlomata*) the greater part of the mesoderm is formed into a definite epithelium limiting a cavity

Fig. 3.—DIAGRAM OF A TRIDERMIC ORGANISM, SEEN IN CROSS SECTION.



Note the somatic and splanchnic layers of mesoderm joined by dorsal and ventral mesenteries ; the hæmocœle is not seen as the mesoderm is closely adherent to the other layers.

or sac which is then termed the *cœlom.* This cœlom does not usually fill the whole primary body-cavity for a large part of the latter remains as the *hæmocœle* or blood-space. In the *Cœlomata* the typical excretory organs are excretory tubules or *nephridia* which open directly into the cavity of the cœlom. The comparative size of the cœlom and hæmocœle varies greatly.

The actual connection, if any, between the two tridermic types is not known. The archicœlic is evidently the simplest, but it is doubtful whether in the evolution of the *Cœlomata*, the flame-cell tubules become transformed into nephridia, whether they were merely replaced by the latter in function and atrophied, or whether the ancestors of *Cœlomata* never had flame-cell tubules.

In a general way, these three types correspond to the three forms of symmetry; the monodermic organism is centro-symmetric, the didermic usually axo-symmetric, and the tridermic is in nearly all cases plano-symmetric.

**Structure and Function.**—Organs of the body are of certain form and structure according to the functions they perform. Hence there is a general similarity in the form of the different systems referred to in the last chapter. Nervous systems, for example, have certain striking resemblances throughout the whole animal kingdom, and so with all other primary systems.

We can only notice here two important parts of this subject. Firstly, there are many instances of loss of function. This invariably leads to reduction or complete extinction of the organ in question. The most endoparasitic animals, such as tape-worms, undergo a complete loss of all alimentary organs as they are not required. Again, in many cases the organs persist as mere vestiges and are then known as *vestigial organs.* Remarkable instances of these are the hind limbs of whales, some of the jaws of the cray-fish, and the splint-bones of the horse.

Other organs are just acquiring the function which is raising them into importance and are still small. These may be called *rudimentary organs.* Organs like everything else in the world, have their rise, their culminating point, and their fall. A *vestigial* organ is in the last phase of its history, whilst a *rudimentary* organ is in the first. The electric organ of the skate may be given as a possible example of a rudimentary organ. Secondly, an organ may change its function or, in other words, may lose its primary function but be preserved and greatly modified by acquiring another function. The skin-armour of placoid scales in sharks is not found as such in higher vertebrates, except the few in the neighbourhood of the jaws, which form teeth. Again, the appendages of the crayfish show every step in modification from the primitive biramous swimming organ to the leg, jaw, or feeler, in accordance with the various functions they have acquired.

**Classification.**—Hence we have seen that the animal kingdom forms an ascending series of organisms of structural complexity, which is due to three kinds of gradations. Firstly, animals show a gradation in symmetry from the simple centro-symmetry to the complex plano-symmetry. Secondly, they show a gradation in construction from simple cells to many-layered individuals. Thirdly, they show a gradation in structure due to the functional division of labour. If these gradations were absolute we could form no classification. It would be impossible to divide the animal kingdom into groups if it presented a *continuous* gradation in structural characters. The breaks in structural sequence permit us to define certain animals and to separate them from certain others.

Whilst our classification is based primarily upon structural characters there is an important reservation. We have seen in the introduction that structural similarity is called *homology* and that there are two kinds of homology, inherited and acquired. The acquired homology is often very difficult to distinguish from the inherited homology, but the ideal classification to which all zoologists aspire is based purely upon inherited homology or upon homogenetic characters; if we place together in one group a number of individuals because they have *homogenous* similarity in structure, we shall by our definition be correlating animals which are descended from a common stock. This is a *natural* classification, for in it we strive to give expression to the natural relationships of the animals. Let us take a very simple example. If we decide to put in one group the animals which swim in the sea, have a tail-fin and pectoral fins and are of a fish-like shape, we create a group containing the whales and fishes. This is an *artificial* classification, for further examination shows that the whale agrees with land-mammals in nearly all the most important mammalian characters and that its fish-like shape is *acquired* or due to adaptation to an aquatic life.

The determination of natural affinities is largely helped by the study of embryology and of palæontology, but there is no exact criterion for recognising a natural affinity (for it is a relative term) and there is no question that our classifications are still very unnatural.

All that can with present knowledge be done in classification of the animal kingdom is to distinguish certain large Phyla or branches, the members of which have certain important structural features in common. The fundamental distinction between unicellular and multicellular animals enables us to separate the *Protozoa* from the rest, which are termed *Metazoa.* Hence we have two sub-kingdoms, the *Protozoa* and *Metazoa.* The *Protozoa* have two phyla, the *Gymnomyxa* and *Corticata*, and the *Metazoa* several important phyla. The two lowest of these differ from the rest by being typically axo-symmetric, retaining the primary axis of the gastrula, whilst the rest are primitively plano-symmetric about a plane at right angles to the primary axis of symmetry. This important distinction is emphasised by the two divisions of *Protaxonia* and *Bilateralia*, the latter being all tridermic.

The Phyla are divided into sub-phyla and classes, the characters of which depend mainly upon general community of structural design. Finally, the classes are further sub-divided into orders, families, and genera until the species is reached.

The various groups are not in all cases exactly comparable, but the same order is always pursued in dividing up a phylum.

The list here given includes all the more important phyla which are dealt with in this work and their division into classes.

It will be seen that, of the phyla of the *Bilateralia*, the first three, or the *Platyhelminthes*, *Rotifera*, and *Nemathelminthes*, are of the *Archicœlic* (or *Acœlomata*) type, whereas the other four are *Cœlomata.*

[TABLE.

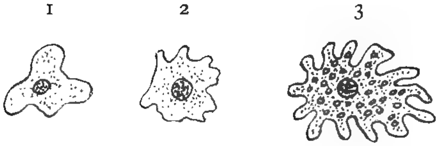
| Sub-Kingdom. | | Phyla. | Sub-Phyla. | Classes. | Type described. |
|---|---|---|---|---|---|
| PROTOZOA. | | 1. **Gymnomyxa.** | | 1. Rhizopoda. | *Amœba.* |
| | | 2. **Corticata.** | | 2. Ciliata. | *Paramœcium.* |
| | | | | 3. Mastigophora. | |
| | | | | 4. Acinetaria. | |
| | | | | 5. Sporozoa. | *Gregarina.* |
| METAZOA. | PROTAXONIA. | 1. **Porifera.** | | 6. Calcarea. | *Sycandra.* |
| | | | | 7. Non-Calcarea. | |
| | | 2. **Cœlenterata.** | | 8. Hydrozoa. | *Hydra (Obelia)* |
| | | | | 9. Scyphozoa. | *Actinia(Aurelia)* |
| | | | | 10. Ctenophora. | *Cydippe.* |
| | BILATERALIA. | 3. **Platyhelminthes.** | | 11. Trematoda. | *Distomum.* |
| | | | | 12. Cestoda. | *Tænia.* |
| | | | | 13. Turbellaria. | |
| | | 4. **Rotifera.** | | | *Hydatina.* |
| | | 5. **Nemathelminthes.** | | 14. Nematoda. | *Ascaris.* |
| | | 6. **Archi-Cœlomata.** | 1. Echinodermata. | | *Asterias.* |
| | | | 2. Archichorda. | | *Balanoglossus.* |
| | | | 3. Brachiopoda. | | *Waldheimia.* |
| | | | 4. Polyzoa. | | *Lophopus.* |
| | | | 5 Chætognatha. | | *Sagitta.* |
| | | 7. **Annulata.** | 1. Annelida. | 15. Archiannelida. | *Polygordius.* |
| | | | | 16. Polychæta. | *Arenicola.* |
| | | | | 17. Oligochæta. | *Lumbricus.* |
| | | | | 18. Hirudinea. | *Hirudo.* |
| | | | 2. Arthropoda. | 19. Crustacea. | *Nephrops.* |
| | | | | 20. Insecta. | *Blatta.* |
| | | | | 21. Protracheata. | *Peripatus.* |
| | | | | 22. Myriapoda. | |
| | | | | 23. Arachnida. | *Epeira.* |
| | | 8. **Mollusca.** | | 24. Gastropoda. | *Helix.* |
| | | | | 25. Cephalopoda. | *Sepia.* |
| | | | | 26. Lamellibranchiata. | *Anodon.* |
| | | 9. **Chordata.** | 1. Atriozoa. | 27. Urochorda. | *Ascidia.* |
| | | | | 28. Cephalochorda. | *Amphioxus.* |
| | | | 2. Vertebrata. | 29. Cyclostomata. | *Myxine.* |
| | | | | 30. Pisces. | *Raia.* |
| | | | | 31. Amphibia. | *Rana.* |
| | | | | 32. Reptilia. | |
| | | | | 33. Aves. | *Columba.* |
| | | | | 34. Mammalia. | *Lepus.* |

# CHAPTER IV.

## HISTOLOGY.

HISTOLOGY is the study of cells. In the case of the *Protozoa* this is the study of the whole organism; in the *Metazoa*, of its constituent units.

Fig. 4.—AMŒBOID CELLS.

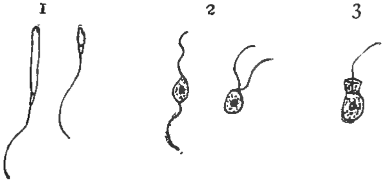


1. Amœba. 2. Leucocyte of Frog. (After HOWES.) 3. Ovum of *Hydra*. (After KLEINENBURG.)

**Independent cells** may occur in several characteristic conditions. The principal are as follows:—

1. AMŒBOID.—These are cells resembling *Amœba*, shapeless, and showing movements by pseudopodia. A number of *Protozoa* show this condition throughout the greater part of their life. In the *Metazoa* free amœboid cells occur with great frequency They are usually termed *leucocytes* and fulfil important functions, such as ingestion of bacteria. Leucocytes of this nature occur in great numbers in human blood.

Fig. 5.—FLAGELLATE CELLS.



1. Spermatozoa. 2 Flagellate *Protozoa*. 3. Collared Cell of Sponge.

2. Flagellate or Ciliate.—These cells are found in the protozoan classes *Ciliata* and *Mastigophora*. The contractility is concentrated in the cilia or flagella, and the rest of the cell-body is often enveloped in a cell-membrane. In *Metazoa* free flagellate cells occur in the case of the male sexual elements or *spermatozoa*. Collared flagellate cells occur in great numbers in *Porifera*, whilst ciliated cells are commonly found in higher *Metazoa*, though not in the free condition. (See below.)

3. Quiescent.—These are cells with no automatic movement; they are usually enveloped in a cell-membrane which may assume the character of a *cyst*. They are usually spherical, or nearly so. Encysted *Protozoa* always assume this character, and some low organisms are permanently in this phase. In *Metazoa* free quiescent cells occur in the case of the *eggs* or female sexual elements, and in the "red corpuscles" of the blood. The former are usually spherical or oval, the latter flattened.

Fig. 6.—Quiescent Cells.

1. Encysted Amœba. 2. Human red blood Corpuscles. 3. Ovum.

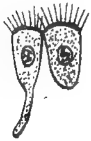
**Dependent** cells of the *Metazoa* are aggregated into masses or surfaces which are termed *tissues*. A tissue is therefore an aggregate of cells which are alike in structure and function.

We may recognise two sorts of tissue—(1) Tissues of two dimensions or surface-tissues (Epithelia); (2) Tissues of three dimensions or mass-tissues.

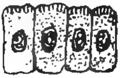
1. Epithelia.—An epithelium is, in its simplest condition, of only one cell thick, but it has often several layers superposed:—

(1) *Ciliated epithelium* is a common type, in which each cell has its outer end or surface covered with vibratile cilia. It is commonly found on the tentacles and

Fig. 7.—Types of Epithelium.

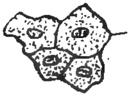


Ciliated Epithelium of Frog's Mouth. (Howes.)

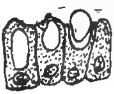


Columnar Epithelium.

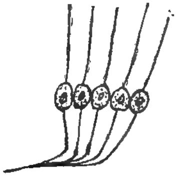
Squamous Epithelium (section).



Squamous Epithelium (surface view).



Glandular Epithelium.



Sensory Epithelium.

gills of *Archicœlomata*, *Annelida*, and *Mollusca*. In some cases the outer limiting surface or epithelium of the body is composed of ciliated epithelium.

(2) *Columnar epithelium.*—The cells are placed side by side in regular order, usually deeper at right angles to the surface than in other directions — in fact, like columns. Their upper or outer surface usually differs from the rest of the cell and may be clear and hyaline, or show striations, or it may be in an amœboid condition with minute pseudopodia. It is a form of epithelium commonly lining the alimentary canal.

(3) *Squamous epithelium.*—Each cell is spread out into a flat, scale-like plate. Each touches its fellows at its edge, and the whole forms a delicate limiting membrane. Simple squamous epithelium forms the outer limiting surface of sponges (pinnacocytes), and the inner peritoneal lining endothelium of many higher types. In the outer limiting surface of these latter the squamous epithelium is not simple but *stratified*. The surface-cells only are flattened, and these gradually pass downwards to *columnar*. By cell-division the columnar produce fresh squamous cells which are lost at the surface by wear or otherwise.

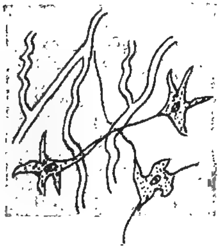
(4) *Glandular epithelium* is a special form of columnar epithelium. Glandular secretion collects in the substance of the cell and is then discharged at the surface.

(5) Lastly, there is *Sensory epithelium*, in which the cells are specially modified for sense-functions.

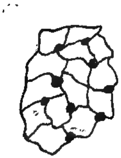
These epithelia may often occur in a mixed condition. Thus the endoderm of *Hydra* is an epithelial mixture of flagellate, amœboid and gland-cells, though possibly the same cells may assume each of these forms. Again, a ciliated glandular epithelium is very common, gland-cells being interspersed amongst the ciliated cells.

2. MASS TISSUES.—Of tissues in three dimensions, or mass-tissues, we may distinguish the most important as—(1) Connective tissues, (2) Muscular tissues, and (3) Nervous tissues :—

Fig. 8.
CONNECTIVE TISSUES.
(1 and 3 after HOWES).



Fibrous Tissue.



Chordoid Tissue.

Cartilage.

(1) *Connective tissues.*—In these the cells themselves usually become subservient to the substance around or within them, which is secreted by them—when outside the cells this is termed the *matrix.* We can here only notice the most important :—

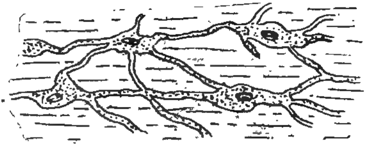
(*a*) *Fibrous connective tissue* consists of a matrix in which there are intersecting elastic fibres. Certain of its cells commonly secrete large globules of fat and give rise to *adipose tissue.*

(*b*) *Chordoid tissue.*—These cells secrete in their substance a clear fluid matrix which almost entirely replaces the protoplasm, the nuclei being squeezed to one side. The whole forms a strong elastic supporting tissue. It is a modified glandular epithelium, and is best known in the notochord of *Vertebrata.*

(*c*) *Cartilage.*—In cartilage the cells lie scattered in a dense mass of secreted matrix, which may be clear or *hyaline*, or may show a *fibrous* structure.

(*d*) *Bone.*—The cells or bone-corpuscles form a meshwork of finely branched cells, anastomosing in every direction, and the matrix consists of concentric layers or lamellæ of calcareous matter, producing a hard, dense, supporting tissue.

Bone.

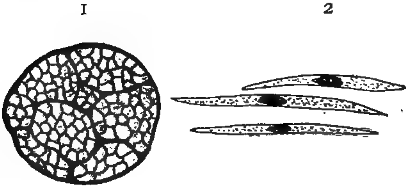


Bone, more highly magnified.

(2) *Muscular tissue.*—The cells or fibres are aggregated into masses, and each is usually elongated in the direction of contraction. The property of contractility is concentrated in them, and they may or may not show a cross striation. In the higher types the whole cell is modified into a fibre, but in *Hydra*, *Ascaris*, and other types, only a part of it is so modified.

Fig. 9.—MUSCULAR TISSUE.

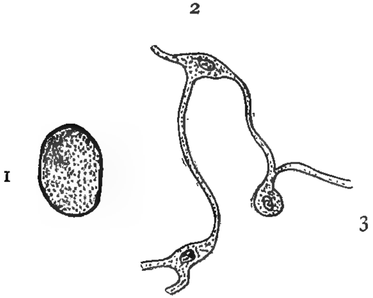
(After HOWES)



1 Transverse section of small muscle. 2. Muscle-fibres.

(3) *Nervous tissue.*—The primary nervous elements are nerve-cells. These are commonly stellate (multipolar), but they may have only one or two branches (unipolar or bipolar). The branches pass from the cells to muscles, or to sensory epithelium, and they form nerve-fibres. A number of nerve-fibres aggregated together and enclosed in a sheath form a nerve.

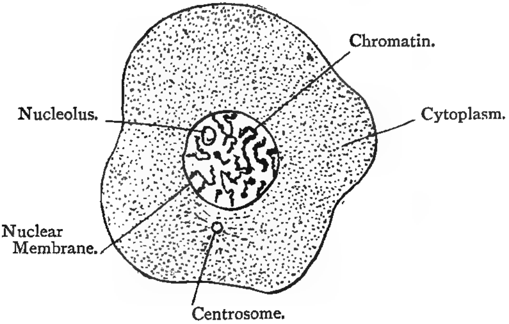
Fig. 10.—NERVOUS TISSUES.



1 Transverse section of small nerve. 2. Multipolar nerve-cell.
3. Bipolar nerve-cell.

**Structure of the Cell.**—We may now pass from the external form of a cell to its internal structure. Inside the cell-membrane is the cytoplasm or cell-protoplasm. Lying in the cytoplasm is the *nucleus* surrounded by a delicate *nuclear membrane.* The nuclear substance is composed of a clear fluid called *nuclear sap* and *chromatin,* so called because of its staining properties, which is usually in the form of a fine meshwork. There may also be one or more rounded bodies, the *nucleoli.* Near the nucleus there is a clear rounded body, with radiating processes, called the

Fig. 11.—DIAGRAM OF A CELL. (After CARNOY.)



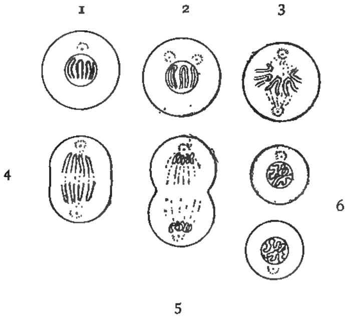
*astrosphere;* it contains in its centre a minute spot called a *centrosome.* The astrosphere and the chromatin appear to play important parts in the process of cell-division.

A cell reproduces itself by binary fission (see Chapter V.), and there are two types of cell-division, according to the behaviour of the nucleus. In both types, the nucleus first divides into two, the cytoplasm following. In the *direct or amitotic* division the nucleus merely constricts into two equal parts without special changes. In the *indirect or mitotic* division the nucleus undergoes division by *mitosis.* This is the most usual method of cell-division.

The changes, in a typical instance (see Fig. 12), may be summarised as follows:—

1. The chromatin network breaks up into a number of chromosomes, usually elongated rods of chromatin.
2. The chromosomes split down the centre into halves, thus doubling their number, and the astrosphere divides into two parts which move to opposite ends of the cell.
3. The nuclear membrane, nucleoli, and nuclear sap disappear and the chromosomes lie in the cytoplasm.
4. Half of the chromosomes migrate to one astrosphere and half to the other, in the neighbourhood of which they are aggregated into a nuclear network, and formed into fresh nuclei.
5. The cytoplasm then divides into two, and cell-division is complete.

Fig. 12.—Diagram of Mitosis. (After Flemming.)



1. Chromatin Loops.
2. Loops split and Centrosome divided.
3. Centrosomes have diverged and loops are at equator.
4. Loops migrate to each Centrosome.
5. Cell commences to divide.
6. Division complete. Re-formation of Nuclei.

This is the *equal* mitotic division, but in certain cases a *reducing* division occurs. In a reducing division the mitotic phenomena are much the same, but *the chromosomes do not divide into two, hence the resulting daughter nuclei have only half the number of chromosomes of the parent nucleus.*

It is difficult to see the full meaning of mitosis, but it has been interpreted as a process for ensuring the *equal* division of the chromatin. The astrospheres appear to act as centres of attraction for the chromosomes, and there can usually be discerned a *nuclear spindle* uniting the rays of the two astrospheres, giving the whole the appearance of a magnetic field.

The reducing division is characteristic of *gonogenesis*, or the production of the sexual elements. The primitive germ-cell produces sperm-mother cells, or egg-mother cells, which at the moment of division contain twice the number of chromosomes. Two rapid reducing divisions then produce four sperm cells in the male, or the mature ovum and polar bodies in the female. Hence the mature ovum and the spermatozoon have in their nuclei (♂ and ♀ pronucleus) just half the normal number of chromosomes. When fused they produce a normal nucleus with the full number.

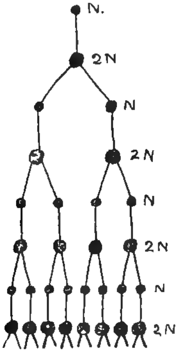
The student should compare this account carefully with that given in Chapter V., page 42, and it will be clear that the reducing divisions and the enumeration of the chromosomes lead to the same conclusion, namely, that *the male and female elements (spermatozoon and mature ovum) are, morphologically speaking, merely half-cells produced by two rapid divisions at the limit of growth instead of the normal single division.*

# CHAPTER V.

## GROWTH AND REPRODUCTION.

THE process by which organisms give rise to fresh generations is called *Reproduction.* There are two main types of reproduction, the asexual and the sexual.

Fig. 13.—Diagram to Illustrate Changes of the Nucleus (**N**) during Cell-Division.



N grows to 2N.

2N divides into two.

Each grows to 2N.

Each divides into two.

Each product grows to 2N.

Each product divides into two.

&c.

**Asexual Reproduction.**—In asexual reproduction a single individual divides into two or more parts or portions. When the individual splits into two parts, approximately equal in bulk, the reproduction is called *binary fission;* when into many equal parts it is called *multiple fission.* If the division is into two or more parts of which one is much the larger, the process is distinguished as *budding*; the lesser part is termed the *bud*, the larger is known as the parent. Buds are usually formed on the outside of the parent but occasionally internal buds occur. In many cases the buds may remain in organic contact with the parent, when a compound organism or *colony* is produced.

Binary fission is the usual method of cell-reproduction throughout the animal kingdom. In unicellular organisms, such as *Amœba*, the nucleus divides into two equal parts with complex changes, called mitosis (see Chapter IV.), and the cell follows suit. Each fresh cell then grows and, when each nucleus and cell has reached the limit of growth, a fresh binary fission takes place.

We may illustrate this process by a diagram (Fig. 13).

In this manner growth and reproduction alternate, and the relationship of cell to nucleus, and of surface to bulk, is maintained at the normal.

In a multicellular individual the constituent cells grow and multiply in the same manner, and the same diagram will serve if we recollect that the cells are aggregated into one compound individual instead of becoming separate organisms.

Returning to the unicellular organism, we might perhaps suppose this cycle of alternate growth and reproduction by binary fission to be capable of infinite repetition, but such is not the case. After a certain number of repetitions another process intervenes called *Conjugation.*

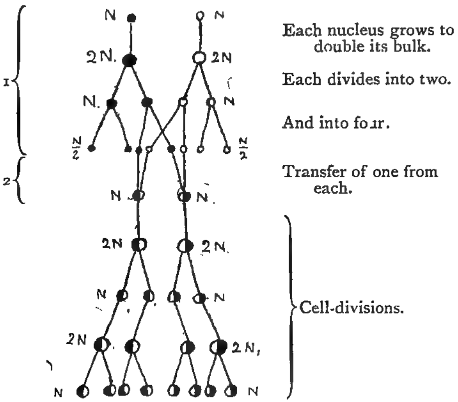
Conjugation consists of two series of events—(1) Preparatory reduction of nuclei in two individuals, and (2) Interchange of nuclear substance :—

1. Preparatory Reduction of the Nuclei.—Two individuals join together in such a way that their protoplasm is continuous. All activity is suspended and the nucleus of each increases in bulk. Each nucleus then divides into two and into four by binary fission.

2. Interchange of Nuclear Substance.—Each individual now has four portions of the nucleus in its substance. Two of these are absorbed and disappear, whilst one from each individual moves across into the other individual, and each of these migrants then fuses with the part still left to form a compound nucleus. The individuals

separate and growth, followed by binary fission, proceeds. The whole process can be illustrated thus :—

Fig. 14.—Diagram to Illustrate Typical Conjugation.



The process is not really quite so simple as here shown, for the nucleus often grows to 4N and divides into eight, or it may be still larger and divide still more, or only one half of the first division may continue the divisions.

The essential part to notice is that whereas, *normally, there is a steady alternation of growth and binary fission, in the first stage of conjugation the nucleus is reduced in size by at least two divisions, following rapidly, before intermediate growth can take place ;* in the second stage, the *normal bulk of the nucleus is restored by the addition of nuclear substance from another individual.* The fresh individuals produced by subsequent binary fissions all have their nuclear material derived from the two conjugating individuals. The cycle of protozoan individuals may be indicated thus :—

↑ Conjugation (mixture of nuclear material). ↓

Series of cell-divisions. Alternation of growth and binary fission producing many unicellular individuals.

Asexual reproduction is found most commonly in the lower phyla of animals, but *cells* are produced asexually throughout the whole kingdom.

In many instances, one or more asexual generations may alternate with the sexual method. This phenomenon is known as *Alternation of generations* or *Metagenesis.* It is usually found in organisms whose life-history is very varied, and involves such dangers at certain periods that a multiplication immediately prior thereto is necessary to the continuance of the species (*cf.* Parasitism, Chap. IX.).

### Methods of Asexual Reproduction :—

| | |
|---|---|
| *A.* Fission—<br>(or division into equal parts). | Binary—two equal parts.<br>Multiple—many equal parts. |
| *B.* Budding—<br>(or division into unequal parts). | Internal.<br>External. |

**Sexual Reproduction.**—It is characteristic of the multicellular animals or *Metazoa* that they reproduce *sexually.* In sexual reproduction a portion of the parent is liberated, as in asexual reproduction, and gives rise to a fresh organism. The main differences are these :—(1) The liberated portion is never more than a single cell (which is called the sexual element) and is produced in special organs. (2) This single cell completely fuses with another single cell, liberated in the same fashion from another individual, but differing in shape and structure. The fused cell so produced divides into a multicellular individual by repeated cell-division. These processes are called respectively (1) Maturation and (2) Fertilisation.

1. Maturation.—The essential reproductive organs are called *gonads* and give rise to cells known as the *primitive germ-cells.* The male element is produced in an organ called the *testis* and the female element in an *ovary.* In the case of the male, the male element or *spermatozoon* is produced by rapid increase to double its size of the

primitive germ cell, to form the sperm-mother cell, which then divides rapidly by two divisions. The mature spermatozoon is usually an active organism with a head-portion derived from the nucleus and a tail formed from the protoplasm of the cell. The nucleus itself is often termed the *male pronucleus* and is evidently one half of the original nucleus of the primitive germ cell. In the case of the female, the primitive germ cell grows to twice the bulk, to form the egg-mother cell, and then divides into two, but they are of very unequal size. The lesser is called the *first polar body* and consists mainly of half the nucleus of the egg-mother cell. Another division of the same kind produces a *second polar body* consisting mainly of one half of the original nucleus. These two polar bodies are seen for some time resting on the exterior of the remaining portion, which is known as the *mature ovum* or female element, its nucleus being the *female pronucleus*. Eventually the polar bodies atrophy.

The phenomenon of maturation consists in each case of the production of the pronucleus, which is a half of the primitive germ cell nucleus, but in the male the protoplasm is also equally divided to form the tails of the male elements, whereas in the female practically all the protoplasm is aggregated to one of the half nuclei, and the others atrophy.

The explanation of this curious process will be easier after we have taken a review of the following processes—

2. FERTILISATION.—The essential part of fertilisation is the fusion of the male and female elements. The spermatozoon embeds itself within the substance of the ovum, the tail is absorbed, and the "head" or male pronucleus fuses with the female pronucleus to form what is called the *segmentation-nucleus* of the fertilised egg.

We may note that the one half of the segmentation nucleus consists of male and the other half of female nuclear material. The life of the new individual dates from the formation of the fertilised ovum.*

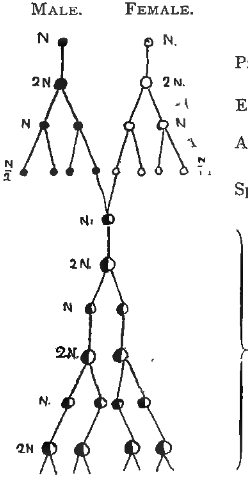
---

* If we suppose that the fertilised ovum is an individual produced by sexual reproduction, and that this by asexual reproduction gives rise to the fresh individual, the adult metazoan, then there is a complete alternation of generations in all metazoa, the sexual individual being always a single cell.

After resting and growth of the segmentation-nucleus a series of cell-divisions takes place called *segmentation*. These cell-divisions continue throughout the life of the individual, but the earlier and more evident divisions are called segmentation.

We may illustrate the process of sexual reproduction thus—

Fig. 15.—DIAGRAM ILLUSTRATING NUCLEAR CHANGES DURING SEXUAL REPRODUCTION.



Primitive germ cell grows to form sperm-mother cell..................

Sperm-mother cell divides into two..............

And into four to form four spermatozoa..........

Primitive germ cell grows to form egg-mother cell.

Egg-mother cell divides into two.

And four to form ovum and two polar bodies.

Spermatozoon and ovum fuse.

Cell-divisions.

After hundreds of these cell-divisions, one N. becomes the nucleus of a primitive germ-cell, increases to 2N. in the mother cell, leaves the organism as $\frac{N}{2}$ in the pronucleus, and the cycle recommences.

If this diagram be carefully studied it will be clear that the process of maturation has for its object *the formation of cells which have only half the usual nuclear element, whereas fertilisation consists of the fusion of these halves to form nuclei of normal proportions.* Further, the dimorphism or difference in structure between the sexual elements, apparently confined to the protoplasm, promotes and ensures the fusion of elements from two separate individuals. The nutritive conditions of the male and female, with a deficiency and an excessive proportion of protoplasm respectively, conduce to their mutual fusion and prevent fusion of the same elements. The *raison d'être* of this nuclear fusion appears to lie in the fact that the nucleus is the carrier of hereditary variations. Hence fertilisation ensures that every cell of the new individual shall partake of the characters of at least two antecedent organisms. This can only be effected by every organism starting as a single cell.

As quite a secondary phenomenon we have what is called *dimorphism of the sexes.* We have seen that the sexual elements differ, the male element being the active agent in reaching the female element, which itself is passive. This physiological division of labour and consequent structural dissimilarity between the sexual elements is, in many higher animals, reflected back to the reproductive organs of the parent, producing male and female individuals or *sexes.*

If the sexual organs are found in separate individuals the species is called *diœcious*, if united in one individual the species is described as *hermaphrodite.* Hermaphroditism is of widespread occurrence throughout the animal kingdom, but is rare in higher types.

In certain exceptional instances the female may produce eggs which, without fertilisation, may develop into fresh individuals. Such a phenomenon is termed *parthenogenesis.*

As a general rule, the sexual organs are the last to mature; hence the reproductive function only takes place after all development has ceased, but in certain rare instances a larval form is known to attain maturity and reproduce itself. The phenomenon is known as *pœdogenesis.* *Axolotl* is a good example.

The differences in the structure and function of the sexual organs are called *primary* sexual characters, but in those animals in which the fertilisation is not promiscuous the sexes often show structural differences other than those of the sexual organs. As examples we may cite the plumage of birds and the antlers of deer. These are called *secondary sexual characters.*

We may illustrate the cycle of metazoan animals thus :—

Sexual Reproduction (fusion of nuclear material).

Series of cell-divisions. Alternation of growth and binary fission producing a single multicellular individual.

If we compare this with the cycle of protozoan animals (page 40), the relation of conjugation to sexual reproduction becomes clear.

We may tabulate the two phenomena as follows :—

| *CONJUGATION.* | *SEXUAL REPRODUCTION.* |
|---|---|
| 1. A preparatory process, consisting of reduction of the nuclear material by divisions of the nuclei only. | 1. Maturation of sexual elements, consisting of reduction of nuclear material by divisions of nuclei and cells. |
| 2. Mutual interchange of nuclear material between the two individuals, and fusion of the respective nuclei. | 2. Fertilisation, consisting of the passage of *all* male element over to the female element, and the fusion of the two. |
| 3. Separation of the two individuals, followed by growth and binary fission to form many unicellular individuals. | 3. Division of fertilised ovum by growth and binary fission to form one multicellular individual. |

# CHAPTER VI.

## *COMPARATIVE EMBRYOLOGY.*

ONTOGENY is the development or production of the individual. The study of ontogeny is *Embryology.* The individual dates its existence from the fertilised ovum sexually produced from the male and female cell-elements. From this and other considerations it will be seen that there is no true ontogeny in the *Protozoa* or unicellular animals, for they are produced asexually (by binary or multiple fission) from their parents.

The first important fact about the ontogeny of the *Metazoa* is that *they commence life as a single cell, the fertilised ovum.* The second point to notice is that *this ovum, by rapid alternation of growth* (or increase in bulk) *and asexual reproduction* (or binary fission), *is transformed into the multicellular adult.* The third is the *differentiation of the multicellular organism from a homogeneous cell-mass to a heterogeneous structure,* in accordance with the law of physiological division of labour. This process, in the vast majority of instances, takes place step for step along with the increase in cells, because the individual requires to be a working organism at every stage of its development. At any developmental stage the organism, as when adult, has a definite environment to which its structure and vital activities must correspond or it would perish.

**Larva and Embryo.**—The environment of developing organisms shows an infinite variety, but for purposes of convenience we may distinguish at least two extremes. In the first, called the *Larval* type, the ovum, either at the very outset or before development has proceeded far, is freed from the parent and lives and fights for itself in the outside world until, after many changes, it becomes an adult. This type is common in *Echinodermata* and occurs in *Amphioxus.*

The larva is an immature organism functionally adapted for its external environment at every stage. Very often the larva passes through a succession of environments before becoming adult, and the series is known as the *ontogenetic migration* of the species. For example, a cod is a ground-feeder and lives at moderate depths near the sea-bottom, but the egg and larva are pelagic, living in the surface-water of the open sea. The larva migrates inshore to the shallows before moving out to join its fellows, thus performing an ontogenetic migration. At each stage its structure is adapted for its particular environment; whilst pelagic it is transparent, when inshore its coloration helps to hide it, and so on.

In the second, or *Embryonic* type, the developing ovum is supplied with nourishment, in one form or another, from the parent and is protected from the outside world by a shell, or by the body of the parent, until all its earliest stages are passed, when it leaves its protecting envelope more or less like its parent.

In the ideal embryonic type cell-formation is completed before differentiation commences, a condition nearly attained in the embryo of some vertebrates. As a general rule, the lower and more primitive members of a marine phylum develop by the larval method and the higher members of marine phyla, together with nearly all terrestrial forms, have an embryonic development.

The past descent of a group of animals is known as *phylogeny*, and in nearly every known instance this past descent reveals a long change of environment of the successive generations, or *phylogenetic migration.* Thus it is usually held that our land amphibians, like the frog, are descended from aquatic ancestors which must have gradually, as time went on, migrated from the sea to fresh water and from fresh water to marsh and eventually to dry land. Doubtless these ancestors were fish-like in their characters at the epoch when they lived in the sea and the rivers, but they gradually acquired amphibian characters as the dry land was reached.

If we picture to ourselves the succession of individuals in this instance we see that each must have passed through the same stage of structure as its predecessor and then passed a little further on. Thus the individual A was a fish and lived an aquatic existence. The individual B, its progeny, lives in the same surroundings, and by the primary law of heredity he develops like his parent, but as he has taken to slightly more air-breathing habits his structure adapts itself slightly to this change of environment and traces of amphibian characters begin. His progeny C will tend to resemble his parent and will pass through the fish-structure of A to the partially amphibian structure of B. Hence we see that it is only a variant of the *tendency* for offspring to resemble their parents that the *ontogeny* (of an individual) *tends* to be a rapid recapitulation of the *phylogeny* (of the group). This is termed the primary *Biogenetic Law of Recapitulation.* The tendency can only be turned into an actual fact in those (practically non-existent) cases in which the *ontogenetic migration* exactly recapitulates the *phylogenetic migration.*

From these considerations it is easy to see that an embryonic development never conforms to the law of recapitulation, for the environment of the embryo is at every stage quite different to that of the corresponding phyletic stage.

A purely larval development may, in the impossible event of an exactly similar sequence of environments (or migration), conform to the law. An approximation only to this ideal can be attained and the want of conformity results in this important truth, that a *larva* at a certain stage of its existence has a given number of its characters which are *palingenetic* or resembling similar stages in the phylogeny, and others which are *cœnogenetic* or developed in conformity with the new environment which has been adopted at that stage. (The palingenetic characters owe their presence to heredity, the cœnogenetic to adaptation, using these terms as applied to the race, not to the individual.) In the embryonic type the environment is so fundamentally changed that the cœnogenetic characters usually outweigh the palingenetic and many of the latter are completely obliterated.

**Segmentation.**—In larval and embryonic forms alike there is the same necessity for the conversion of the unicellular ovum into a multicellular organism. This is attained by rapid cell-divisions or segmentation of the ovum. In some embryonic types the multiplication is at first confined to the nuclei, the cell-walls only appearing later, but this is clearly only a retarded instance of segmentation.

TYPES OF SEGMENTATION.—In many larval types the ovum segments by a series of binary fissions into a hollow (or occasionally solid) ball or sphere of cells. The segments are termed *blastomeres*, are produced in multiples of two, and are equal. This type is called *total equal segmentation*, and occurs in eggs with little or no yolk, usually termed *alecithal* eggs.

In the majority of developments, however, the egg has an endowment of nutritive material from the parent, called yolk, which is the beginning of the embryonic type. This yolk enables the young form to dispense with the necessity for ingestion of food. At the same time it affects the segmentation. If the yolk were evenly distributed throughout the egg, and not too abundantly, the only effect of its presence would probably be a retardation of segmentation, but it is usually either aggregated towards the centre of the egg or in one hemisphere. Eggs with central yolk are often called *centro-lecithal*, and those with polar yolk are often called *telo-lecithal.*

In centro-lecithal eggs the segmentation is usually equal, but the presence of the yolk retards or prevents the inner part from segmenting; hence this type of segmentation is called *superficial* (see *Nephrops*). In telo-lecithal eggs, if the yolk be not too great in amount, it merely retards the segmentation of the hemisphere in which it is situated and we have a *total unequal* segmentation (see *Frog*). In many telo-lecithal eggs, however, the amount of yolk is so enormous that it entirely prevents segmentation of the part occupied by it and the cell-formation only proceeds at one pole. This is called *partial segmentation* (see *Chick*).

There are numerous transitions and modifications of these types.

SUMMARY :—

1. Equal segmentation (retaining centro-symmetry).
   - (1) *Total Equal.*— Found in eggs with no yolk (alecithal) or with evenly distributed yolk.
   - (2) *Partial Equal* (superficial).—Found in eggs with yolk aggregated symmetrically round the centre.
2. Unequal segmentation (showing axo-symmetry, one pole of the egg differing from the other).
   - (1) *Total Unequal.* — Found in eggs with moderate quantity of yolk, aggregated at one pole.
   - (2) *Partial Unequal.* — Found in eggs with a great quantity of yolk.

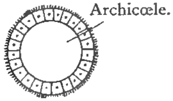
**Types of Larvæ.**—Several important larval types are found in the *Metazoa.* Many of them occur in several groups and with sufficient persistency to indicate that they represent phyletic stages. We may briefly note some of the following :—

### 1. Monoblastic Larvæ.

1. THE BLASTULA.—The blastula larva is a hollow ball of cells of one-cell thickness, it is usually free-swimming and marine, and the cells bear either cilia or flagella,

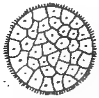
by which it rotates freely about the centre. It represents the typical centro-symmetric and monoblastic organism. The layer of cells is called the *archiblast* and the internal cavity the *archicœle* (or *blastocœle*). As the organism is completely centro-symmetric there can be no division of labour between the cells; hence the blastula represents the phyletic stage of a colonial protozoan rather than a true metazoan.

Fig. 16.
SECTION OF BLASTULA.



2. MORULA.—The morula differs from the blastula in having the internal cavity filled up with cells, thus forming a solid ball or mulberry-mass. It is difficult to imagine a living adult organism like a morula, and it is probably a cœnogenetic larva.

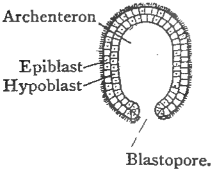
Fig. 17.
SECTION OF MORULA.



## 2. Diploblastic Larvæ.

3. GASTRULA.—This is possibly the most widespread and important larval form. It is typically of a "bell" shape, varying from a "cup" to nearly a sphere or cylinder. Like the blastula it is usually a free-swimming marine larva. It has two layers of cells—the outer, termed the *epiblast*, and the inner, the *hypoblast*. The internal cavity is termed the *archenteron*, and its opening to the exterior is called the *blastopore*. The epiblast cells are usually ciliated, and the larva is free-swimming, with motion in a spiral direction along the long axis through the blastopore. The gastrula is the typical diploblastic axo-symmetric larva, with physiological division of labour between the epiblast and hypoblast, the latter being specially concerned with the function of alimentation, the former with those of locomotion, sensation, and excretion. Its body-plan is much the same as that of living *Cœlenterata*. The gastrula is produced from the

Fig. 18.
SECTION OF GASTRULA.



blastula in several ways. The four most important are as follows:—

(1) *Archiblastic Invagination.*—This method is common in the typical (or free-swimming) larva. It consists of the tucking-in of the whole of one hemisphere of cells, very much as a hollow india-rubber ball when punctured may be tucked in. The rim of the hemisphere gradually narrows to form the blastopore.*

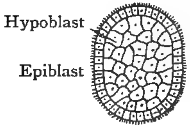
(2) *Unipolar Ingression.*—Single cells at one spot or pole of the blastula break away from the archiblast and migrate inwards, arranging themselves later as an inner layer, the pole of ingression afterwards forming the blastopore.

(3) *Multipolar Ingression.*—Single cells at indefinite parts of the whole archiblast break away and migrate inwards, arranging themselves as an inner layer, a blastopore being acquired later as a perforation.

(4) *Delamination.*—Each archiblast cell divides into two by tangential division and thus the one layer is converted into two. A blastopore is then formed as a perforation.

It is probable that multipolar ingression is the most primitive of these methods of gastrula production and that it leads, on the one hand, to the very cœnogenetic (or embryonic) delamination, and, on the other, to unipolar ingression and finally invagination.

Fig. 19.
SECTION OF PLANULA.



4. THE PLANULA.—The planula bears much the same relation to the gastrula as does the morula to the blastula. It is an oval larva, formed by an outer layer of ciliated epiblastic cells, containing a solid mass of hypoblast in its interior. It is usually active, free-swimming, and marine. It is found very commonly in *Cœlenterata* and is a cœnogenetic modification.

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* In embryonic developments with much yolk the epiblast cells may grow gradually over the hypoblast cells, as the latter are too large to be tucked into the former. This type of *gastrulation* (formation of gastrula) is termed *epibolic* in contrast to the true invagination, often called *embolic.*

### 3. Triploblastic Larvæ.

There is great variety in the external form of the triploblastic larvæ and a description of each will be found in the account of the phyla in which they occur. The most important are:—*Bipinnaria* and *Pluteus* (*Echinodermata*), *Tornaria* (*Balanoglossus*), *Trochophore* (*Annelida* and *Mollusca*), *Nauplius* (*Crustacea*), *Chordula* (*Atriozoa*), *Tadpole* (*Amphibia*).

The third layer or *mesoblast* develops from the hypoblast in the same variety of manner as does the hypoblast from the archiblast. Hence the mesoblast may arise by invagination, ingression, or delamination.

With the origin of the mesoblast the diploblastic larva becomes plano-symmetric; hence the mesoblast usually shows a more or less paired arrangement. The hypoblast arises by *one* invagination or by one ingrowth, but the mesoblast arises by never less than two rudiments, which soon become arranged laterally.

There is great variety in the details, but after the mesoblast is established it *usually* shows the following characters:—It consists of a more or less complex double layer of cells, of which the outer layer lines the epiblast and the inner covers the hypoblast. These two layers enclose a spacious cavity called the *cœlom*, which usually is filled with a nutrient fluid. The cœlom is not usually continuous but it may be divided in the median plane by dorsal and ventral mesenteries, which are double, and serve to support the hypoblastic canal; or it may be divided up by lateral mesenteries or septa running transversely to the long axis of the organism. The mesoblastic walls later form the muscles, skeletal tissue, gonads, and partly the excretory organs; and the cœlom often communicates with the exterior by paired canals called nephridia.*

The *cœlom* is therefore a cavity entirely surrounded by mesoblast; its walls give rise to the muscular, skeletal and reproductive systems; and it usually communicates by paired apertures or canals to the exterior.

It may arise in continuity with the cavity of the hypoblast or archenteron which is obviously the case when the mesoblast arises by invagination. This origin is called *enterocœlic*.

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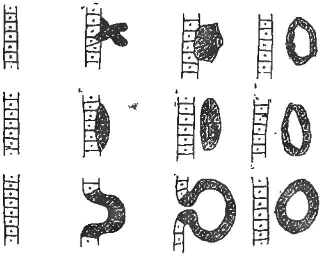
* This should be compared with the types of structure in Chap. III.

In other instances, it may arise as a split in a solid mass of mesoblast which has been itself produced by delamination or by polar ingression. This origin is called *schizocœlic.*

A third origin of the cœlom is found in the case in which the mesoderm arises by *multipolar ingression.* In this case the ingressive cells arrange themselves in two layers to enclose the cœlom, which is thus a transformed part of the archicœle. Hence this origin is called *archicœlic.*

The same methods of origin for the archenteron of diploblastic larvæ can be made out. It will, however, be clearly seen that the origin of the layer itself (hypoblast or mesoblast), and not that of the cavity, is the important consideration. We must regard the primary layers of hypoblast and mesoblast as *organs*, and as such they arise according to circumstances in any of the ways in which an organ may arise. These may be conveniently generalised as follows:—

Fig. 20.—The Origin of an Organ.



The upper row shows the cytic origin by single (dark) cells detached from parent layer (light). The middle row shows the dermic origin and the lower the tomic.

1. As a number of detached cells from the parent layer (*cytic*). These may be diffused or localised in their origin.

2. As a layer of cells or epithelium detached from the parent layer (*dermic*).

3. As a hollow sac of cells invaginated from the parent sac (*tomic*).

Organs originating in these ways from the three primary layers form together the complex organisms found in the animal kingdom. In a very general way, the organs usually arise from the three primary layers as follows :—

1. EPIBLAST.—Epidermis.
    Sense-organs and nervous system.
    Excretory system (partly mesoblast).
2. MESOBLAST.—Muscular system.
    Skeletal system.
    Blood-vascular system.
    Reproductive system.
3. HYPOBLAST.—Alimentary system.

Fig. 21.—THE METAMORPHOSIS OF THE SILK-WORM MOTH.

The larva or caterpillar spins a cocoon and changes into a pupa (on the stem) which later gives rise to the winged moth. Both sexes are shown.

**Metamorphosis.**—From the foregoing we see that in the course of time any stage in the life-history of a species may, to meet a special environment, be especially and cœnogenetically developed until a larval stage is produced in marked contrast to the adult.

In some instances this independent evolution of two stages in the life of one organism has reached such a climax that the adult stage can only be reached by an entire reconstruction of the larva. The reconstructive stage is known as a *pupa* (or pupal stage), and the whole change is termed a *metamorphosis.*

The insects show us a complete series in the origin of metamorphosis. One instance, of the silkworm moth, must suffice: the caterpillar, or silkworm, is a worm-like larva which lives often for a considerable time with all the functions active except that of reproduction. It then becomes transformed into a quiescent pupa and a number of its organs are broken down and others constructed until, finally, the perfect winged moth is set free.

Some instances of this *divergent evolution* of two stages in the life of one individual have a deceptive likeness to the growth of a fresh individual or generation upon the preceding one.

### Summary.—

The individual commences life as a *fertilised unicellular ovum.*

By growth, cell-division and differentiation, it is converted into the adult organism.

The early cell-division is called *segmentation*, which varies in type according to the quantity and arrangement of the yolk.

Segmentation usually results in the production of a *monoblastic* stage, with one primary layer, or *archiblast.*

The *archiblast* is converted into two primary layers, the *epiblast* and *hypoblast*, forming a *diploblastic* stage.

The adult may remain at this stage or the third primary layer, *mesoblast*, may be produced, forming a triploblastic organism.

Each primary layer then produces a series of *organs* in regular sequence.

The primary layers and the other organs all arise by one of three methods.

All or part of a development may be *larval* or *embryonic.*

In larval development, a divergent evolution of larva and adult produces a *metamorphosis.*

# CHAPTER VII.

## *GEOGRAPHICAL DISTRIBUTION.*

THE **distribution** of animals may be divided into distribution in time and in space. The former is usually termed GEOLOGICAL distribution, and in the latter we may distinguish GEOGRAPHICAL distribution, divided into *physical* and *topographical*.

**Physical Distribution.**—If we take note of the place of animals in nature we see at once that some inhabit the land and are *terrestrial*, others again live in the sea or fresh-water and are termed *aquatic*, and yet others are found spending most of their life in the air, these being termed *ærial*.

The aggregate of animals which are found in one of these particular *habitats* is termed the *fauna* of the habitat, just as that of plants constitutes the *flora*.

Hence we can distinguish three primary *habitats* of animals, called the *terrestrial*, *aquatic*, and *ærial*. The fauna of any one of these may be very diverse and be made up of animals differing widely from each other in many respects, but still we shall be able to notice that connected with each habitat there are certain main structural features in the fauna. For example, all the ærial types must have some form of wings or organs of flight.

1. **Aquatic Fauna.**—In this fauna are included the inhabitants of the ocean, of our seas, lakes, rivers, streams, and ponds.

With such an enormous diversity of physical conditions, there are few general features to be discerned. We may at once divide it into (1) Marine and (2) Freshwater.

(1) MARINE FAUNA.—The importance of the marine fauna can hardly be over-estimated. The ocean has been

nature's cradle, and in it still dwell numerous low types of animals, which indicate to us the structural plan of the earliest animals of our earth.

If we take the four groups which stand at the base of animal creation, namely, the *Protozoa*, *Porifera*, *Cœlenterata* and *Echinodermata*, we find that the sea has an entire monopoly of the *Echinodermata*, a practical monopoly of the *Porifera*, and an immense preponderance of the other two. The same tale is told if we go on to the *Polyzoa*, *Brachiopoda*, and *Annelida*. It is only when we come to the *Mollusca*, *Arthropoda* and the *Vertebrata*, that a considerable number of terrestrial and ærial types make their appearance.

There is evidence for believing that the ocean was peopled with animal life for many ages before the dry land, hence it is not surprising that a number of nature's lowest types still live on with little modification in the somewhat similar environment.

Let us recollect that in the structural characters of animals, both young and old, we have attempted to distinguish between the inherited and the acquired, the palingenetic and the cœnogenetic. In a precisely similar way we may discern in marine fauna the palingenetic and the cœnogenetic inhabitants. In the case of the great majority of the lower phyla there is no reason to suppose that the sea has ever been forsaken. The marine *Protozoa*, *Porifera*, *Cœlenterata* and *Echinodermata*, have ever been marine, but there are a number of marine birds, some marine mammals (*Cetacea* and *Sirenia*), and a few marine insects, which are evidently descended from terrestrial ancestors and have fallen from their high estate to once more rejoin their more lowly organised relations in the ocean.

The marine fauna may be sub-divided into:—

Pelagic zone.
Neritic zone.
Abysmal zone.

(*a*) *Pelagic Zone.*—Of all the marine fauna, the pelagic zone includes probably the most primitive types. They consist of those animals which dwell at or near the surface of the ocean far away from land. They belong mainly to the

*Protozoa* and the *Cœlenterata*, though there are a considerable number of *Crustacea* and fishes and a few representatives of the *Mollusca* and *Tunicata*. It is very important to notice that a great number, if not the majority, of the neritic types pass the earlier part of their career in the pelagic zone. Many have pelagic eggs, as, for example, most fishes, *Amphioxus*, and a number of *Crustacea* and worms, whilst still more have pelagic larvæ. Nearly all the important larval types are pelagic, such as the different kinds of echinoderm, cœlenterate, crustacean and annelid larvæ. The blastula, planula, gastrula, trochophore, bipinnaria, pluteus and nauplius are all typical of this zone. All these perform an *ontogenetic* migration from shore to pelagic water and back again, and the most natural inference is that this is a repetition of a past phylogenetic migration when the neritic zone was peopled from the open sea. Throughout the pelagic zone are countless myriads of microscopic algæ which form the chief food-basis of the animal life. Hence the food-supply, although of small individual dimensions, is inexhaustible, evenly diffused, and easy of capture. Upon these organisms feed the multitudes of *Radiolaria* and *Foraminifera* and swarms of *Copepod Crustacea*. The smaller pelagic animals exhibit a perfect translucency, the only means of concealment from foes in a region suffused with light. The larger types, of too great a bulk for this device (such as dolphins, mackerel, &c.), have the dorsal part of the body of a sea-green or dark-bluish tint and the ventral part a pearly-white.

We may note that the majority of pelagic organisms have pelagic eggs and have no connection at any time of their life with the neritic region. Some of the jellyfishes form a remarkable exception to this rule.

Pelagic organisms may be divided into two great groups, according to their habits, often called the Plankton and Nekton. These two rather cumbersome words merely mean the floating and swimming forms respectively.

The Plankton are the lowest and simplest types, and either drift passively or sustain themselves actively in the water. Many have air-vesicles to render themselves buoyant and the majority show axial symmetry (*Cydippe* and *Aurelia* are examples).

The Nekton swim about actively and determine their own movements. They are, as a rule, higher and more complex types and show plano-symmetry (*Sepia* and *Sagitta* are examples).

(*b*) *Neritic Zone.*—The neritic zone extends from high tide-mark down to about 500 fathoms. It includes only the animals found at or near the bottom, and is a zone containing a rich variety of forms. It can be divided into two well-defined sub-zones—(1) the littoral, and (2) the katantic. The littoral sub-zone extends between extreme tide-marks. It has a variety of animals capable of exposure to great extremes of temperature, and often to lack of water. Exploration of rock-pools gives one a very good idea of its inhabitants. There are numerous *Echinodermata*, *Crustacea*, *Mollusca* (especially gastropods), and *Annelida*, whilst *Cœlenterata* and fishes are common.

We may divide neritic forms into two groups, according to habits, as in the case of the pelagic. These are the Nekton, as before, and the Benthos.

The Nekton are swimmers which usually feed upon the Benthos, less commonly upon each other. They present many modifications similar to those of the pelagic Nekton, but can usually be distinguished from them. For example, a pelagic fish can usually be at once distinguished from a neritic fish.

The Benthos are a heterogeneous assemblage that live on the sea-floor itself. We can discern the important group of sedentary forms which corresponds to the Plankton of the pelagic zone. They are fixed at one end to a foreign body, and may have a tube or a burrow. They always show more or less axial symmetry, and the higher types have a U-shaped alimentary canal, mouth and anus opening away from the point of fixation. They also frequently occur in colonies. They belong to the *Protozoa*, *Porifera*, *Cœlenterata*, *Echinodermata*, *Polyzoa*, *Brachiopoda*, *Crustacea*, *Mollusca*, *Annelida* and *Tunicata* (*Sycandra*, *Obelia*, and *Actinia*, are examples).

The second group creep or crawl over the surface of the bottom, their weight being borne by it. These consist principally of the creeping *Mollusca* and the crawling *Crustacea*. These types are important, for they are the first to become adapted to locomotion over a hard surface, and to support against gravity upon this surface. From types which have been so adapted in the past originated all the land animals, for the same problem in more pressing degree has to be solved in them.

In marked contrast to these are the sedentary group, which are never found on land and remain neritic.

The katantic sub-zone resembles in most respects the littoral but there is great variety and diversity in so large an area. This zone in a general way has the greater proportion of our valuable food-fishes, together with great numbers of bivalve and univalve *Mollusca* and *Crustacea*. *Cœlenterata*, such as corals and zoophytes, are in great profusion and all the classes of marine fauna are well represented (*Nephrops* and *Raia* are examples).

(*c*) *Abysmal Zone.*—The Abysmal zone extends from 500 fathoms downwards to the greatest depths of the sea. The physical conditions of this zone are unique. Below 500 fathoms it is practically certain that no light penetrates, hence the abysmal zone, so far as natural light is concerned, is in eternal darkness. The pressure increases rapidly with the depth so that "at a depth of 2500 fathoms the pressure is, roughly speaking, two-and-a-half tons per square inch." The greatest storms never affect this zone, hence there is perpetual stillness. The temperature varies enormously but is always lower than that of the surface-water, in many cases very low indeed. This is probably due to extremely slow but widespread polar currents which make their way along the bottom towards the equator.

No plants can live in this zone for there is no sunlight, but the pelagic life far above appears to shed downwards a continual rain of shells and dead organisms. These former are found in vast numbers in some parts of the ocean. The floor consists of at least three important sediments called ooze. The Red mud is found widely scattered in the greatest depths. It contains the siliceous remains of Radiolarian and diatom shells. *Globigerina* ooze occurs in shallower water (2000 fathoms upwards) and is characterised by numbers of calcareous shells of *Globigerina* and other *Foraminifera.* Pteropod ooze appears to occur at depths of about 1500 fathoms upwards in certain tropical regions. It has far less lime than *Globigerina* ooze as it contains siliceous radiolarians and numerous pteropod shells. The abysmal region is peopled by a fair number of species scattered throughout the same phyla as are found in the neritic zone. Indeed there is every indication that the deep-sea has been gradually peopled from the neritic region by immigrants.

All the animals show more or less striking modifications. All are carnivorous and many are phosphorescent. There are numerous *Crustacea* which often attain enormous size. Many of the large species are blind and of a light carmine colour. The fishes, as at present known, are few in species, all bony fishes or *Teleostei*, and of extraordinary appearance.

(2) FRESHWATER FAUNA.—The freshwater fauna is very diverse, as it includes dwellers in lakes, ponds, rivers and streams. It shows clear indications of having been derived from the Neritic zone of the marine fauna, though doubtless in some cases terrestrial animals have reverted to the freshwater.

The same divisions, into swimmers or Nekton, Plankton and Benthos, can be made out, but the Plankton are very few in number, including *Protozoa* and a few freshwater Medusæ. Amongst the swimmers we can notice two very primitive orders of fishes, the *Ganoidei* and *Dipnoi*, which are confined to freshwater, apparently driven from the sea by more specialised types.

Two important points should be noted. Firstly, a great number of freshwater forms can meet the physical vicissitudes of their habitat by encapsuling themselves and remaining dormant for some time (*e.g.*, *Amœba*, *Infusoria*, *Rotifera*, and *Tardigrada*). Secondly, the eggs and larvæ are hardly ever of the floating or free-swimming types, and are commonly protected by a hard capsule. As the rivers have been the lines of migration, the eggs and larvæ would, if floating, be borne back to the sea.

The primitive freshwater types are especially interesting as leading along the path towards the terrestrial fauna.

**2. Terrestrial Fauna.**—The terrestrial fauna has evidently been derived in the past from the aquatic. Only a few phyla appear to have effected this migration. Of these the

*Vertebrata* and *Arthropoda* stand pre-eminent. In the first we find the lowest class (*i.e.* fishes) is aquatic and mainly marine; the amphibians are freshwater and terrestrial. The reptiles still cling to the aquatic life but the majority of birds and mammals are typically terrestrial or ærial.

In the *Arthropoda*, again, the *Crustacea* are typically aquatic and are in many respects the lowest class, but the *Arachnida*, and above all the *Insecta*, are large and important terrestrial classes. Other terrestrial animals belong to the *Mollusca (Gastropoda)*, *Platyhelminthes*, *Nematoda* and *Annelida*. With the exception of these three lowest phyla, all show special air-breathing respiratory organs, moisture is supplied to the food by salivary glands, and iron replaces copper in the blood. All are plano-symmetric (with very few exceptions).

We may distinguish several subsidiary divisions:—

1. Cursorial (running).
2. Fossorial (burrowing).
3. Arboreal (tree-dwelling).
4. Reptant (creeping).

3. **Ærial Fauna.**—This fauna is still more select and smaller in numbers than the last. Nearly all the birds, a few mammals, one or two fishes, some extinct reptiles, and any number of insects make up the group. They are mainly characterised by extremely active bodies, paired "wings" as locomotor organs, and highly-developed sense-organs.

They resort to the terrestrial or aquatic habitat for their reproduction and they have themselves been derived from terrestrial ancestors. (In one or two cases from aquatic.)

SUMMARISING, we may distinguish in the physical distribution of animals certain habitats which involve special physical conditions and are inhabited by special faunas. Of these we can clearly distinguish—

1. Pelagic.
2. Neritic.
3. Abysmal.
4. Freshwater.
5. Terrestrial.
6. Ærial.

There is also evidence for believing that the general trend of evolutional progress, the phylogenetic migration of the animal kingdom, has been from Pelagic to Neritic, from Neritic to the Abysmal and the Freshwater. From the Freshwater it has passed to the Terrestrial and thence to the Ærial. This general conclusion is not vitiated by the equally certain fact that there have also been cross-migrations and back-migrations of certain types. Certain mammals (whales) have obviously reverted to pelagic habitat and some neritic types (land-crabs) have passed directly to the terrestrial.

**Topographical Distribution.**—Just as the animal kingdom is classified into phyla, classes and orders, so the world's surface is divided by zoologists into realms, regions and provinces, to emphasise degrees of difference in the fauna. The same ideal of a natural classification is striven after, and there is the same difficulty of distinguishing between resemblances due to parallel evolution and those due to genetic connection.

The limits of the realms, regions and provinces are mainly defined by the presence or absence of certain *Mammalia*, for, as will be seen later, they are specially suitable for this purpose. Hence we need here merely note the chief zoo-geographical realms and leave more detailed consideration of them to the section dealing with *Mammalia*.

### Zoological Realms—

1. ARCTOGŒA = N. America, Eurasia and Africa.
2. NEOGŒA = S. America, W. Indies and part of Central America.
3. NOTOGŒA = Australia, New Guinea, Polynesia, New Zealand and certain Malay Islands.

These three realms are divided into a number of important regions.

The Regions of Arctogœa are—

A. HOLARCTIC = Europe, N. Asia and N. America.
B. ORIENTAL = India and Further India.
C. ETHIOPIAN = Africa (South of the Sahara).
D. MALAGASY = Madagascar.
E. SONORAN = United States.

**Oceanic Islands.**—We have now to distinguish between the terrestrial and ærial, for the distribution of terrestrial types is profoundly modified by the present and past distribution of land surface. Ærial types, on the other hand, are not affected by comparatively large straits or channels.

This is well illustrated by the fauna of *Oceanic Islands.* An oceanic island is an island which has been widely separated from the mainland either from its very origin or from a very remote date. Its fauna consists entirely of immigrants from the adjacent mainland. Its truly terrestrial fauna is usually small, consisting of small invertebrates, reptiles, or mammals which may have effected the journey in logs of wood or by other accidental means. On the other hand its ærial fauna may be rich, for bats, birds and insects can easily migrate across the water.

The most remarkable feature is that these ærial types, especially in small and widely-isolated islands, show a tendency to give up their ærial habits and become terrestrial. Thus "wingless" birds and "wingless" insects are characteristic of oceanic islands. The explanation of this will be clear after reading Chapter X., but we may only indicate here that these wingless types are, in most instances, assumed to be descended from winged ancestors, and that the very wings which bore their ancestors to the island would to them be a source of danger, their use involving a risk of being blown out to sea. The entire absence of terrestrial predatory forms removes one of the first necessities for wings; hence the loss of wings resolves itself into an adaptation to a very peculiar environment.

**Discontinuous Distribution.**—The consideration of oceanic islands shows that there is no finality nor permanency in the fauna of an area. There is the same ceaseless change and succession of types as we find elsewhere in nature. A particular species of animal will spread slowly from one or more centres and reach a climax of wide distribution, from which it will slowly recede till extinction ensues. This extinction will not take place in regular order, from the original centre outwards, but will, in most instances, leave isolated remnants of the race in more or less separated areas. Thus is produced the phenomenon known as "discontinuous distribution."

From the causes producing discontinuous distribution it is evident that such a distribution will prevail amongst *primitive* or vestigial types. The mudfishes were at one time a widely scattered marine order of fishes, but at the present day the only survivors are the vestiges of the race which are found in various rivers. Amongst terrestrial forms, one of the best instances is the archaic *Peripatus*, which is found at the Cape, in New Zealand and Guiana, but not in intermediate districts.

# CHAPTER VIII.

## GEOLOGICAL DISTRIBUTION.

THE past history of animals might conceivably have been a sealed book to man's investigations but fortunately the succession of organisms has left considerable vestiges behind it. These vestiges, in a general way, are termed *fossils,* which are mostly found deposited in earth. The surface of the earth for a slight but varying depth consists of a loose soil, but below this there are layers or strata, formed of various substances, such as limestone, sandstone, coal and so on. These strata have been gradually deposited in past ages by the action of natural forces. At the present time the same process is going on. The dry land is slowly being broken up by the action of rain, frost and other agencies, and the finely divided remains are being carried out to the sea by rivers. There the sediment in the form of mud and sand is slowly deposited on the sea-floor. All along the sea-coasts the waves are ceaselessly carrying on the same work of destruction, the pebbles, sand and mud being deposited out to sea. Hence the physical agencies of wind, tide, rain and wave work to a common end—the reduction of the earth's surface to a dead level which, if ever attained, will be some feet below the general surface of the sea. At present there is a counteracting force to the attainment of this in the elevation of the earth's surface by the active agencies in its interior.

We must therefore conceive of the whole of the earth's surface as a shifting scene of land and water, upon which the levelling and elevating agencies are constantly at work in opposite directions. Should the elevating agencies, due to the internal energy of the earth, be dissipated, as no doubt they will in the far future, the dry land would disappear for ever below the sea.

The products of destruction, in the form of mud, sand, or silt, are deposited as strata, and in these are found the organic remains we term *fossils*. The commonest form of fossil owes its existence to the power of organisms to construct skeletons for their mechanical support in life. These as we have seen are either calcareous, siliceous or chitinous. They are shed in aquatic organisms into the mud or sand and covered up by fresh deposits, or in the case of land animals they may be carried out to sea or into lakes by floods and other accidents.

In many cases, the skeletons only remain sufficiently long for a cast of their shape to be taken, the fossil really consisting of mineral matter but of precisely the same shape as the original skeleton. Another way in which fossils may be produced is by impressions. Soft sand takes an exact impression of any body from a footmark to a scratch, and in many instances these impressions have been produced by the soft and perishable parts of an organism. If mud or some fresh deposit differing from the sand be then deposited in the impression a permanent memorial of the organism is preserved in the rocks.

Skeletons and other remains of more recent date may be found deposited in caves, peat-bogs and elsewhere, little altered from their normal condition.

The strata of rocks can be arranged or classified by careful study into a series corresponding with their succession in time. They are thus divided into five primary groups, called :—

I. Primordial.
II. Primary.
III. Secondary.
IV. Tertiary.
V. Quaternary.

These five groups are further subdivided into a number of *Systems*. Each group evidently corresponds to a certain lapse of time, during which it was produced, which is called an *Era*, and each system represents a lapse of time called a *Period*. These may be tabulated as follows :—

| *GROUP—(Era). | | SYSTEM—(Period). | Approximate thickness of Strata. |
|---|---|---|---|
| I. | Archizoic. | Cambrian.<br>Ordovician.<br>Silurian. | 70,000 feet. |
| II. | Palæozoic. | Devonian.<br>Carboniferous.<br>Permian. | 42,000 feet. |
| III. | Mesozoic. | Triassic.<br>Jurassic.<br>Cretaceous. | 15,000 feet. |
| IV. | Cainozoic. | Eocene.<br>Miocene.<br>Pliocene. | 3000 feet. |
| V. | Anthropozoic. | Pleistocene.<br>Recent. | 600 feet. |

This enormous thickness of about 130,000 feet represents a vast duration of time and we can only compare one part with another.

It has been estimated that at the present time the *average* rate of deposition may be taken as about 1 foot in 1500 years. This would give us about 200,000,000 years, which with corresponding periods of elevation might be 400,000,000 years. Such a calculation is really of practically no value as there are many factors which might easily multiply the figures.

The Archizoic group have strata in many cases modified by heat and pressure and they are probably by no means the first strata. In other words, the origin of animals is antecedent to the Archizoic Era. Thus, the strata of this era show *Arthropoda*, *Echinodermata*, *Mollusca* and other phyla, all sharply differentiated as at the present day.

The geological record does not, therefore, help very much in giving us the original ancestors of these phyla, but it forms a very important guide with regard to the higher animals. Thus, although fishes are found in the Silurian system the other five orders of *Vertebrata* only occur thereafter. Hence there is always hope that the geological record may assist us in tracing the descent of the higher vertebrate

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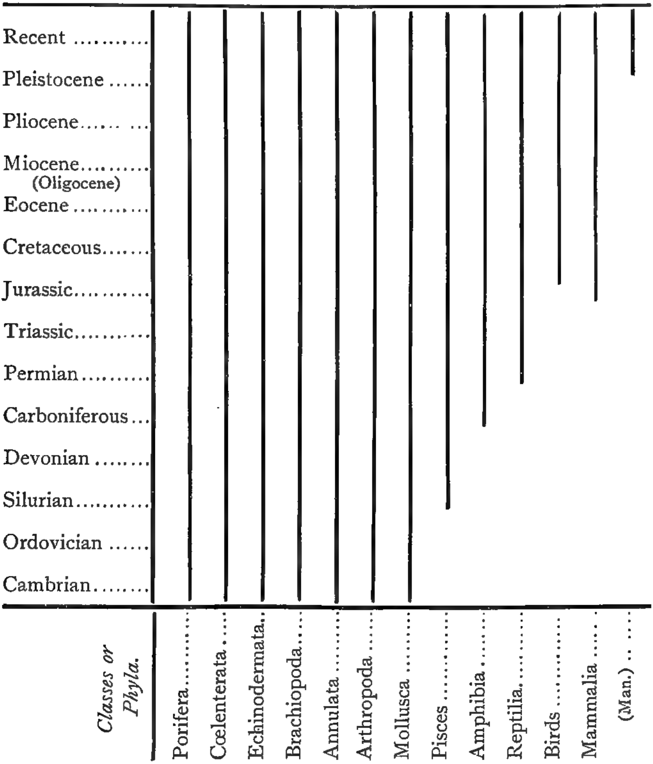
* This table is taken from Hæckel's "History of Creation."

classes, and, in the case of *Mammalia*, the past history of some orders has by this means been largely unravelled. If the progress of evolution has been from lowest to highest this is exactly the state of affairs we should expect to find.

We may tabulate the classes and the order of their appearance in time.



The geological record must therefore be regarded as merely a last chapter of the history of creation, a chapter with enormous imperfections and numerous omissions, written in a language which is capable of many delineations depending largely upon the imagination and ingenuity of the reader.

Lastly, we may note that there are important animal types which have their origin, and their end, within the geological record. These are called *extinct* animals and their study forms one of the most interesting chapters in zoology.* Orders and classes which now are represented by a small remnant appear to have flourished in the past in an astonishing manner until they were replaced by other types. The proximate agent causing their extinction may in many cases be obscure, but it is evidently part of a general law which ensures that the phylum, the class, the order, the genus, and the species shall arise, flourish, and depart in the same way as the individual.

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* The study of extinct animals is often termed Palæontology, but it is inseparable from Zoology.

# CHAPTER IX.

## *BIONOMICS.*

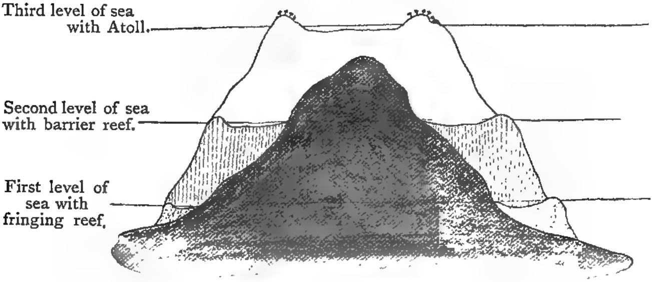
THE term *Bionomics* is used to denote the study of the relationship of an organism to its environment, in the widest sense. We may here briefly notice (1) The relationship of an organism to the inorganic world, and (2) The relationship of an organism to other organisms.

1. **Physical Relations.**—Many organisms live their life and pass away, leaving very little, if any, direct material impression on the world around them. Such may be illustrated by *Amœba* or a jelly-fish. Others, again, have by their resultant energy done a great deal in determining the present physical condition of the earth. Amongst the *Protozoa* there are the *Radiolaria* and *Foraminifera*. Their countless numbers compensate for their microscopic size. They secrete from the sea-water around them hard skeletons, some calcareous and others siliceous, which, on the death of the animals, collect on the sea-floor in great quantities. In Chapter VII. (page 60), on deep-sea fauna, the "oozes" thus formed are alluded to. Whatever may be the ultimate fate of these oozes, we know that large strata of limestones, especially also chalk, are often made up almost entirely of shells of *Foraminifera*.

Other rock-building forms are the sponges, echinoderms, certain worms, *Crustacea*, and *Mollusca*, all having calcareous skeletons which contribute to the formation of limestone rocks, consolidated under water, and then upheaved and exposed. But the most important rock-builders are the corals. The ceaseless, united energy of these animals has resulted in the production of enormous structures, such as the Great Barrier Reef, extending for more than 1000 miles along the N.E. coast of Australia.

In pure water of a certain temperature the deposition of lime by corals is very rapid. Coral Islands, or *atolls*, are, as a rule, nearly circular or horse-shoe shaped, the inner lagoon being shallow and communicating with the open sea by a channel on the leeward side. There is usually deep water off the island. Coral Reefs are small and skirt the shore of an island, frequently as a long ridge parallel to the shore and some distance from it when they are called *Fringing Reefs*, or if they be large and a long way out from the shore they are called *Barrier Reefs*. The water outside of a barrier reef is often of great depth.

Fig. 22.—Diagram to Illustrate Darwin's Theory of Coral Reefs.



The slow subsidence of the land causes successive changes of sea-level.

The difficulty in accounting for the origin of coral islands and coral reefs lies in the fact that the commonest and best reef-builders do not find suitable conditions of temperature below about 25 fathoms, whereas great depths are found immediately outside atolls and barrier reefs. This is overcome by various suppositions. That connected with the name of Darwin assumes extensive subsidence of the land, gradually converting a fringing reef round a peak into an atoll, the process being so slow that the coral is always built up to the surface, whereas that which passes below the 25-fathom line ceases to grow, owing to death of the animals. Other theories hold that a deeply-submerged peak can be built up to the 25-fathom line by a rain of foraminiferan shells, assisted in many cases by deep-sea corals, and that when once a coral colony is established on the summit, it can progress seawards on its own detritus broken off and rolled down the slope. It may be taken for granted that a coral colony growing in moderate depths will reach the surface as a cup or small atoll, by the ordinary laws regulating the growth of a sedentary organism.

Many marine organisms thus play an important part in nature's economy by the formation of chalks and limestones. Others constitute powerful destructive agencies. As examples we may cite the boring *Mollusca* which tunnel through wood or rocks.

When we turn to terrestrial organisms, we find that their efforts are quite as effective in modifying the surface of the land, though usually they act indirectly through the plant kingdom.

Earthworms have been shown to have an important function in burrowing through the earth and passing it through them. They are nature's ploughs, and are ceaselessly employed in bringing fresh soil to the surface, as can be easily observed in an unrolled tennis-court. The lobworm (*Arenicola*) performs much the same function on the seashore.

Insects, birds and mammals act on the physical world mainly through plants. Birds are great distributors of plant seeds, and thus conduce to supplying oceanic islands and other districts with plants, which themselves alter the physical constitution of the islands. Grazing cattle may denude a well-wooded district of its trees by feeding on the young shoots, and the loss of forests may alter the rainfall and other physical conditions. It has been suggested that the Pampas of Argentina have thus lost their primeval forests.

2. **Organic Relations.**—No organism can live without having some action and reaction upon other organisms. Animals, as we have seen, are either plant-eaters (herbivora) or animal-eaters (carnivora). This connection, as regards food, often leads to more permanent connection which is known by different terms according to its intimacy.

Animals of a similar structure or species often find it advantageous to seek for food together, either for mutual protection (herbivora) or for mutual support in attack (carnivora). These are said to be *gregarious.*

In some cases, animals of a different kind are found in partnership. Strange combinations of two or more animals of divergent structure are found dwelling together. If this partnership appears to be an equal one, with mutual benefit accruing, it is termed *Commensalism.* A good instance is found in the common hermit-crab, which has a particular species of sea-anemone living upon its shell. If one organism obtains all the benefit, then commensalism shades off into *Ectoparasitism:* In many instances it is impossible to decide between the two categories.

Sedentary marine organisms are nearly always intimately connected. A cockle may have a hydroid zoophyte growing upon it with *Vorticella* upon the hydroid zoophyte and a few tunicates with small *Polyzoa* upon them. A tubicolous worm may be fastened to the back of an oyster, with acorn-barnacles covering its tube, and so on. In each case it is impossible to decide how far commensalistic or ectoparasitic proclivities predominate.

Ectoparasitism also gradates into the carnivorous habit. The lion can hardly be termed an ectoparasite on the antelope, but the hagfish has often had this appellation because it feeds on fish, and a leech is another difficult instance.

If commensalism becomes still more intimate, and the two organisms become inseparable in their vital processes, the union is termed *Symbiosis.* Numerous instances of symbiosis occur. One of the best examples is that of radiolarians and their partners the unicellular algæ, termed *yellow-cells.* The plant furnishes the oxygen required by the animal, and itself uses the carbonic acid produced by the animal.

As in the case of the physical connection, so in this organic union the partnership may be one-sided, in which case it is termed *Endoparasitism.* In endoparasitism the parasite depends for nutrition upon its host, living more or less permanently in its body. Lastly, we can see that the organic union of *like* individuals is termed a *colony*, which is very common in *Protozoa*, *Porifera* and *Cœlenterata*, the lowest phyla.

We may classify the dwelling habits of animals into Physical Partnership and Organic Partnership, thus:—

| | *PHYSICAL.* | *ORGANIC,* |
|---|---|---|
| | 1. Similar Organisms. | |
| | Gregarious. | Colonial. |
| | 2. Dissimilar Organisms. | |
| *Equal*— | Commensalistic. | Symbiotic. |
| *Unequal*— | Ectoparasitic. | Endoparasitic. |

**Endoparasitism.**—All animals which adopt the endoparasitic habit acquire certain features in common by adaptation to their peculiar surroundings.

In following out these features we may divide endoparasites into two groups:—(1) *Somatic* and (2) *Enteric.*

1. Somatic.—Somatic endoparasites live in the body of their host, usually in the muscles or one of the organs, *e.g.*, the liver. They feed upon the actual substance of the host, and are therefore provided with a definite mouth and alimentary canal. They may, in addition, be often provided with locomotor organs. Their systems, which are most modified, are the sensory, integumentary (skeletal), and reproductive. Living inside their host, all sense-organs are to them superfluous as they are removed from contact with the outside world. In a similar manner all protecting integuments, or exoskeletons, are superfluous. Many crustacean parasites, whose free-swimming allies have a hard calcareous skeleton, have a soft colourless skin. A loss of colour is also usual. Lastly, an endoparasite requires well-developed reproductive organs. Both sexes are usually represented in one individual, owing to difficulties of fertilisation, and enormous numbers of eggs are also required. The number of individuals in one host must be strictly limited, or the host would perish and with it the parasites. Hence the young are forced to seek fresh hosts, and the difficulties and perils of the migration are such that a high fecundity can alone counteract the danger of extinction. A common device is the invasion of an intermediate host, which itself forms an article of food to the original host. If the intermediate host be not an article of the original host's diet,

a further migration has to be instituted, which is reinforced by a second reproduction, causing metagenesis (*cf. Distomum*). It is also usual for the eggs to be provided with yolk and a hard outside shell, to withstand the vicissitudes of the outside world. Thus a somatic parasite is usually characterised by:—

(1) Loss of sense-organs.
(2) Loss of exoskeleton and pigment.
(3) Hypertrophy of reproductive organs.

2. ENTERIC.—An Enteric parasite may go considerably further in its adaptation. It is usually resident in the enteron or alimentary canal of its host, and is bathed on all sides by soluble and diffusible proteids prepared for the use of the host. Its alimentary organs are therefore superfluous and atrophy, absorption taking place through the skin. The intestine of higher animals has rhythmic (peristaltic) contractions which tend to drive egestive products to the exterior. Hence enteric parasites usually have organs of fixation, such as hooks or suckers, to attach them to the intestinal wall. All the characters of somatic parasites are also shared by enteric, hence the adaptations of enteric parasites read as follows:—

(1) Loss of sense-organs.
(2) Loss of skeleton and pigment.
(3) Loss of alimentary organs.
(4) Hypertrophy of reproductive organs.
(5) Acquirement of fixative organs.

*Tænia* and *Gregarina* are two good examples of highly adaptive enteric parasites.

**Protective Resemblance* and Mimicry.**—One of the most interesting sections of bionomics is the study of these two phenomena. Protective resemblance comes under the first heading above (physical relations), for it covers the cases of resemblance between an animal and its surroundings. In mimicry an animal shows a resemblance to some other animal. In each case it is usually supposed that the animal obtains a benefit or immunity from ever-watchful foes by such resemblance. The simplest cases are those of protective coloration, in which an animal has the power to

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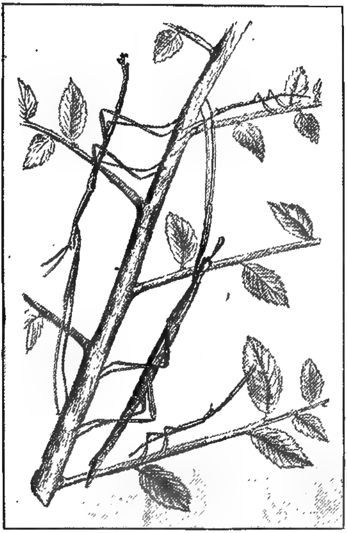
* Certain resemblances may be distinguished as aggressive rather than protective as they are meant to attract the prey or to put it off its guard.

Fig. 23.—PROTECTIVE RESEMBLANCE.



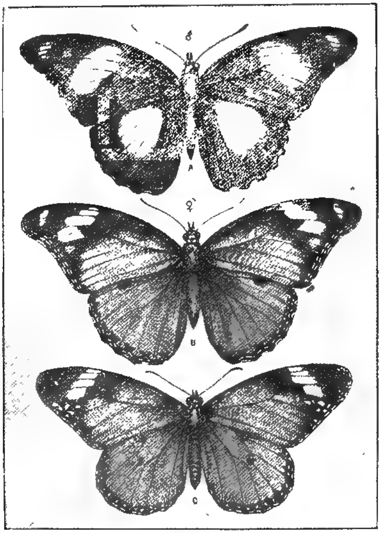
Two examples of *Bacillus Rossii.* A European stick-insect.

Fig. 24.—THE LEAF-BUTTERFLY OF INDIA.
*(Callima inachis.)*

On the left is an individual with wings closed; on the right is another flying.

become of the same colour as its immediate surroundings. As examples we may cite the chrysalides or pupæ of many butterflies, which may be any shade of brown, golden or green, according to their surroundings. The common frog, the cuttle-fish, chameleon, and many fishes are familiar examples. Protective coloration is also of almost universal occurrence amongst mammals. The outline of the body is destroyed by spots or stripes or there is a uniform colour like its surroundings. In other cases there may be an almost ludicrous resemblance to inanimate objects or parts of plants. We may take as an example the familiar Indian *Callima.* This butterfly has the upper surface of the wings gorgeously coloured with yellow, white and metallic blue. On the under surface there is a dull brown pattern which closely resembles the dried leaf of a common tree. When the butterfly settles the wings close, and the sudden change from a bright colouring to a dull leaf-like tint and shape serves to effectively remove it from the vision of its pursuer. It should be noted that we have here a "contrast effect." The more gorgeous the upper surface the more sudden and effective is the change. Hence the bright colours of the upper surface may indirectly conduce to protection. Other insects imitate the droppings of birds and thus obtain immunity.

Fig. 25.—HYPOLIMNAS MISSIPUS.



A. A male.
B. Same species but a female mimicking C.
C. *Danais chrysippus*, a noxious species unmolested by birds.

An instance of mimicry is shown in Fig. 25. Certain brightly coloured butterflies (*Danais*) are of acrid taste and hence secure immunity from foes. Other butterflies (*Hypolimnas*), by closely imitating their coloration, share in the same immunity although themselves not endowed with the acrid taste. In this instance the mimicry is confined to the female sex. Some common flies in a similar manner mimic the colour and manner of wasps, and hence indirectly make capital out of the wasp's sting.

In a very general way coloration in the animal kingdom is supposed to either secure concealment to its possessor by harmony with its surroundings or immunity from attack to its armed possessor by a warning display of bright tints, but with our present knowledge there appear to be numerous unexplained exceptions.

Fig. 26.—An Example of Protective Resemblance.

The common British Orange-tip Butterfly. The upper surface is white, with a large orange patch on each wing. The mottled green and white under-surface is seen in the figure.

# CHAPTER X.

## *HEREDITY AND DESCENT.*

IT is an everyday observation that an organism resembles its parents. This tendency to structural resemblance in genetically-related forms constitutes the principle of *Heredity.* On the other hand, it is equally evident that the offspring is never identical in structure with either parent or even its immediate ancestors; there is always a structural divergence which constitutes the principle of *Variation.* A cursory inspection of a flock of sheep might fail to furnish any individual variations, but a closer study would reveal slight differences, which might enable one to discern the particular sheep which had hereditary resemblances, or were relatives of each other from others similarly connected. A still more intimate acquaintance with them, such as possessed by the shepherd, would lead to the recognition of individual variations sufficiently definite to identify each sheep at once by sight. In the ordinary way the similarity due to heredity far outweighs the dissimilarity due to variation. Hence a rabbit may differ in small particulars, such as colour of hair or shape of head, from its parents, but nevertheless it resembles them in the vast preponderance of structural characters, which we understand by the name "rabbit." The individuals exhibiting the small differences are often termed *varieties*, those exhibiting the more fundamental resemblances being termed *species.* There is no real distinction between these two, as a certain number of individuals of one species may form a marked variety to which the appellation of a *separate species* is a mere matter of opinion.

The subject of heredity is intricate and it is difficult to lay down any general law governing the principle. Individuals having the same parents differ widely from each other. Some varieties or races have a much greater power of transmitting their structure to their offspring than others. These are sometimes termed *pre-potent*, and, as a general rule, the male is probably pre-potent over the female. A peculiar form of heredity of very doubtful occurrence is *Telegony*. If a high-bred bitch have a litter to a mongrel it is a commonly accepted tradition amongst breeders that future litters, although to high-bred dogs, will be contaminated by mongrel characters. There is at present no definite evidence for the occurrence of telegony.

But heredity is not confined to parents or others of the preceding generation. Many structural characters are transmitted to the second generation leaving the intermediate generation apparently unaffected. Insanity is a remarkable instance of this.

Lastly, an individual may exhibit characters which resemble its more remote ancestors. These characters are, of course, variations from the point of view of the parents and are often termed *atavistic*.

The term *Reversion* is also used to describe this phenomenon as well as the wider return of a whole species to ancestral structure (see *Columba*).

EVOLUTION.—If we apply the principle of heredity to the whole animal kingdom we are led to explain the structural similarity of genera, orders, classes, and phyla as due to a common descent from the same early types. The process of descent with modification is called *Evolution*, and hence an evolutionist is one who holds that all living animals are genetically connected in the past.

Assuming this to be the case, how can this descent or evolution have been effected? If we are able to show that one *species* can, under certain conditions, evolve into another, the same argument will apply to the higher grades, such as genera, orders, &c. If there were no variation, each generation of a species would by heredity be like its predecessor and no structural change could be effected. But we have seen that, owing to variation, the offspring never quite resembles its parents, and it is evident that if these differences could be accentuated and made permanent, an eventual transformation of the species could be effected.

Darwin was the first to show that there are certain conditions in nature which make this actually possible. Starting with the first principle of variation, as stated above, he went on to show that all animate nature tends to reproduce itself at a far higher rate than the available means of subsistence. This is the direct cause of the *struggle for existence*. Every animal in nature has to struggle for its very means of subsistence with other animals and above all with its own kind. The inevitable result is the *survival of the fittest*, *i.e.*, those which are best adapted to their environment live and reproduce their kind, and the less fit die early. The net result is a selection of the superabundant offspring which, as it occurs throughout nature, has been termed *Natural Selection*. Darwin's theory of evolution by Natural Selection therefore depends upon two main principles or natural phenomena:

1. Variation, or the structural differences between a parent and its offspring.
2. The struggle for existence, due to production of offspring above the means of subsistence.

The second principle acting upon the first *must* result in a selection of the variations. All variations which tend to higher efficiency are preserved and intensified through many generations till a fresh species is produced.

Animals under domestication are not, as a rule, subjected to a struggle for existence, and hence there is no natural selection. Man has, however, persistently selected the variations which appealed to his fancy, and by this *artificial selection* has been enabled to produce the numerous breeds of dogs, horses, cattle, pigeons, rabbits, &c. In this case the mental faculties of man perform the selective operation which is automatically effected in nature by the fierce struggle for life.

It is questionable if these artificially produced "breeds" are really comparable to the natural "species" for, if the breeds are left to themselves, rapid intercrossing results, in a few generations, in the disappearance of the "breed" characteristics and a *reversion* to the primitive ancestors from which they were originally derived.

SEXUAL SELECTION.—In certain cases, especially among the higher animals, the female individuals exercise a selective faculty among the males. Contests of various kinds take place among the males, and the successful competitors alone pair with the females. This form of natural selection, termed sexual selection, probably accounts for the production of the secondary sexual characters referred to in Chapter V. (See page 44.)

Let us apply the Darwinian theory of evolution to the case of oceanic islands referred to in Chapter VII. (p. 64). Suppose a number of winged insects have been blown by a high wind to a small oceanic island and have successfully established themselves there. Among the variations produced in the fresh generations some will have larger and better-developed wings than others. These will run more risk of being blown to sea and perishing, whilst their wings, being no longer required for spreading the species nor for protection against terrestrial enemies, become a positive handicap in the search for food. In a few generations the variations with smaller wings will become predominant and eventually a wingless variety will be produced.

Again, we obtain from the same principles a plausible explanation of the extraordinary phenomena of *Protective Resemblance* and *Mimicry* referred to in Chapter IX. (See page 78.)

An "accidental" variation causing an individual to bear a faint resemblance to an inanimate object may be sufficient to give it partial immunity from ever-watchful foes, and such variations transmitted and accentuated may in time produce these phenomena, which appear to imply such purposeful resemblance.

The student should be careful to recognise that Natural Selection is only a step, however important, in the explanation of evolution. Zoologists are still groping in the dark with respect to the origin and transmission of variations and the factors determining heredity. The most important question pressing for solution is—Does Natural Selection work through the experimental method of selecting from a number of *indefinite* variations, or are the variations produced in a *definite* manner in response to the environmental needs? The only way in which the variations can be definitely related to the environmental needs is as follows:—During the life of an organism, especially during its early stages, it is susceptible to external impressions which leave an indelible mark upon its adult structure. Two individuals with the same parents and the same hereditary tendencies may be subjected to environments so dissimilar that they become structurally adapted in different directions. These adaptations are called *acquired characters* (see Introduction). If we assume that the offspring of these individuals have the acquired characters transmitted to them, even in a modified degree, then the acquired characters of one generation become the hereditary characters of the next and the adaptation in nature has a simple explanation. This theory of evolution involving the *Transmission of Acquired Characters* is connected with the name of Lamarck. The transmission of acquired characters has never yet been experimentally demonstrated and has been strenuously denied by Weismann and others. Should such a process be indubitably proved to take place in nature, natural selection would take a subordinate position as a factor in evolution. On the other hand, if hereditary variations are all indefinite, and natural selection can only act when favourable variations chance to occur, then this factor is all-important in causing evolution. The difficulties in this assumption are—firstly, the enormous time required by the theory of probabilities for the occurrence of favourable variations; secondly, the inability of natural selection to operate till the variations are sufficiently great to become of some vital importance; and lastly, the necessary assumption that living matter does not conform to Newton's third law of motion, *reactions* in the form of variations being produced with no correlation to *action* of the environment.

EVIDENCES FOR EVOLUTION.—We may conclude this chapter by mentioning a few of the chief evidences which lead zoologists to believe in the evolution of the organic world:—

1. The animal kingdom can be arranged in a series, according to structure, which forms a more or less unbroken gradation from lowest to highest.

2. Certain structures, called vestiges and rudiments, can be best explained as examples of parts of an organism which are either in their earliest or their last stages of evolution.

3. On an non-evolutional hypothesis the species should and must form the lowest unchangeable unit, and yet it is so variable that it is found quite impossible in any particular case to define a species.

4. Series of fossil forms have in certain instances, *e.g.*, the crocodile and horse, enabled scientists to actually re-create all the stages in the evolution of the group.

5. Facts of geographical distribution, such as the fauna of oceanic islands and discontinuous distribution, are unexplainable by any other hypothesis.

# Part 2.

# CHAPTER XI.

## TYPES OF PROTOZOA.

AMŒBA. PARAMŒCIUM. VORTICELLA. GREGARINA.

### I.—AMŒBA.

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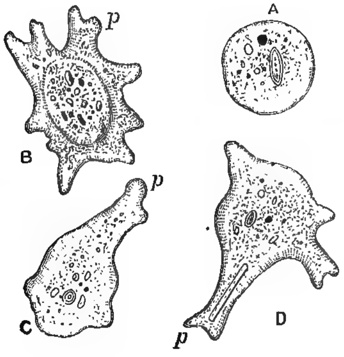
| SUB-KINGDOM | PROTOZOA. |
| PHYLUM | GYMNOMYXA. |
| CLASS | RHIZOPODA. |

Fig. 27.—AMŒBA PROTEUS (Magnified).



A, In the encysted state; B, C, D, different shapes assumed; *p*, pseudopodia.

**Size and Habitat.**

**Amœba Proteus** is a microscopic organism commonly found in the mud of ponds and streams. It varies considerably in size, the average diameter being about $\frac{1}{30}$ to $\frac{1}{100}$ inch. The whole body is of no definite outline, but looks like an irregular transparent drop of semi-fluid jelly.

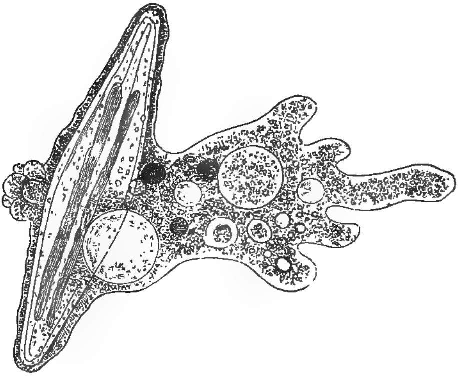
**External Features.**

If the outline of an *Amœba* be sketched every few seconds and the series of drawings examined, it will be seen that the shape has undergone considerable change, and it will also probably be found that the whole animal has moved somewhat from its original position.

**Movements.**

Further, this peculiar change of shape is evidently due to the pushing outwards of processes, which gradually grow larger and larger. If a drop of treacle be placed on a flat surface and the surface gently inclined, the drop will progress in a similar fashion by processes thrust out in the direction of least resistance; but the treacle processes differ from those of *Amœba*, because in the former the energy for such movement is derived from without (the acceleration due to gravity), and they are hence only in a downward direction, whereas in the latter the energy is provided by the chemical decomposition of the protoplasm itself, hence their direction is determined by other factors and the

Fig. 28.—AMŒBA PROTEUS (Magnified).



A large diatom is enveloped on the left. The largest sphere is the *contractile vacuole*; the smaller is the *nucleus*.

movements are effected in any direction on a flat surface. Lastly, the treacle processes cannot be again withdrawn unless the inclination of the surface be reversed, whereas the processes of *Amœba* may be, and often are, withdrawn. These processes are termed *pseudopodia.* If the flow of protoplasm be maintained in one particular pseudopodium, it results in a locomotion of the whole animal.

**Structural.**

The body is not the same throughout in appearance and structure. A thin superficial layer of more dense and clear protoplasm, the *ectoplasm*, can be distinguished from the more fluid interior formed of *endoplasm*. In the endoplasm we can discern numerous bodies. The majority of these are food-particles which lie in small spaces, called *food-vacuoles*, but in addition we can usually recognise the *nucleus* and the *contractile vacuole*. The *nucleus* lies loosely in the endoplasm and appears in the living animal like a clear glassy sphere. It consists of *nucleoplasm* differing somewhat in composition from protoplasm.

The *contractile vacuole* is a large spherical space filled with colourless fluid and always lies in or immediately below the ectoplasm. It gradually expands in size and then its walls suddenly contract. A temporary passage or duct is formed through the ectoplasm to the exterior by which the fluid is extruded. The same process is then repeated. This contractile vacuole is usually interpreted as an excretory organ for removing waste nitrogenous matters. Lastly, there are scattered throughout the endoplasm minute granules, the meaning of which is not known, small regular crystals, and particles of debris such as sand grains.

If *Amœba* be subjected to a rise in temperature the movements become more and more active, but when a temperature of about 35°C. is reached the pseudopodia are withdrawn, the animal assumes a contracted spherical shape, and at about 40°C. it perishes. *Amœba* also reacts to chemical and electrical stimuli, but in every case the whole protoplasm reacts. In other words, there are no definite sense-organs nor nervous system.

We have already seen the method of locomotion by pseudopodia. When *Amœba* in the course of its slow

**Alimentative.**

peregrinations comes across one of the microscopic algæ* upon which it feeds, the protoplasm flows round the alga which passes through the ectoplasm into the endoplasm, the former closing up behind it. This is the process of *ingestion* of food, and with the alga is usually ingested a small drop of water which constitutes the food-vacuole. In the endoplasm the food is slowly *digested*; its insoluble proteids are converted into soluble and diffusible proteids which then pass into the substance of the endoplasm. The cellulose walls of the alga and the siliceous coats of some are not digestible, and they are extruded or egested by the inverse process by which they were ingested.

Two points are important. *Firstly*, ingestion may take place at any point of the surface as *Amœba* has no localised *mouth* or ingestive aperture, and the same remark applies to egestion and the *anus* or egestive aperture.

**Reproductive.**

*Secondly*, the food of *Amœba* appears to be confined to the class called proteids which are themselves constituents of protoplasm. It is said that *Amœba* cannot digest carbohydrates or fats, hence it does not build up its protoplasm from lower chemical constituents. *Amœba* cannot live without free access to oxygen and it exhales carbonic acid. As there is no definite respiratory organ the whole surface of the animal must act in this capacity. The visible effect of good feeding and equable surroundings upon an *Amœba* is an increase in bulk—it grows. When a certain size is attained, the nucleus divides in two and then the protoplasm. Two equal-sized individuals are produced from the one by *binary fission* or splitting into two. The parent individual ends its life at the moment of reproduction in giving rise to two fresh individuals.

The process of conjugation (page 39) is said to take place but it has not been fully followed in *Amœba.*

Under unfavourable conditions, such as drought, *Amœba* has the power of withdrawing its pseudopodia or becoming spherical. The ectoplasm secretes a thin hyaline case or

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* The food consists of diatoms, desmids, spores of algæ and other vegetable matters, but animal matter such as fragments of rotifers and of Protozoa such as *Arcella* have also been observed in the endoplasm.

cyst. Under the protection of this cyst the *encysted Amœba* lies dormant. All the active vital processes are suspended and are only resumed in more favourable surroundings. Such a cyst is termed a *hypnocyst*. Encysted *Amœbæ* are doubtless transported from pond to pond by the wind or other means.

Such is the simple structure and life-history of this little animal. It may be taken as a type of the Sub-kingdom PROTOZOA, for it is a single cell and its vital activities are conducted within the limits of this cell. It is a type of the phylum **GYMNOMYXA** (naked jelly), for its protoplasm is freely exposed to the surrounding water. The whole surface of the body performs the functions of ingestion, egestion, sensation, and respiration. Lastly, it is a type of the class RHIZOPODA, for the protoplasm throws out blunt pseudopodia.

## II.—PARAMŒCIUM.

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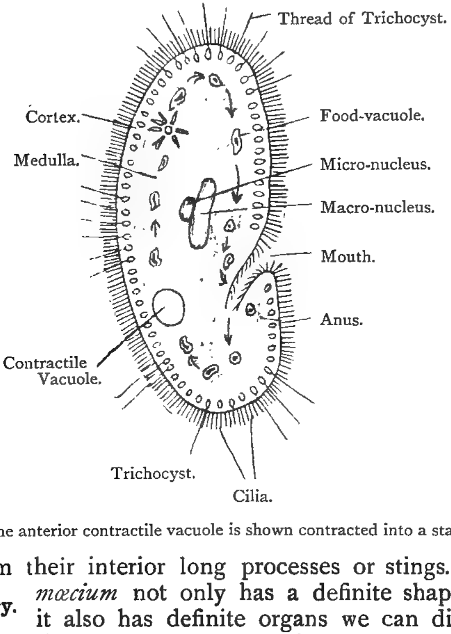
|---|---|
| SUB-KINGDOM | PROTOZOA. |
| PHYLUM | CORTICATA. |
| CLASS | CILIATA. |
| ORDER | HOLOTRICHA. |

**Paramœcium caudatum** is a minute freshwater animal which can be easily distinguished with the naked eye. Its body is flexible but has a definite shape. It is elongated, cylindrical, and rounded at each end. The protoplasm in the interior of the animal is of a semi-fluid consistency, like that of *Amœba*, but the definite shape is maintained by a hardened outer part of the protoplasm, called the *cortex*. This cortex should be carefully distinguished from the ectoplasm of *Amœba*, which is but slightly differentiated from the endoplasm, and is too mobile to affect the shape of the body.

The cortex secretes on its outer surface a thin hyaline *cuticle*, which is punctured by numerous minute holes. Through these holes the cortical protoplasm protrudes in the form of *cilia*, short vibratile hair-like processes which contract forcibly in a definite direction.

*Paramœcium* can be seen, by the naked eye, to move with extreme rapidity through the water, and this movement is performed by the uniform layer of cilia covering its body. There are also scattered all over the body a number of *trichocysts* or little oval bodies which, upon stimulation, eject from their interior long processes or stings.

Fig. 29.—PARAMŒCIUM CAUDATUM.
Lateral view of entire animal from right side. × 60. (*Ad nat.*)



The anterior contractile vacuole is shown contracted into a star.

**Symmetry.** *Paramœcium* not only has a definite shape, but as it also has definite organs we can distinguish a symmetry in the arrangement of its parts. The animal, in fact, is *plano-symmetric*, and has a dorsal and ventral surface, two lateral surfaces and an anterior and a posterior end (page 23).

Usually the anterior end is directed forwards in movement, but, when required, the animal is quite capable of "backing." From about the middle third of the ventral surface there slopes backwards a shallow cone-shaped depression, the *vestibule*. It is lined by special cilia, which cause food-currents. At its base or inner end is an opening into the inner fluid protoplasm, which is the permanent mouth or ingestive aperture. Food-particles, usually microscopic algæ, are driven by the ingestive cilia down the vestibule and through the mouth into the interior of the body. Here they are then digested and their residua are egested, but they appear to follow a definite course within the organism, first towards the posterior end, then forwards dorsally and backwards along the ventral surface, to be eventually extruded or egested at a special spot just behind the mouth. There appears to be no permanent opening or anus, but the temporary anus is always formed at the same spot.

**Alimentative.**

Under the dorsal surface and lying towards the anterior and posterior ends of the animal there are two *contractile vacuoles* which do not differ essentially from the single one found in *Amœba*. About the centre of the animal there lies a large oval *macro-nucleus*, in close contact with which there is a small *micro-nucleus*.

There are no definite organs of respiration, sense-organs, nor nervous system.

Growth in *Paramœcium* is succeeded by binary fission into two equal parts by an oblique division, but sooner or later the process of conjugation must intervene in order that life may be maintained.

We have already dealt with the general phenomenon of conjugation (see Chapter V.). *Paramœcium* proceeds normally in conjugation. During this process two individuals are in close contact along their ventral surface, their protoplasm becoming continuous through their mouths. The essential changes are as follows:—

**Conjugation.**

(1) In each individual the macro-nucleus breaks up and disintegrates, to be thrown out or absorbed, and the micro-nucleus grows rapidly and then divides by two rapid divisions into four, two of these pieces being absorbed. Thus by these processes the macro-nucleus and micro-nucleus are now reduced to two fragments

of a micro-nucleus. These fragments are each one-fourth part of the original overgrown micro-nucleus.

(2) In each individual one of the parts moves across into the other individual and fuses with the remaining part of that individual. Sometimes the migrating parts are termed the *male pronuclei*, and the other two the *female pronuclei*.

(3) Soon after this communication between the two individuals becomes interrupted and they part. In the meanwhile the single-fused nucleus in each divides into two and then into four, so that each individual has then four nuclei.

(4) Two quarters pass to each end of the animal and binary fission takes place. One quarter grows into a macro-nucleus and the other remains a micro-nucleus. The result is a pair of offspring with a macro-nucleus and a micro-nucleus each

This account should be carefully compared with the remarks in Chapter V. It will then be seen that the presence of two kinds of nuclei is the principal factor causing complication.

*Paramœcium* is a type of the Sub-kingdom PROTOZOA, for it is a single cell with all the vital activities confined therein. It is a type of the phylum **CORTICATA**, for it has a definite shape of the body due to a limiting cortex; this involves the important feature of a definite mouth. In the **CORTICATA** it belongs to the class CILIATA for its locomotive organs are in the form of cilia. The cilia are evenly distributed over the surface of the body, and hence it is a member of the order *Holotricha*.

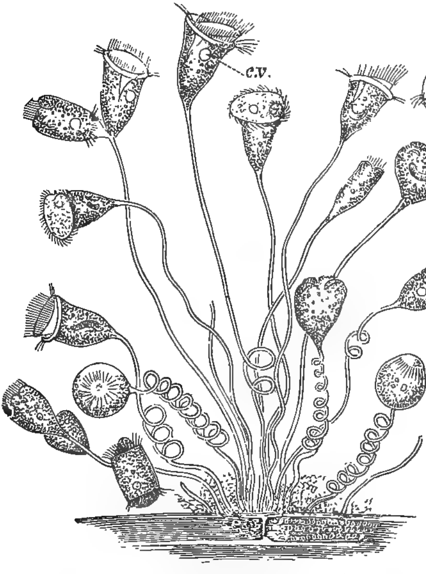
## III.—VORTICELLA.

*Vorticella* is a small freshwater and marine animal closely allied to the last type, from which it chiefly differs in being sedentary or fixed. It may affix itself to almost any foreign body, living or non-living. The body of the animal is bell-shaped with a long stalk. As in *Paramœcium* there is a cuticle and cortex. The cilia are confined to the rim of the bell and produce vortex-currents by which food-particles are brought to the mouth. The thickened ciliated rim is called the *peristome*, and immediately inside there runs a circular groove leading down at one part into a funnel-shaped *vestibule*. The base of the vestibule opens into the inner protoplasm by a small aperture—the *mouth.*

Under the upper surface there is a single contractile vacuole and deeper down there appears a horseshoe-shaped macro-nucleus with a small micro-nucleus. The feeding processes are very like those of *Paramœcium* as regards the course of the food and the temporary anus.

*Vorticella* is, like most sedentary animals, axo-symmetric. The stalk is straight when expanded, but on stimulation it contracts into a spiral coil. The peristome is contracted and the whole bell becomes spherical. As in *Paramœcium,* there are no excretory nor respiratory organs.

Fig. 30.—VORTICELLA NEBULIFERA
(Entire Colony Magnified).



*C.V.* Contractile Vacuole. A free-swimming individual with two rings of cilia is seen on the right.

Reproduction is by binary fission, the bell dividing down the centre. In allied species the two fresh individuals remain on the same stalk and so on for several generations. In these instances a "colony" is produced, but in *Vorticella* one of the individuals leaves the stalk soon after fission and settles elsewhere. In such a case we may regard the migrating half as the offspring and the other as the parent.

At any time *Vorticella* is capable of breaking free from its stalk and swimming away, and it can also encyst, in which condition it may, like *Amœba*, experience considerable vicissitudes with impunity.

Conjugation is effected by one individual setting free by budding a number of small buds which acquire a second band of cilia and swim away. One of these settles upon another individual and interchange of nuclear material is effected. The bud is said to then atrophy, the total result being the transfer of nuclear material from one individual to another. In this respect the conjugation of *Vorticella* more nearly resembles the sexual reproduction of *Metazoa.*

*Vorticella* belongs to the same class as *Paramœcium (Ciliata)* but to the order *Peritricha*, the cilia being confined to a ring around the mouth.

## IV.—GREGARINA.

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|---|---|---|
| SUB-KINGDOM | -- | PROTOZOA. |
| PHYLUM | | CORTICATA. |
| CLASS | | SPOROZOA. |

**Habit.** **Gregarina blattarum** is a small animal found in part of the intestine (the mesenteron) of the common Cockroach (*Blatta*). Hence it is an *endoparasite.* Its body is elongated and has a definite shape. In the protoplasm there can be discerned an outer cortex which appears to be more or less contractile and an inner more fluid medulla. The cortex secretes a thin *cuticle* which envelopes the body. At one end, usually regarded as the anterior end, the cuticle is thickened into a cap with a rim of hooks. At about one-third of the length of the body from the anterior end, the cuticle extends a as thin septum or partition across the protoplasm, dividing the body into an anterior *protomerite* and a posterior *deutomerite.* In the medullary substance of the deutomerite is an oval nucleus and occasionally there can also be seen a small *nucleolus.*

**Structural.**

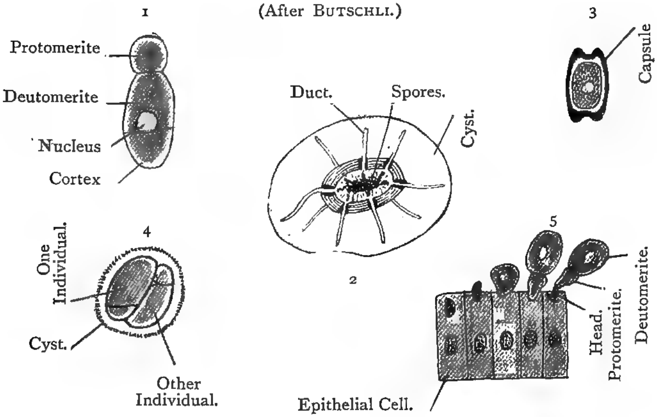
**Alimentary.** There are no cilia nor pseudopodia and the animal can progress only slowly by a creeping movement of the cortex. There is no mouth nor anus, and no solid food passes into the body of the animal. *Gregarina* is, from its habitat, surrounded on all sides by soluble and diffusible proteids which have been prepared by its host, the cockroach, for its own use. These are absorbed by *Gregarina* through the cuticle as required. There appears to be no contractile vacuole and no nervous nor respiratory organs.

**Reproductive.**

The cuticular cap serves to fix the animal to the wall of the intestine in its young stages, but it is shed soon after the attachment is lost. Conjugation takes place but in a modified form. Two gregarines become closely opposed to each other but do not fuse. They together form a sphere which then becomes enveloped in a cyst. Under cover of this cyst the reproductive process is effected, hence it is distinguished as a *sporocyst* from the simply protective cyst (or *hypnocyst*) of *Amœba*. The cyst is somewhat complex, for it has small tubular apertures for the subsequent escape of the spores.

Fig. 31.—Life-History of Gregarina.

(After Butschli.)



1, The adult individual. 2, The cyst containing spores. 3, A single spore. 4, Two conjugating individuals. 5, Five stages in the intracellular parasite, from left to right.

Inside the sporocyst the two gregarines break up by multiple fission into a great number of small fragments or *spores*, each of which secretes around itself a hard case. Sometimes the conjugates separate and a single *Gregarina* encysts and divides into spores.

The degenerate state of the conjugation appears to be of a similar nature to the degenerate sexual process in certain low fungi, such as *Saprolegnia*, in each probably an effect of parasitism. In each case there is a sort of imitation of the real process although the essential interchange of nuclear material is absent.

**Life history.**

The sporocyst finally bursts and the coated spores are set free out of the anus of the cockroach. Protected by the hard coat these spores lie dormant till any of them happen to be introduced with food into the intestine of another cockroach. In this event the spore-case bursts and its contents escape as a creeping amœboid nucleated mass of protoplasm. This works its way into the epithelial cells of the cockroach's intestine and there remains for some time. It is then termed an *intracellular* parasite, living *within* the epithelial cell. Here it grows and assumes the elongated form and other characters of the adult. Contemporaneously it gradually protrudes from the cell into the lumen of the intestine, still attached by the anterior end with its cap. Finally it becomes detached and lives free in the lumen or cavity of the intestine.

We may note that there is a definite limit to the number of gregarines which can dwell in one cockroach, and when this limit is reached the gregarines would perish with their host. Hence the gregarines and all endoparasites must at some time, if the species is to be maintained, migrate and by some means reach a fresh host. This is not essentially different from a sheep moving to fresh pasture after having exhausted the previous one, but in the former case the probabilities of reaching the fresh scene of action are infinitely less. The difficulties of the migration are overcome in two ways:—Firstly, an enormous number of the migrating units are produced just before the migration, the number roughly corresponding to the probabilities of survival; secondly, the migrating units are protected for their hazardous journey by hard coats or cases. In these respects the gregarine is typical of endoparasites. (See also Parasitism, Chapter IX.)

## THE PROTOZOA.

We have seen in Chapter III. that the animal kingdom can be naturally divided into two sub-kingdoms,

1. PROTOZOA.
2. METAZOA.

All the *Protozoa* are homologous with single cells. The body of a Protozoan is a single cell, and all differentiations take place within the cell, or are intra-cellular. For example, the mouth of a Protozoan leads into the interior of a cell and not, as in the *Metazoa*, into a space between a number of cells. The same consideration applies to every other organ. This is sometimes emphasised by using the terms *cell-mouth*, *cell-anus*, &c.

In a number of sedentary *Protozoa* (*cf. Vorticella*) the products of binary fission remain in organic continuity, and form a "colony" of many individuals. The colony is evidently a multicellular aggregate, but in the majority of cases each cell retains all its vital functions of alimentation, locomotion, sensation, and excretion. Hence there is little or no united individuality of the aggregate, and it is regarded as a colony of *Protozoa* rather than a metazoan individual. In a few colonial *Protozoa*, such as *Zoothamnium*, there is a physiological division of labour *not affecting the primary vital functions, but only between these and the secondary reproductive function.* Some of the individuals of the colony have no mouth nor cilia, and are themselves solely concerned with the production of reproductive elements, depending for the exercise of vital functions upon the other individuals. This is the nearest approach in colonial *Protozoa* to the complete physiological dependence of the constituent units of a metazoan.

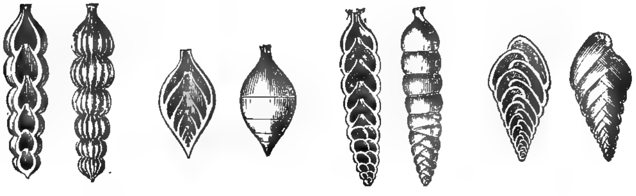
The *Protozoa* must be regarded as the representation in miniature of the metazoan type, showing us the possibilities of adaptation with the single cell as a unit; hence, although the sub-kingdom only includes very small and apparently unimportant animals, it must be regarded as having the same morphological value as the *Metazoa*.

## GYMNOMYXA AND CORTICATA.

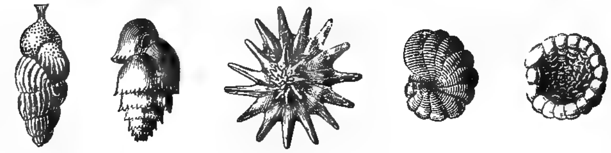
The *Protozoa* fall into two fairly well-defined *Phyla*, in accordance with an important character. In the *Gymnomyxa* the body of the animal consists of naked protoplasm which has no definite shape of itself. In many cases the protoplasm has a shell to which it clings, inside or outside of it, and under tonic contraction or when the vital processes are dormant it assumes a spherical shape. The nakedness of the protoplasm implies a very low differentiation, the alimentary functions of ingestion and egestion being co-extensive with the surface (*cf. Amœba*). In the *Corticata* the living organism assumes a definite shape, which is maintained by a hardened cortex and often a cuticle as well. The form of the body is not determined each moment by the forces acting upon it, but a definite shape or plan is assumed and adhered to for each species. A definite mouth, definite egestive spot and definite motor organs are involved. The *Corticata* are evidently a great step in advance of the *Gymnomyxa*, from which apparently they have been derived.

## PHYLUM GYMNOMYXA.

Fig. 32.—TYPES OF FORAMINIFERAN SHELLS (After D'ORBIGNY)



Nodosaria. Glandulina. Textularia.



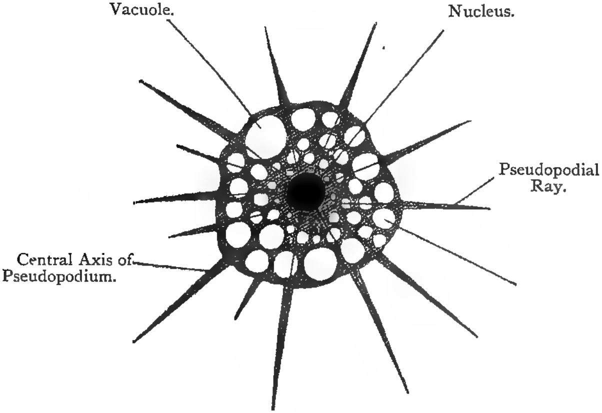
Uvigerina. Bulimina. Calcarina. Peneroplis. Planorbulina.

**_Amœba_ is a type of the single class RHIZOPODA in which there are pseudopodia, and of the order _Lobosa_ with blunt or lobose pseudopodia, but there are three other important orders to which we may briefly allude.**

The *Heliozoa* or sun-animalcules are usually spherical in shape, and are found in freshwater. The pseudopodia are long rays usually stiffened with an axial rod of silica. The central mass of protoplasm is vacuolated, and some have a hollow perforated shell like those of the next order. Nearly all are centro-symmetric.

Fig. 33.—A HELIOZOAN (*Actinophrys sol*).

The entire animal magnified. (*Ad nat.*)

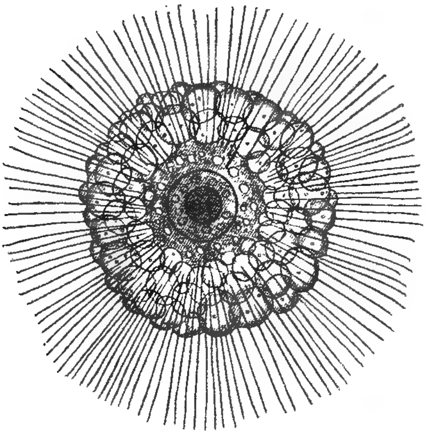


Note the central nucleus and stiffened pseudopodia.

The second order is that of the *Radiolaria*. They are marine pelagic organisms of microscopic size and have a siliceous skeleton of isolated pieces called *spicules*, or a continuous perforated shell through the holes of which the fine radiating pseudopodia protrude. The main mass of protoplasm has a thin capsule dividing it into central and peripheral portions, and in the peripheral parts there are often found a number of minute algoid bodies called *yellow-cells*. They live and multiply in close organic unity with the radiolarian. Such a union is termed *symbiosis* (see Chapter IX.). Radiolarians are commonly centro-symmetric, but some are axo-symmetric. Countless numbers of them live and die in the pelagic water, and their shells and spicules cover the sea-floor at great depths, constituting radiolarian ooze (Chapter IX.).

The third order, *Foraminifera*, also consists of a vast assemblage of small pelagic organisms. They usually have a shell, made of calcareous, arenaceous or chitinous material. It is often chambered,

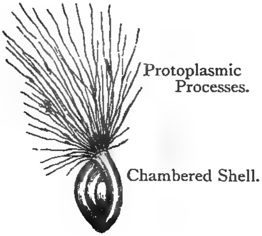
Fig. 34.—A RADIOLARIAN (*Thalassicola pelagica* × 20).
(After HÆCKEL.)



Note the radiate pseudopodia, the vacuolated protoplasm and the central capsule.

and the protoplasm consists of a main mass in and around it and a fine anastomosing network of thin protoplasmic strands which serve to entangle the food. The shells of these *Foraminifera* cover the sea-floor in various regions, and similar shells form the main constituent of many chalk-strata. The pyramids of Egypt are built of nummulitic limestone which is an aggregate of *Foraminiferan* shells. Hence, by virtue of their vast numbers and the imperishable nature of their shells, the *Foraminifera* are an important agency in the physical changes of the earth's surface.

Fig. 35.—A LIVING FORAMINIFERAN
(*Miliola*).



## PHYLUM CORTICATA.

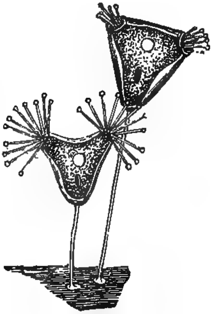
The CORTICATA contain the important class CILIATA, of which *Paramœcium* and *Vorticella* are typical. They are all active organisms, those like *Paramœcium* moving rapidly in pursuit of prey, whilst others like *Vorticella* are themselves fixed and use their cilia to bring food-particles to them. They are divided into orders according to the arrangement of the cilia.

The second class is that of the MASTIGOPHORA. They are also small active organisms, often of very minute size. They have only one, or sometimes two, long whip-like processes which are called *flagella*. The flagellum may be situated at the posterior end and serve to drive the body forwards, in which case it is called a *pulsellum*, or it may be at the anterior end and may draw the body after it, when it is known as a *tractellum*. The *tractellum* may also by spiral movements assist in bringing food to the mouth.

In one large section of these MASTIGOPHORA, often placed in a class by themselves, the *Choano-Flagellata*, the ingestive action of the tractellum is supplemented by a "collar" of protoplasm which surrounds the mouth and the base of the tractellum. Colonial forms are common in this class.

The ACINETARIA are a specialised class of much the same general habit of life as the preceding classes, but there are no cilia nor flagella. Their place is taken by a number of fine processes terminating in minute suckers or adhesive discs with which other *Protozoa* are caught and their juices extracted. Most are fixed and stalked, but some are free and even parasitic. The young are often actively ciliated, and the whole class is probably derived from ancestral CILIATA.

Fig. 36.—ACINETA TUBEROSA EXPANDED AND CONTRACTED.



The last class is that of the Sporozoa, the members of which are endoparasitic. *Gregarina* is a type of the class. They are found in nearly all the higher animals. *Monocystis* is found in the seminal vesicles of the earthworm and has a simpler body than *Gregarina.* The young are intra-cellular parasites within the sperm-cells.

The *Coccidia* are small *Sporozoa* of simple structure which occur commonly in the liver of the rabbit and elsewhere. They may give rise to tumours and serious pathological results.

### *SUB-KINGDOM PROTOZOA.*

1. Unicellular or when multicellular the units are not mutually dependent.
2. No true sexual reproduction, asexual by binary or multiple fission, preceded by conjugation.
3. Mostly minute, marine or freshwater.

| Phylum I.—Gymnomyxa. | Phylum II.—Corticata. | |
|---|---|---|
| Naked protoplasm with no definite shape to body. | A cortex with definite shape to body. | |
| Class I.—Rhizopoda. | Class II.—Ciliata. | Class III.—Sporozoa. |
| *Type—Amœba.* | *Types—Paramœcium; Vorticella.* | *Type—Gregarina.* |
| 1. Locomotion by pseudopodia. | Locomotion by cilia or flagella. | Little or no locomotion. Hooks for fixation. |
| 2. No localised mouth, diffuse ingestion. | Localised mouth. | No mouth nor solid ingestion. |
| 3. Many have a chambered, calcareous, siliceous, or arenaceous shell. | No shell. | No shell. |
| 4. Reproduction mainly by binary fission. | Reproduction usually by binary fission. | Reproduction by multiple fission with coated spores. |
| 5. Floating or creeping, marine or freshwater. | Active, moving or sedentary, freshwater or marine. | Endoparasitic. |

# CHAPTER XII.

## *TYPE OF PORIFERA.*

## SYCANDRA.

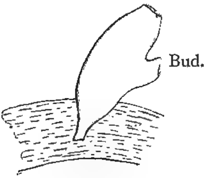
| | |
|---|---|
| PHYLUM | PORIFERA. |
| CLASS | CALCAREA. |

*Sycandra compressa* is a small marine sponge of a dull yellow tint, found fixed to rocks or weeds between tide marks.

**Form and Habits.**

It is in shape like a flattened flask and varying in length up to 1½ inch. It is like all sponges axially symmetrical (though the symmetry is often obscured), hence we can distinguish merely a main axis, a base, and an apex. The base is fixed to a foreign body and the apex has a large opening, the *osculum*, which leads into the interior of the sponge.

Fig. 37.—SYCANDRA COMPRESSA.



Fixed to sea-weed, with bud, natural size.

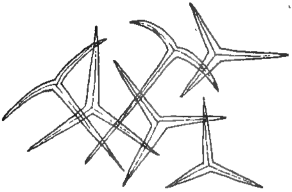
If the living *Sycandra* be watched carefully in a vessel of water, it will easily be seen that currents of water are, without intermission, pouring out of the osculum. Further examination of the surface of the sponge would reveal an immense number of extremely minute openings all over the surface, into which the water perpetually flows. These are termed the *pores*.

If a hand-section of the sponge be made it is seen to be hollow, and the wall appears of even thickness all round the central cavity. This cavity is called the *paragastric cavity*, opening through the osculum to the exterior.

**Internal Structure.**

The walls of the sponge are of a somewhat firm leathery consistency and when boiled in potash the animal matter is destroyed, leaving a residue of numerous small *spicules*, transparent and tri-radiate in shape. These hard spicules dissolve immediately, with effervescence, on the application of any dilute

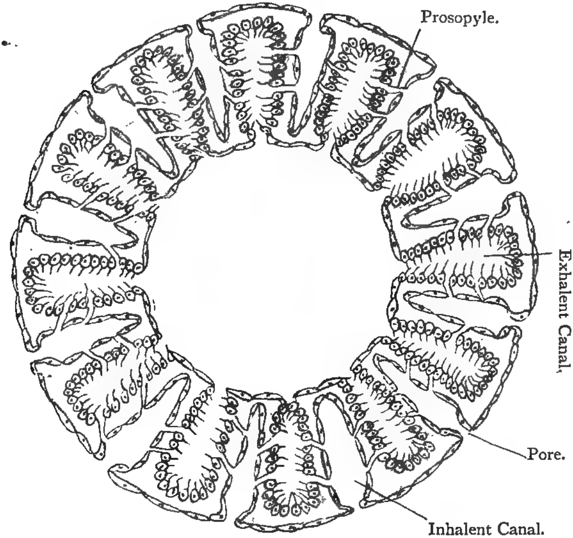
Fig. 38—Calcareous Triradiate Spicules of Sycandra (*Grantia*).



Highly magnified.

acid. They are found to be *calcareous* in nature. They support the wall of the sponge and form its skeleton. The further structure of *Sycandra* must be followed by prepared microscopic sections or by teasing to pieces and examination with the microscope. A transverse section as seen with low powers is shown in Fig. 39. The wall here shows

Fig. 39.—Transverse Section of a Sycandra (*A Sycon*).



The central cavity is the paragastric cavity.

a number of *radial canals*, some of them with thick walls and others with thin. The former open into the paragastric cavity by small contracted apertures and are called *exhalent* canals, whilst the latter open by the pores to the exterior and are termed *inhalent canals*. Further examination would show that the two sets of canals are in communication with each other towards their inner ends by minute cross-canals, sometimes called *prosopyles*.

The thickened appearance of the exhalent canal-walls is due to the peculiar structure of the cells lining them. These are arranged in a single layer, and they consist of collared-flagellate cells, closely similar to those found in the choano-flagellate *Protozoa*. The currents of water bearing food-particles are due to the activity of these cells and their flagella. They are termed *choanocytes*. The outside surface of the sponge is formed by flat irregular cells without flagella, which are known as *pinnacocytes*. Similar pinnacocytes line the inhalent canals and the paragastric cavity. The whole limiting surfaces of the sponge are therefore formed either by a layer of pinnacocytes or of choanocytes. The space enclosed by the limiting surfaces seems to be filled with a semi-gelatinous matrix in which are numerous scattered cells. Most of these are branched or amœboid in appearance. Some surround and secrete spicules, one to each cell; these are the *sclerocytes* and they are said to periodically shed the spicules at the surface of the sponge. Others are in some way connected with nutrition, and yet others become ova and spermatozoa. These latter are the *gonocytes* or sexual cells, whilst the former are *phagocytes*.

**Alimentary.**

The alimentary processes of the sponge are not yet certainly known. Food-particles can be seen to pass in with the water at the pores and later the choanocytes are crowded with them. Further, these food-particles may be seen in the phagocytes in the interior of the body. The choanocytes can withdraw their collars and flagella and become amœboid,* and it is questionable whether all the cells of the sponge are not capable on occasion of becoming amœboid, though this may not be normal.

There are no definite excretory nor respiratory organs and no sense-organs nor nervous system. A few cells round some of the openings have been described as specially contractile and have been termed *myocytes* or muscle-cells.

DEVELOPMENT.—*Sycandra* is diœcious, one sponge producing spermatozoa and another ova. The ovum is an amœboid gonocyte which protrudes into the lumen of an inhalent canal till it is fertilised

---

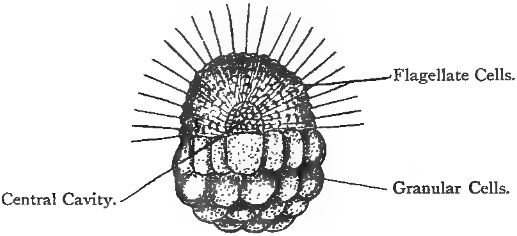
* It is "more than probable" that the phagocytes are choanocytes which have changed to the amœboid condition and migrated inwards.

by an incoming spermatozoon, after which it withdraws into the body of the sponge and undergoes segmentation.

The spermatozoa are produced from gonocytes apparently similar to the female cells. A male gonocyte divides up into a great number of spermatozoa which are discharged into the water.

The ovum segments totally and equally (Chapter V.) to produce a hollow sphere of cells, each of which in some other sponges bears a flagellum. This stage has been compared with the blastula larva of other *Metazoa*. The cells of one hemisphere then become more numerous and acquire *flagella*, whilst those at the other hemisphere remain few, large and granular. The larva escapes from the parent and swims freely. This larva is only found in sponges and only in certain of them ; it is called an *amphiblastula*. The granular cells then grow round the flagellate cells, forming a sort of invagination of the latter, and the larva settles down by the free edge of the granular cells upon a foreign body. A sort of metamorphosis then appears to take place, the cells being largely reduced to an amœboid condition and withdrawing their flagella. In a manner little understood the amœboid cells of the body of the sponge are produced between the two layers. The nutritive granules in the outer layer are slowly consumed during this process.

Fig. 40.—AMPHIBLASTULA LARVA OF A CALCAREOUS SPONGE. (After SCHULZE.)



The osculum then opens at the apex, and pores are formed through the sides. The inner layer then becomes flagellate. At this stage the whole internal paragastric cavity is lined by flagellate cells. As soon as the radial canals are produced the collared cells lining the paragastric cavity become pinnacocytic, and the young sponge comes to resemble its parent. The development is thus :—

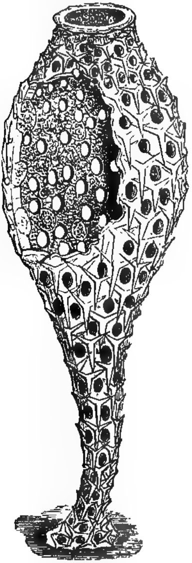
1. Total equal segmentation to blastula larva.
2. Differentiation into amphiblastula.
3. Invagination of flagellate half into granular half.
4. Fixation and quiescent amœboid stage.
5. Differentiation of ascon stage.
6. Modification into sycon (sycandra).

*Sycandra* may also reproduce asexually by budding. A part of the body-wall protrudes and acquires an osculum. It then separates from its parent, or the bud may remain in connection with it and form a *colony*.

# PHYLUM PORIFERA.

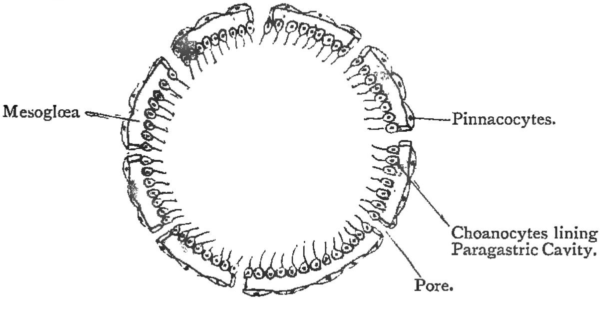
The Porifera or Sponges are a clearly-defined group. Their true relationship to other *Metazoa* is not clear. They are evidently cell-aggregates with a large amount of physiological division of labour between the cells, and as they also have sexual reproduction they are undoubtedly *Metazoa*. On the other hand, the sponges have no metazoan mouth nor anus — food is ingested by the cell-mouths of the choanocytes, so that ingestion, digestion, and egestion are purely intracellular. The cells are not aggregated into tissues and division of labour prevails more between individual cells than between epithelia of these cells. Hence *sponges must be regarded as very simple cell-aggregates*, belonging to the *Metazoa*. Most sponges are colonial, the colonies being produced by budding. In many sponge-colonies the number of oscula alone indicates the theoretical number of individuals of which the colony consists.

Fig. 41.—Ascetta Primordialis (Hæckel).



A simple Ascon. Part of body-wall is removed to show Paragastric Cavity (×50).

Fig. 42.—Transverse Section of an Ascon. (Diagrammatic.)



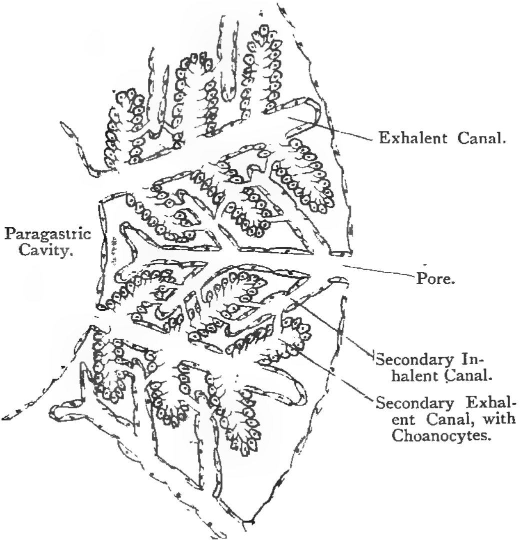
In the phylum there can be discerned at least four different types of sponges according to the distribution of the choanocytes.

(1) *Ascon* type. In this simplest type the whole paragastric cavity is lined by choanocytes and there are no radial canals (Fig. 39).

(2) *Sycon* type. The choanocytes are restricted to the exhalent radial canals; inhalent canals and prosopyles are present (Fig. 42).

(3) *Leucon* type. The choanocytes are restricted to a number of secondary radial canals opening into the primary radial canals (Fig. 43).

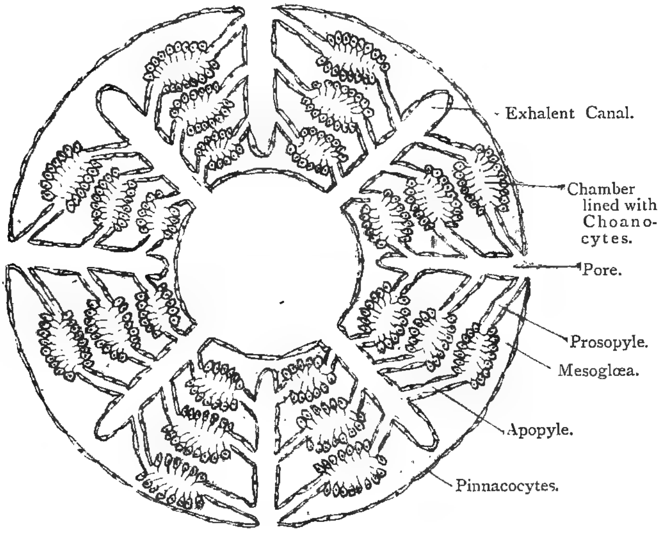
Fig. 43.—TRANSVERSE SECTION OF PART OF THE WALL OF A LEUCON. (Diagrammatic).



(4) *Rhagon* type. The secondary canals are contracted into small round chambers and only open into the primary radial canal by a number of exhalent canals or *apopyles* (Fig. 44).

In these four types there will be noticed *a progressive increase in bulk of the body of the sponge and a progress of the choanocytic areas from within outwards.* Numerous transition types are found, and these types are distributed quite indiscriminately throughout the classes or orders.

Fig. 44.—TRANSVERSE SECTION OF A RHAGON. (Diagrammatic.)



Sponges fall into two well-defined classes—(1) CALCAREA, (2) NON-CALCAREA.

1. CALCAREA.—The Calcarea all have a calcareous skeleton and the collared-cells are much larger than those of the next class. They are usually Ascons and Sycons, and in many points they are simpler and more primitive than the *Non-calcarea.*

2. NON-CALCAREA.—In these the skeleton consists of ceratin (horny) fibres (with or without spicules), siliceous spicules which may fuse, or there may be no skeleton. The collared-cells are minute and the canal system is mostly complex.

*Euspongia* has only horny fibres, hence its skeleton is used for domestic purposes. *Spongilla* is a little fresh-water sponge, found in lakes and rivers. In many, like *Euplectella* (Venus' flower-basket), the siliceous spicules welded together make a beautiful network like spun glass.

The external form and habitat of Sponges have infinite variety. Very few, like *Ascetta*, retain their simple axial symmetry. Large colonies of indefinite shape are produced, in which the constituent individuals can only be recognised by the number of oscula. A remarkable little sponge (*Cliona*) forms burrows in oyster shells, and a great number of sponges are commensalistic (see Chapter IX.). *Chondrocladia* shows a remarkable protective resemblance to a bleached skeleton of a gadoid fish, *e.g.*, a cod, while others have more or less similitude to stones and seaweeds.

## *PHYLUM PORIFERA.*

1. Multicellular organisms, with physiological division of labour between the cells. } All Metazoa.
2. Sexual reproduction. }
3. Axially symmetrical.
4. A central cavity (paragastric) with inhalent pores and exhalent osculum.
5. A skeleton of calcareous, siliceous or fibrous nature.
6. Mostly marine and sedentary, forming colonies.

| Class I.—CALCAREA.<br>*Type—Sycandra.* | Class II.—NON-CALCAREA.<br>*Type—Euspongia.* |
|---|---|
| 1. Skeleton of calcareous spicules. | 1. Skeleton of siliceous spicules, horny fibre or none. |
| 2. Large collar-cells. | 2. Small collar-cells. |
| 3. Mainly Ascons and Sycons. | 3. Complex systems of canals. |

# CHAPTER XIII.

## *TYPES OF CŒLENTERATA.*

HYDRA. OBELIA. ACTINIA. ALCYONIUM. AURELIA. CYDIPPE.

### I.—HYDRA.

| | |
|---|---|
| Phylum - | Cœlenterata. |
| Class | Hydrozoa. |

**Hydra viridis** is a small fresh-water organism, which may attain a length of one-half inch, but is usually smaller. It is found in ponds and streams attached to water-weeds and is of a bright green colour.

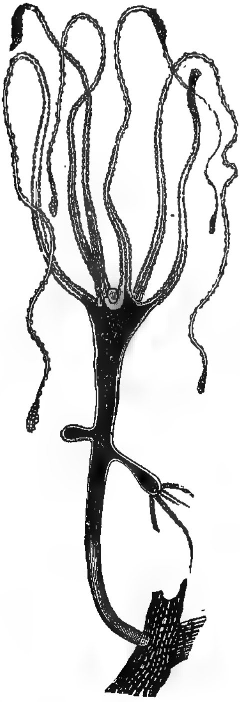
[**Hydra fusca** is the brown species; with the exception of the absence of green chromatophores it resembles the above.]

*Hydra* is axo-symmetric, hence we can distinguish merely an oral and an aboral end and axial and peripheral parts. With the naked eye it can be seen that the body is an elongated cylinder fixed at the aboral end. At the oral end there is a ring of tentacles, thin processes which radiate in all directions. In the centre of this ring is a small raised part, the *peristome*, upon which is situated the *mouth*.

**External Characters.**

We may notice at once that this aperture, though usually termed the mouth, functions both as a mouth and an *anus*.

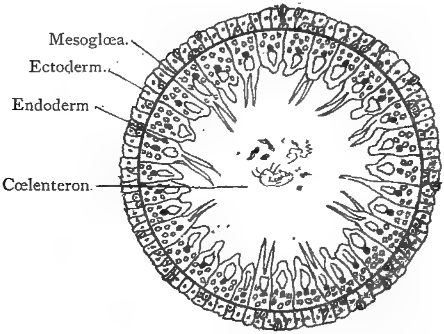
Fig. 45.—Hydra Viridis with Two Buds (Magnified).



On agitation of the water, *Hydra* contracts its body and tentacles till it becomes a round knob, but if left to itself it will soon expand again to its normal condition. Very often the body appears to fork into two parts each of which has a ring of tentacles. One of these is a *bud* which is destined later to drop off the parent.

**Internal Structures.**

Fig. 46.—Transverse Section of Hydra (Magnified). (*Ad nat.*)



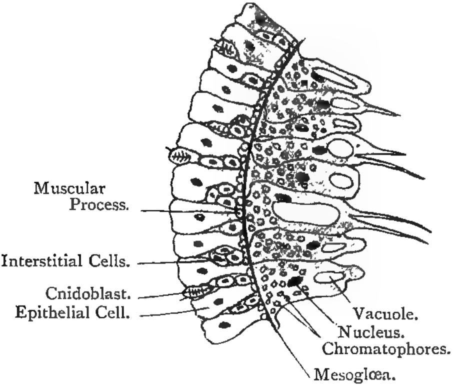
If the animal be killed and preserved and cut into transverse sections, a low-power examination of such sections reveals the fact that the whole body is a hollow sac, the internal cavity being known as the *cœlenteron.* The wall of the body is of two layers, the outer layer or *ectoderm* and the inner or *endoderm*, between which is a thin supporting lamella, the *mesoglœa.*

The cœlenteron may occasionally contain the bodies of small animals which constitute the food of *Hydra.*

**Histology.**

On examination with a higher power of the microscope the endoderm cells prove to be arranged in a single layer and the cells themselves are considerably larger than those of the ectoderm. Each cell contains a nucleus and a number of small bodies scattered through its protoplasm.

Fig. 47.—Portion of Body-wall of Hydra.
(Highly Magnified.) (*Ad nat.*)

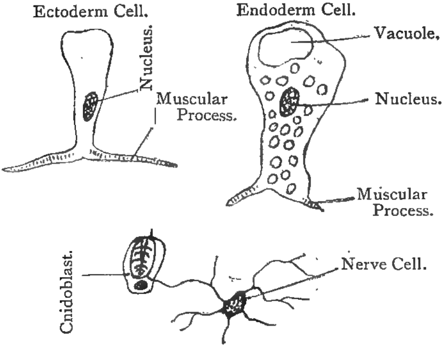


The *chromatophores* are numerous spherical bodies with definite walls. They are bright green owing to the presence of a green pigment called *chlorophyll.* This chlorophyll is characteristic of the plant kingdom (see Chapter II.), and some have regarded the chromatophores as symbiotic algæ living in the tissues of *Hydra.* The green tint of *Hydra,* already noticed, is due to these bodies which are seen through the transparent ectoderm. In about the centre of the body the endoderm cells have one or more large vacuoles, containing a clear fluid. The fluid is said to be discharged into the cœlenteron and to be digestive in function. Other bodies in the endoderm cells may be recognised as particles of food. The inner ends of the endoderm cells appear to have no cell-wall, and are either produced into several flagella or into amœboid-like pseudopodia.

The ectoderm cells are of two kinds, the larger *epithelial* cells and smaller *interstitial* cells.

The epithelial cells are arranged in a single layer; each has a definite cell-wall and a nucleus. In most of them the inner end is produced into one or more processes, which are not amœboid but show fine striation and appear to be specially contractile. They are therefore known as *muscular* *processes.* The muscular processes are pressed closely against the mesoglœa, to which their ends are probably attached. In a general way the processes run parallel to the long axis of the animal though they are somewhat indefinite in arrangement. Similar processes of the endoderm cells run in a circular direction, in a transverse plane.

Fig. 48.—An Ectoderm Cell, Endoderm Cell, and a Nerve Cell (After Jickeli) connected with a Nematocyst.

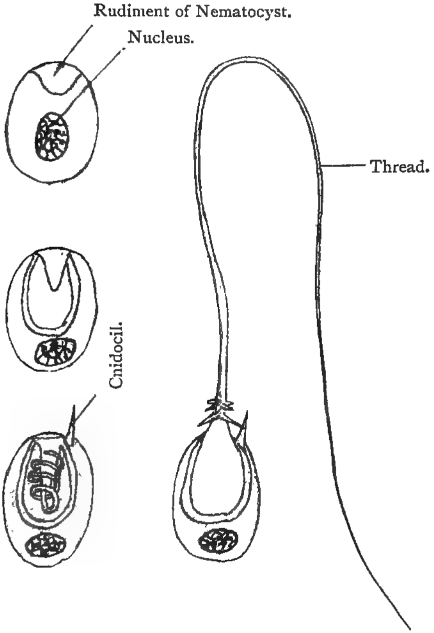


The interstitial cells lie at the base of the epithelial cells between their tapering ends. They appear in sections as simple rounded and nucleated cells. In the living animal they may be amœboid. All over the body, but especially on the tentacles, the interstitial cells give rise to the *cnidoblasts.* These grow outwards between the epithelial cells till they reach the surface. They are large ovoid cells which develop in their interior a cyst containing a long thread with barbs at its base and a fluid. On stimulation the cyst, or *nematocyst,* discharges the thread or sting which has a paralysing effect on small animals.

**Reproductive.**

Other interstitial cells accumulate in a mass to form the *germ-cells.* The *testis* is a mass of these germ-cells covered by epithelial cells and situated under the tentacles. The *ovary* is a similar mass towards the aboral end of the animal. The spermatozoa are produced in great numbers by division of the germ-cells

Fig. 49.—DEVELOPMENT OF THE NEMATOCYST IN CNIDOBLAST CELLS.



and are set free by rupture of the epithelial cells. The ovum is produced by the growth and enlargement of a single germ-cell in the ovary, which appears to grow at the expense of the other germ-cells. It escapes by rupture of the epithelial cells and is a creeping amœboid cell.

Both testes and ovaries are found in the same animal, hence *Hydra* is hermaphrodite. The testes usually appear and ripen prior to the ovaries, a condition known as *protandric*.

*Hydra* has no definite respiratory, excretory, or sensory organs, and there are no nervous* nor vascular systems. Movement is effected by the contraction of the muscular

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* Certain stellate ectoderm cells in connection with the cnidoblasts have been described as nerve-cells. (See Fig. 48.)

processes probably reacting with the elastic mesoglœa. The food is ingested and egested through the mouth which thus functions as a mouth and an anus. In the cœlenteron it is said to be digested partly by an *inter-cellular* process, consisting of the reduction to a soluble condition by the digestive fluid discharged from the vacuoles of the endoderm, and partly by an *intra-cellular* process, the particles of food being taken into the endoderm-cells by their amœboid ends.

*Hydra* reproduces, not only by the sexual method, but by the asexual process of budding. A bud is a simple process of the body-wall which grows outwards, acquires a mouth and tentacles and finally detaches itself from the parent.

The amœboid ovum containing a few scattered yolk granules protrudes from the ectoderm of the parent and is here fertilised. It loses its power of movement, becomes spherical, and encysts. The cyst is secreted by the ovum itself and the egg then falls from the parent and remains dormant for several weeks. It segments by total equal segmentation producing a blastula. Certain of the cells then wander into the archicœle cavity to form the hypoblast, which is thus formed by *multipolar ingression.* Eventually the diploblastic larva escapes from the cyst and elongates. At one end the mouth is formed by rupture of the layers and the other end becomes attached. The two embryonic layers, epiblast and hypoblast, become the ectoderm and endoderm and the archenteron becomes the cœlenteron.

The following special points in *Hydra* should be noted:—

1. The two-layered body.
2. The axial symmetry and sedentary habitat.
3. The nematocysts and simple hermaphrodite sexual organs.
4. The asexual reproduction by budding.
5. The intra-cellular and inter-cellular modes of digestion.
6. The protected development and formation of hypoblast by multipolar ingression.

*Hydra* belongs to the phylum **CŒLENTERATA** because its body is didermic or formed of two layers, and to the class HYDROZOA because its mouth leads directly into a *simple* cœlenteron.

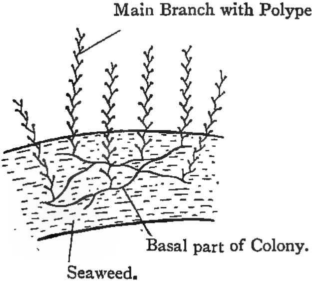
# II.—OBELIA.

| | |
|---|---|
| PHYLUM | CŒLENTERATA. |
| CLASS | HYDROZOA. |
| ORDER | HYDROMEDUSÆ. |

OBELIA GENICULATA is a small marine organism, usually covering seaweeds, such as the brown *laminaria*, between tidemarks. It has the appearance of a small plant and is hence often called a *zoophyte*. It has a creeping basal portion from which there grow up main branches.

Fig. 50.—COLONY OF OBELIA GENICULATA.

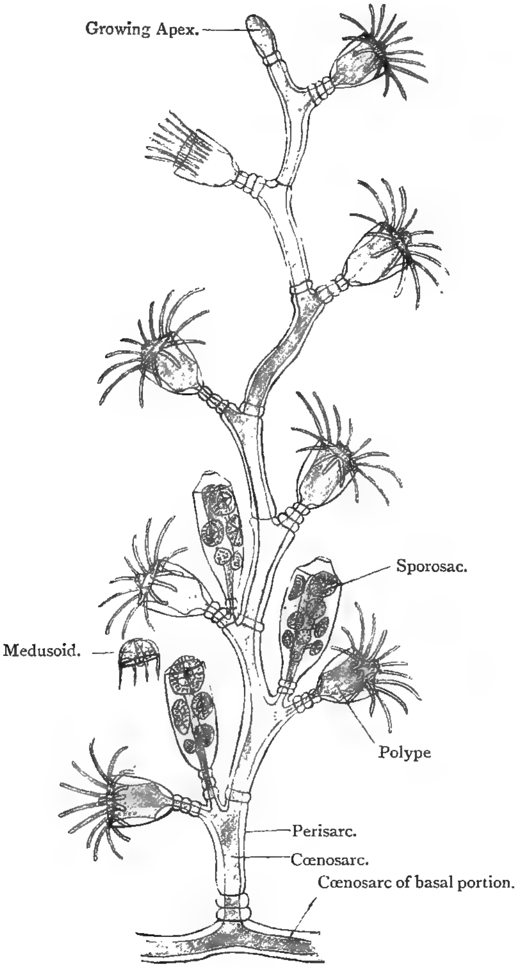
(Natural size.)



The main branch appears a zigzag, from each corner of which is produced a small branch. With a lens it can be seen that each branch terminates in a swollen cup-shaped head or *theca*, and, if the zoophyte be alive and undisturbed, a ring of delicate tentacles will be seen protruding from the theca.

Further examination shows that there are two separate structures—the outer, hard and non-living part, and the inner, soft and living portion of the zoophyte. The outer part is called the *perisarc*, consisting of thin translucent chitin. It forms the hollow axis terminating in the thecæ or cups. Inside the perisarc is a central protoplasmic axis, called the *cœnosarc*, which runs up to the thecæ and here terminates in small round bodies, having a ring of tentacles. These are the *polypes* which conform closely in structure to *Hydra*. Each has a terminal mouth inside the tentacles; each has a two-layered body-wall with nematocysts and cœlenteron. They differ from *Hydra* in having the aboral end of the body produced into a long central axis or *cœnosarc*, and sections show that this cœnosarc is similarly formed of two layers with a central canal, the cœnosarcal canal, which communicates with the cœlenteron of all the polypes.

Fig. 51.—Colony of Obelia Geniculata (Magnified).

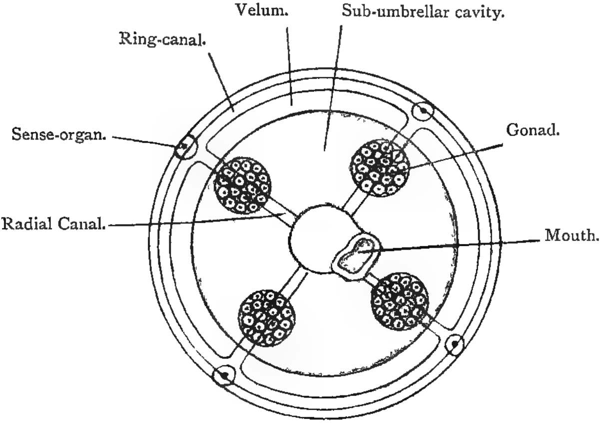


We may therefore regard *Obelia* as formed of a *colony* of individuals like ***Hydra***, organically connected by the cœnosarc. In this we are justified, as it first arises as a single polype individual which buds like *Hydra*, but in this case the bud does not become detached. It remains in continuity with the parent and later buds in its turn. *Obelia* is therefore a hydroid (or hydra-like) colony produced by asexual budding. The perisarc is secreted by the outer layer or ectoderm and is evidently a necessity to a colonial form to give support.

Occasionally, at the base of the colony, there may be noticed large ovoid masses completely enveloped in perisarc. These *sporosacs* contain modified polypes which have no mouth nor tentacles and appear cylindrical in outline. Later on the sporosac bursts and the modified polypes are detached from the cœnosarc and become free. They are then known as *medusæ.*

Fig. 52.—A Medusa of Obelia.

Seen from the oral surface, magnified. (*Ad nat.*)

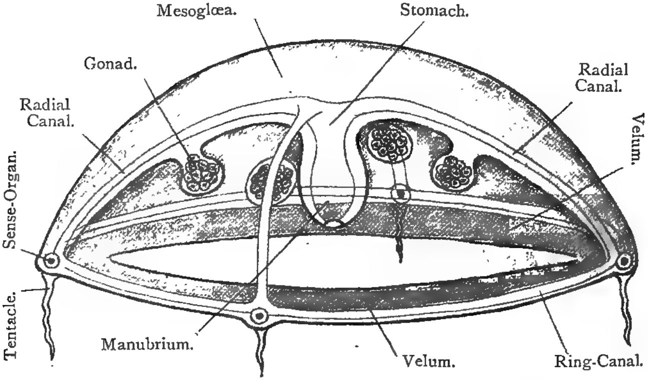


A medusa of *Obelia* is bell-shaped with the opening downwards. The cavity of the bell is known as the *sub-umbrellar cavity* and in its centre there hangs the *manubrium* upon which the mouth opens. The mouth leads into a cœlenteron which is continued down the wall of the bell by four radial canals. These run to the rim of the bell to fall into a ring-canal, passing completely round the rim. At each of the four corners, at which the radial canals meet the ring-canal, there is a sense-organ usually termed an *otocyst.* These otocysts are connected by a double nerve-ring. They are probably balancing organs. The opening of the bell is partially reduced by a thin membrane or *velum* projecting from the edge of the bell. Sections show that the medusa, like the polype from which it is derived, consists of two layers, ectoderm and endoderm, but the mesoglœa is much thicker and forms the bulk of the body. The radial and ring-canals are produced from a continuous cœlenteron by the squeezing together of the two layers of endoderm in the intermediate parts.

The medusa moves through the water by contractions of the "umbrella" or bell, which force water out of the sub-umbrellar cavity. After some time there appear four swellings of the ectoderm lining the sub-umbrellar cavity, overlying the four radial canals. These are the *gonads* or reproductive organs. The medusa is diœcious, the sexes being separate. The egg develops into a larva which swims to the bottom, fixes itself and grows into a young hydroid polype. Thus *Obelia* is an illustration of *metagenesis* or alternation of generations, the hydroid giving rise to a number of other hydroids, some of which grow into medusæ which in turn give rise to hydroid polypes by sexual reproduction.

Fig. 53.—Lateral View of a Medusa of Obelia.

Magnified. (*Ad nat.*)



*Obelia* is also a remarkable instance of physiological division of labour between the individuals of a colony producing nutritive hydroid polypes and reproductive medusoids (*cf. Zoothamnium*). The following differences of *Obelia* from *Hydra* should be noted :—

1. *Obelia* is a compound animal or colony, produced by asexual reproduction from a simple polype.

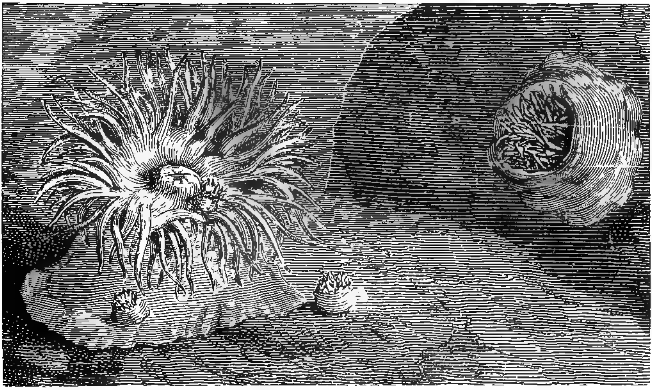
2. It has two phases: a sedentary hydroid and a free-swimming medusoid.

3. It has a chitinous exoskeleton, the perisarc.

## III.—ACTINIA.

| | |
|---|---|
| PHYLUM | CŒLENTERATA. |
| CLASS | SCYPHOZOA. |
| SUB-CLASS | ACTINOZOA. |
| ORDER | HEXACTINIA. |

Fig. 54.—ACTINIA MESEMBRYANTHEMUM.



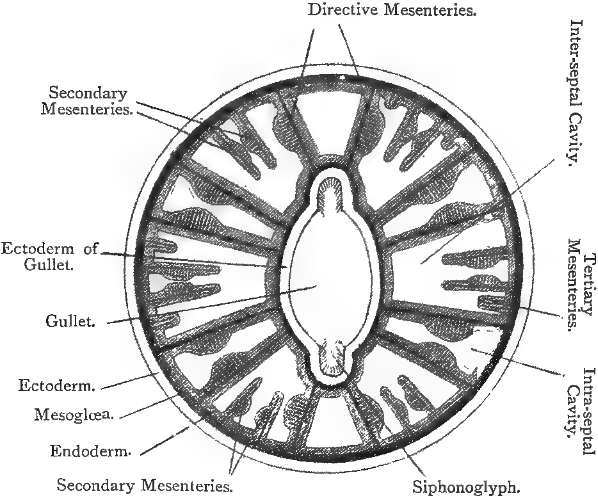
On the left is an expanded individual with viviparous young escaping from mouth. On the right is a partially contracted specimen.

**External Features.**

**Actinia mesembryanthemum** is a common marine organism found between tide-marks. It is, at least externally, axo-symmetric and cylindrical in shape; when expanded it may be about two inches long. The base or aboral end is attached to a foreign body, such as a rock, and the oral end has a ring of numerous short *tentacles* surrounding a flat *peristome*, in the centre of which is situated the *mouth*. The exterior of the body is smooth and of various shades of brown and green, matching its surroundings The body often has particles of sand and fragments of shell adhering to it, which assist in hiding the animal. On stimulation the tentacles are withdrawn into the peristome, and the whole animal assumes a rounded and contracted form. So far the general appearance closely resembles that of a very large but short and broad *Hydra*. An examination of the mouth, however, will show that it is not circular like that of *Hydra* but elongated in one direction, and at each corner of the long axis there is a small groove called a *siphonoglyph*. The walls of these grooves are ciliated and water apparently passes down one groove and up the other, even when the rest of the mouth is shut.

Fig. 55.—TRANSVERSE SECTION THROUGH THE UPPER PART OF A YOUNG ACTINIAN.

Magnified. (After HERTWIG and others.)



Hence *Actinia* is not truly axo-symmetric like *Hydra*, but is symmetric about two perpendicular planes, the one parallel to the long axis of the mouth, the other at right angles to it. This comparatively rare form of symmetry is called *bi-plano-symmetry*.

**Symmetry.**

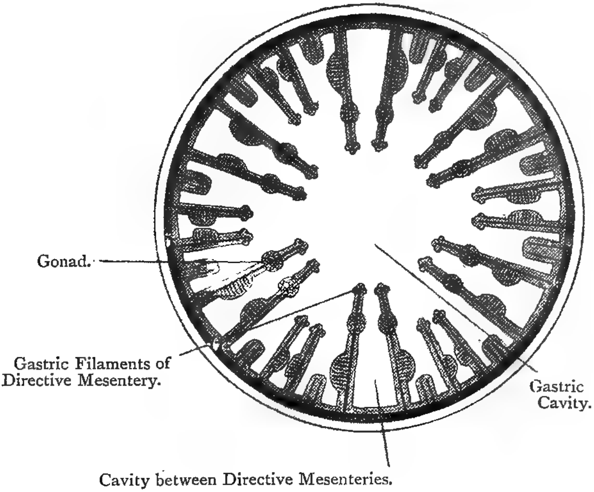
The interior of *Actinia* yields still more striking differences. A transverse section through the lower part shows that the internal cavity or cœlenteron is not simple like that of *Hydra*, but is partially divided into a central gastric cavity and a

**Internal Features.**

number of peripheral cavities by a series of radial mesenteries or *septa.* A section through the upper part shows that the peripheral cavities run up all round a central gullet or *œsophagus* derived from the ectoderm. The cœlenteron is lined with endoderm throughout, but digestion appears to be confined to the central gastric cavity, the peripheral cavities being filled with a more or less nutritive fluid.

Fig. 56.—Transverse Section through Lower Part of a Young Actinian.

Magnified. (After Hertwig and others.)



The free ends of the mesenteries bear numerous *gastric filaments* which assist the processes of digestion. On the walls of the peripheral cavities are the *muscles* and the reproductive organs or *gonads.*

The muscles consist of (1) a circular or sphincter muscle running round a slight rim outside the tentacles. Contraction of the circular muscle causes the rim to tighten over the retracted tentacles like the mouth of a bag. (2) The longitudinal muscles which run down one special side of the mesenteries. They originate at the aboral end and are inserted in the peristome. On contraction they shorten the animal. There are also diagonal or *parietal* muscles across the lower corners, connected with the suction of the base, and thin radial muscles on the mesenteries.

The mesenteries in a large *Actinia* are very numerous, but in the young form there are only six pairs. Of these the two pairs opposite the siphonoglyphs are called the *directive* mesenteries and can be recognised by having the muscles on their outer *surfaces*. The muscles on the other four pairs are opposite each other on the inner *surfaces* of each pair. The cavities *within* the pairs of mesenteries are termed *intra-septal*, those *between* the pairs are known as *inter-septal*.

All six pairs join the gullet. The subsequent mesenteries grow from the outer wall in pairs towards the centre. They always have opposite muscles, never join the gullet, and arise only in the inter-septal cavities. They are known as *secondaries*, *tertiaries*, *quaternaries*, and so on, and continue to grow and increase in number throughout life.

**Histology.**

The cellular structure of the anemone is somewhat in advance of that of *Hydra*. The ectoderm contains nematocysts, sensory cells and unicellular glands. Scattered nerve-cells have also been described. The mesoglœa is a thicker layer than in *Hydra* and passes along the mesenteries. The endoderm contains, as in *Hydra*, flagellate and amœboid cells and also glandular and possibly sensory cells.

**Reproduction.**

*Actinia* reproduces both sexually and asexually. Buds are periodically produced and shed. Our type is somewhat exceptional in being viviparous, *i.e.*, the young are developed in the radial cavities and leave the parent by the mouth. Most of the group have a free larval development with a *planula* larva.

The important point to notice in *Actinia* is the advance in complexity upon *Hydra*. The perfect axial symmetry of *Hydra* is replaced by a symmetry intermediate between this and plano-symmetry, namely bi-plano-symmetry. We can distinguish two ends with siphonoglyphs and two sides, but we cannot distinguish *between* the two ends. Some allies have only one siphonoglyph and are plano-symmetric.

Again, the organs, such as muscles, gonads, and gastric filaments, are much more definite. Thirdly, the cœlenteron is not simple but partially divided thus:—

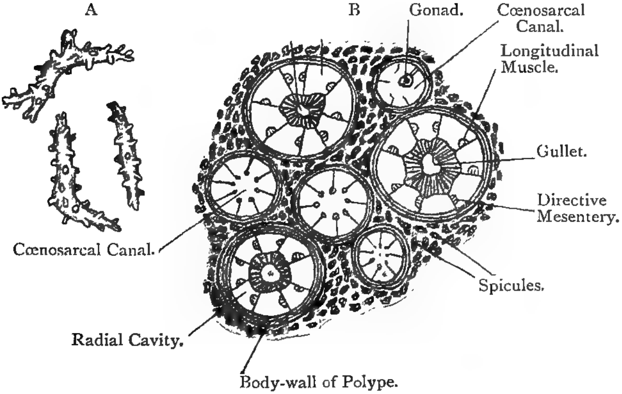
CŒLENTERON < *A*, Gastric cavity for digestion.
*B*, Radial cavities — nutritive and vascular, walls form motor (muscles), skeletal (mesenteries), and reproductive (gonads) organs.

Lastly, the ectoderm is tucked in to form a gullet. At the same time we may note the absence, as in *Hydra*, of definite respiratory, excretory and blood-vascular organs.

## IV.—ALCYONIUM.

| | |
|---|---|
| PHYLUM | CŒLENTERATA. |
| CLASS | SCYPHOZOA. |
| SUB-CLASS | ACTINOZOA. |
| ORDER | OCTACTINIA. |

Fig. 57.—ALCYONIUM DIGITATUM. (*Ad nat.*)



A, Isolated spicules. B, A tangential section through the entire colony showing the polypes in cross section.

**Alcyonium digitatum** (Dead Man's Fingers) may be taken as a type of the colonial *Actinozoa*. The colony may be fixed at its base to a foreign body and branching like a coral, or it may grow closely adherent to the tube of an annelid or other body. It is found most plentifully in moderately deep water, and is often obtained attached to the hooks of fishermen's lines. It is of a dull fleshy hue, hence the popular name. When the polypes or individuals are contracted it has a slightly rough appearance which enhances its resemblance to its gruesome appellation. When the polypes are expanded all over its surface the colony is converted into a zoophyte of great beauty. Each polype has eight feathered tentacles surrounding a central mouth. The body of the polype stands out from the general surface of the colony, but on contraction is completely withdrawn. The general structural principle of the interior of each polype is similar to that of *Actinia*, but there are only *eight mesenteries*, of which *two only are directives*, and the muscles of the other mesenteries are *all on the same face;* there is also only one *siphonoglyph*.

Fig. 58.—VIEW OF ENTIRE COLONY WITH TENTACLES EXPANDED. (After M'INTOSH.) (Magnified.)

Further, the cœlenteron is continued aborally into a cœnosarcal canal communicating with similar canals from the neighbouring polypes.

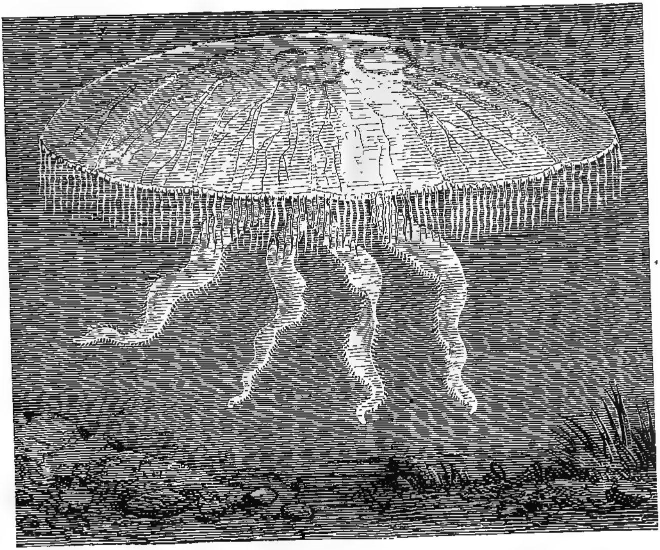
The bulk of the colony is made up of cœnosarc, which contains a great number of nodular calcareous spicules. These give a tough consistency to the colony.

The colonial habit is found largely amongst the order *Hexactinia*, to which *Actinia* belongs, but the arrangement of the mesenteries and the feathered tentacles are characteristic of the order *Octactinia*.

## V.—AURELIA.

| | |
|---|---|
| PHYLUM | CŒLENTERATA. |
| CLASS | SCYPHOZOA. |
| SUB-CLASS | SCYPHOMEDUSÆ. |

Fig. 59.—AURELIA AURITA.



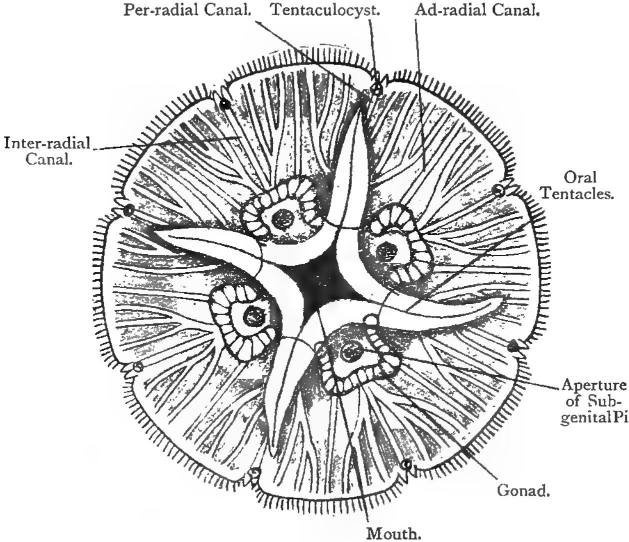
Lateral view. About one-third natural size.

**Aurelia aurita** is a large medusa or "jelly-fish" about the size and shape of a large saucer. It may be found swimming in the sea in any numbers during late summer or early autumn, supporting itself by rhythmic contractions of the body. It is perfectly transparent except for the four gonads which are of a beautiful violet hue.

It differs in shape from the medusoids of *Obelia*, for it is flat, not bell-shaped. However, the general principles of its construction are in many respects similar. It is axially symmetrical and tetramerous, *i.e*, the peripheral parts are arranged in fours. The mouth is four-cornered and opens on a short manubrium. It is surrounded by four large *oral tentacles* which correspond to the four corners of the mouth and are *per-radial.* The disc or umbrella is almost circular but slightly divided

**External Features.**

Fig. 60.—ORAL VIEW OF AURELIA AURITA × ½. (*Ad nat.*)



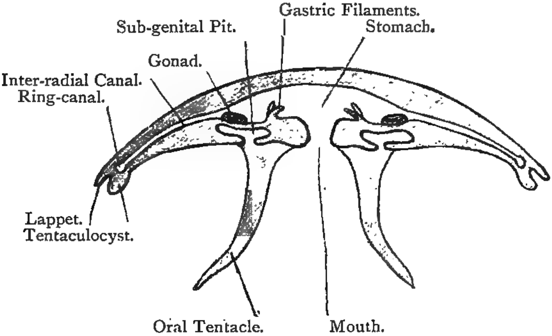
into eight lobes, the indentations between them being at the four per-radii and the four *inter-radii.* In each depression or indentation there is situated a sense-organ or *tentaculocyst* covered by a hood and having a pair of small processes or *lappets*, one on each side. The whole border of the disc is fringed by a great number of small tentacles and there is no velum.

**Internal Features.**

The mouth passes by a short œsophagus into a gastric cavity which is produced into four pockets in the inter-radii. Each pocket contains on its oral wall a horse-shoe-shaped *gonad*, and near the middle a row of *gastric filaments* which assist in digestion. The gastric cavity is continued outwards towards the edge of the disc by numerous *vascular canals.* The eight primary branched canals are the four per-radial and the four inter-radial. Between these there are the eight secondary unbranched canals or *ad-radials.* All the canals open into a ring-canal round the edge of the disc. The gastric cavity and the canals are ciliated. They are derived from the cœlenteron, as in *Obelia.* In the inter-radii, immediately below the gonads, are four *sub-genital pits*, each opening on the oral surface by a pore.

The mesoglœa between the two layers is a thickened jelly which in this case contains scattered cell-elements.

Fig. 61.—Median Longitudinal Section through the Inter-radial Plane of Aurelia. (Diagrammatic.)



There is no nerve-ring, but there is a diffuse nerve-plexus concentrated round the sense-organs or *tentaculocysts.* These latter are complex and appear to unite the senses of sight, hearing and smell in different parts.

Development. — *Aurelia* is diœcious and the sexual elements are discharged by the mouth. A free-swimming planula larva (Chapter V.) settles down on rocks or weeds and forms the *hydra-tuba*, a minute hydra-like individual. It is a two-layered sac, with a mouth at the oral end, leading into a stomodæum and cœlenteron. The eight primary and eight secondary tentacles soon appear, and the cœlenteron becomes divided into a central gastric cavity and four peripheral cavities by four inter-radial mesenteries or *tæniolæ*. Four hollow processes of epiblast, or *septal funnels*, grow down the interior of these mesenteries. This polype has been termed a *Scyphula*, the presence of the tæniolæ and stomodæum constituting a resemblance to the preceding type (*Actinia*). The Scyphula grows in length and by transverse fission it sets free

Fig. 62.—THREE STAGES IN DEVELOPMENT OF AURELIA.
(After GÖTTE.)

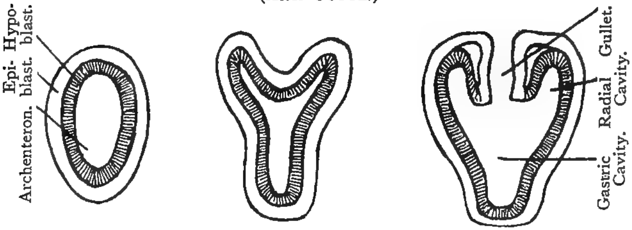


Fig. 63.—TRANSVERSE SECTION THROUGH UPPER PART OF SCYPHULA LARVA.

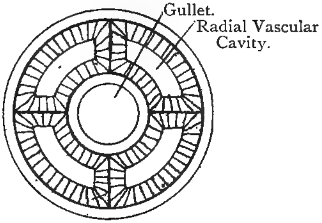
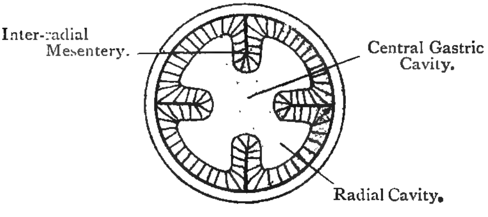


Fig. 64.—TRANSVERSE SECTION THROUGH LOWER PART OF SCYPHULA LARVA.



a number of free-swimming forms, called *Ephyræ*. An *Ephyra* has eight long arms, *per-radial* and *inter-radial*, down which are produced the eight primary canals. The end of each arm is bifid, forming the two lappets, between which is the tentaculocyst. By differential growth the *Ephyra* fills up the ad-radial depressions and becomes a young *Aurelia*. The tæniolæ disappear, leaving only the gastric filaments, whilst the bases of the *septal funnels* form the sub-genital pits.

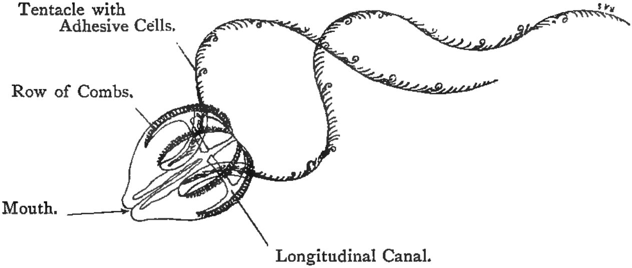
Here we have a metagenesis, as in *Obelia*, but the scyphula does not form a true colony, abbreviating this stage by rapid transverse fission.

## VI.—CYDIPPE.

| | |
|---|---|
| PHYLUM | CŒLENTERATA. |
| CLASS | CTENOPHORA. |

*Cydippe* is one of the most beautiful little organisms to be found in the sea. It is pelagic and appears like an almost spherical transparent ball of glass, usually about one-half inch in diameter. It feeds voraciously on pelagic organisms, *e.g.*, young fish. When alive it moves with ceaseless activity and is iridescent with rainbow (interference) colours. One axis is slightly longer than the other, at one end of which (oral) is the *mouth*; at the aboral end is a sense-organ. From oral to aboral end there run eight meridional rows of rapidly moving *combs* which are formed by a row of cilia fused at their base. All the combs strike in an oral-aboral direction and the result is a steady, fairly rapid movement forward. Two long tentacles trail behind the animal and give stability to its movements. They bear small branches which are covered with spirally stalked *adhesive* cells. The tentacles are very sensitive and can be completely retracted within a pair of *sheaths* or pockets. The *mouth* leads into an ectodermal *gullet* which passes into a *stomach*. The stomach tapers towards the aboral end and branches into four ducts which open symmetrically round the aboral sense-organ.

Fig. 65.—CYDIPPE PLUMOSA.
(After CHUN.)



Externally, *Cydippe* is bi-plano-symmetric, for the plane passing through the tentacles and their sheaths, called the *coronal plane*, differs from that perpendicular to it, or the *sagittal plane*. Both planes, however, divide the animal into symmetric halves. The gullet is flattened and elongated in the sagittal plane, as in *Actinia*. Each of these planes corresponds to two opposite per-radii. The stomach gives off, near the gullet, four inter-radial canals which run horizontally outwards, each bifurcating into two ad-radials. Each of these joins a long *meridional canal* running from oral to aboral end just below each row of the combs.

Fig. 66.—Aboral View of Cydippe. (After Chun.)

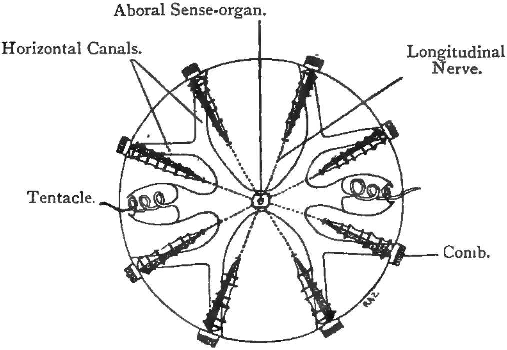
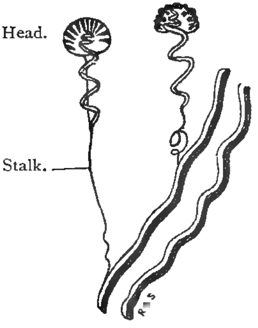


Fig. 67.—Adhesive Cells of Cydippe. (After Hertwig.)

Highly Magnified.



The aboral sense-organ consists of a ciliated depression containing small otoliths (*cf. Obelia*) and probably governs the equilibrium of the animal. From it there pass eight nerves down the eight rows of combs.

The cœlenteron is here partially divided, as in *Actinia*, into a central gastric cavity or stomach and peripheral nutritive, or vascular cavities. The muscles are not represented, but the gonads (*Cydippe* is hermaphrodite) are situated on the walls of the meridional canals. The mesoglœa is enormously developed and forms the main bulk of the organism, filling the space between ectoderm and endoderm. Nematocysts are not found in *Cydippe* but they have been described in some members of the group.

*Cydippe* resembles *Actinia* in the presence of an ectodermal gullet and of central and peripheral portions of the cœlenteron, but it differs from all the preceding types in the possession of "combs" of cilia.

## PHYLUM CŒLENTERATA.

The **Phylum Cœlenterata** is extensive and of great zoological importance. The six types described above (*i.e.*, *Hydra*, *Obelia*, *Aurelia*, *Actinia*, *Alcyonium*, *Cydippe*) give a good general idea of its organisation and place in nature.

They are mostly marine, all aquatic and all retain the primary metazoan axis, about which they are usually axo-symmetric though, as in the last two types, they may progress to bi-plano-symmetry. They are usually either sedentary or pelagic.

In structure they are all formed of two epithelia (or derms), an outer layer or ectoderm and an inner or endoderm, between which is a thin or thick mesoglœa. This two-layered condition has been compared to that of the typical diploblastic larva, the gastrula. The comparison is as follows:—

| GASTRULA.— | CŒLENTERATA.— |
|---|---|
| Epiblast. | Ectoderm. |
| Hypoblast. | Endoderm. |
| Archenteron. | Cœlenteron. |
| Blastopore. | Mouth. |
| Central axis. | Primary axis. |

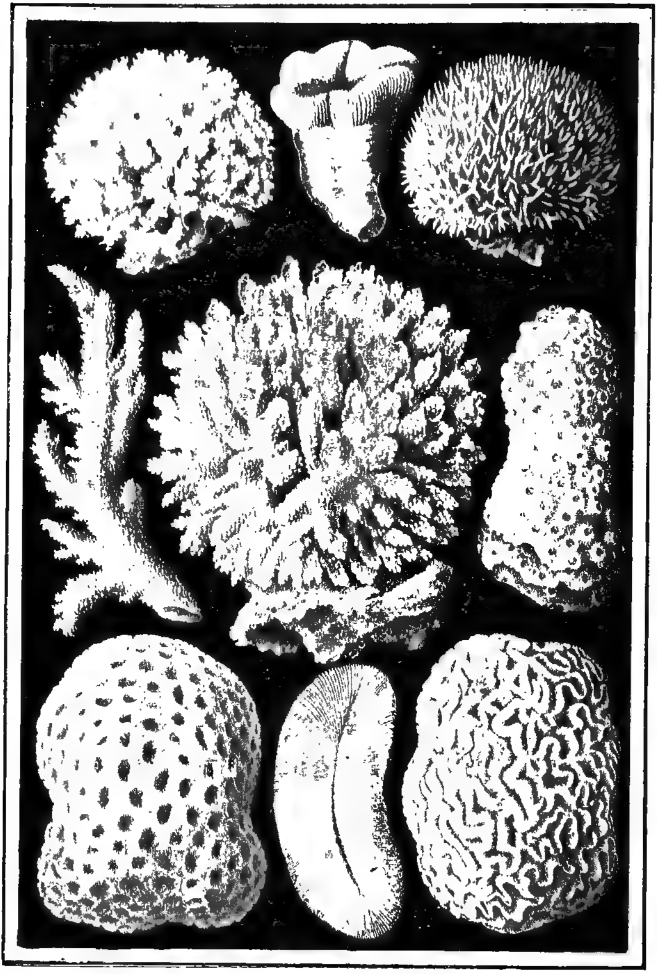
We can divide *Cœlenterata* into three classes:—

1. Hydrozoa.
2. Scyphozoa.
3. Ctenophora.

### CLASS I.—HYDROZOA. (*Hydra* and *Obelia.*)

In these animals the cœlenteron remains simple, the axial symmetry is undisturbed and there is no ectodermal gullet. They include hydra-like forms with only a hydroid phase; obelia-like zoophytes which have a hydroid and a medusoid phase (though the medusoid may be degenerate); and others (*e.g.*, *Narcomedusæ*) with only a medusoid phase.

Fig. 68.—Types of True Corals. (After Hæckel.)



The *Hydrocorallinæ* are peculiar in having a massive calcareous skeleton instead of the usual chitinous one and for their very primitive little medusoids. Their calcareous skeletons can be distinguished from the true corals by the absence of *septa* in the apertures left by the polypes. The *Siphonophora* are floating pelagic colonies with little or no skeleton but with remarkable division of labour, the members of the colony being modified into a great variety of kinds.

### CLASS II.—SCYPHOZOA. (*Actinia* and *Aurelia.*)

In these the cœlenteron at one time of their life is divided into central (gastric) and peripheral (vascular) cavities, and there is usually an ectodermal gullet. The gastric cavity usually has gastric filaments and the gonads are endodermal. *Aurelia* represents those types which have hydroid and medusoid phases, but a number of other jelly-fishes have only the medusoid phase. All these form the sub-class *Scyphomedusæ.* The important forms with only hydroid phase (*e.g.*, *Actinia*) form the sub-class *Actinozoa. Actinia*, like *Hydra*, is solitary and without an exoskeleton, but actinozoan colonies (like hydroid zoophytes) also occur. The skeleton, usually ectodermal, is most commonly of calcareous matter, and may assume vast proportions. These colonial types are called *corals* and their skeletons may be recognised by the presence of radial septa in the holes formerly inhabited by the polypes. (Coral Islands, see page 72.) The *Actinozoa* are divided into two important orders, the *Hexactinia* and *Octactinia*, according to the number of mesenteries and other structural features mentioned in the types *Actinia* and *Alcyonium.*

### CLASS III.—CTENOPHORA.

The unique motor organs of this class tend to separate them from the other two classes, but they are connected by certain intermediate forms.

*Cydippe* is a very fair representative of the class.

They are typically free-swimming pelagic organisms of carnivorous habits. Some (*Cestum*) become elongated in one plane to form a long ribbon, or they may (*Beroë*) form a large bell by increase of the stomodæum.

## PHYLUM CŒLENTERATA.

1. Metazoa with radial (axial) symmetry.
2. Body of two layers of cells, ectoderm and endoderm, enclosing one continuous gastric cavity, which communicates to exterior by one opening, the mouth-anus.*
3. A structureless lamella, the mesoglœa, between the two layers.
4. Ectoderm cells bear nematocysts.
5. Asexual reproduction by budding produces colonies.
6. Aquatic and mostly marine, free-swimming and sedentary (tending to coral formation).

| Class I.—HYDROZOA. | Class II.—SCYPHOZOA. | Class III.—CTENOPHORA. |
|---|---|---|
| *Types—Hydra; Obelia; (Tubularia).* | *Types—Actinia; Alcyonium; Aurelia; (Madrepora).* | *Types—Cydippe; (Beroë).* |
| 1. Simple gastric cavity. | 1. Gastric cavity divided by mesenteries into central and peripheral cavities. | 1. Gastric cavity consisting of stomach and gastro vascular canals. |
| 2. No ectodermal gullet. | 2. An ectodermal gullet. | 2. An ectodermal gullet. |
| 3. Two phases, a free-swimming medusoid and sedentary hydroid. | 3. Two phases, a free-swimming medusoid and sedentary hydroid. | 3. One phase only, a free-swimming, modified from medusoid type. |
| | | 4. Eight longitudinal rows of cilia. |
| | | 5. Nematocysts rare. |
| | | 6. Single aboral sense-organ. |
| MEDUSOID. | MEDUSOID. | |
| A velum. | No velum. | |
| Gonads ectodermal. | Gonads endodermal. | |
| Four radial canals. | Many radial canals. | |
| Simple sense-organs. | Tentacles modified into complex sense-organs. | |
| Nerve-rings. | Diffuse nerve fibres. | |
| HYDROID. | HYDROID. | |
| 1 When colonial, usually has horny perisarc. | 1. When colonial, has calcareous skeleton. | |
| 2. Skeleton has no septa. | 2. Skeleton has septa. | |

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* Usually termed the "mouth."

# CHAPTER XIV.

## PLATYHELMINTHES, ROTIFERA AND NEMATHELMINTHES.

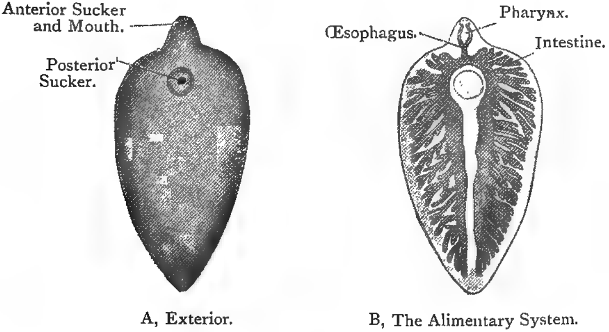
DISTOMUM. TÆNIA. HYDATINA. ASCARIS.

### I.—DISTOMUM.

| | |
|---|---|
| PHYLUM | PLATYHELMINTHES. |
| CLASS | TREMATODA. |

Fig. 69.—VENTRAL VIEW OF LIVER-FLUKE (*Distomum hepaticum*).

Natural size. (*Ad nat.*)



A, Exterior. B, The Alimentary System.

**Distomum hepaticum** is the liver-fluke of the sheep. It may grow considerably over one inch in length and shows a flat leaf-like shape. It is plano-symmetric and flattened dorso-ventrally.

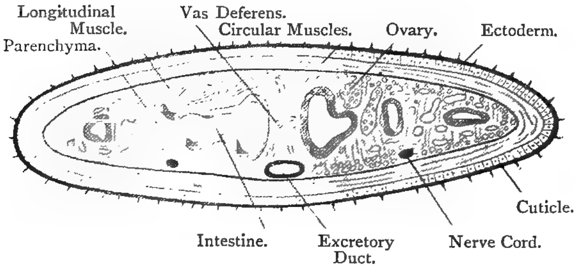
It infests the liver and bile-ducts of the domestic sheep, and causes the disease called "liver-rot" which is fatal to great numbers of sheep. Obstruction of the bile-duct by hundreds of these parasites causes inflammatory processes and bleeding of the liver-tissues. General wasting and often jaundice lead on to death. The life-history clearly shows the reason why sheep incur this disease after grazing on damp pastures.

**External Features.** At the anterior end is a blunt cone, at the tip of which opens the mouth in the centre of a sucker. The body tapers from two shoulders to a point. In the mid-ventral line, about $\frac{1}{10}$th of its total length from the anterior end, is situated a second sucker.

**Integumentary.** The body is of a dull yellow colour and enveloped in a thin cuticle, which forms hook-like processes or *spinules* pointing backwards and scattered over the surface.

Fig. 70.—Transverse Section through the Liver-Fluke. (*Distomum.*)

(Somewhat diagrammatic.)



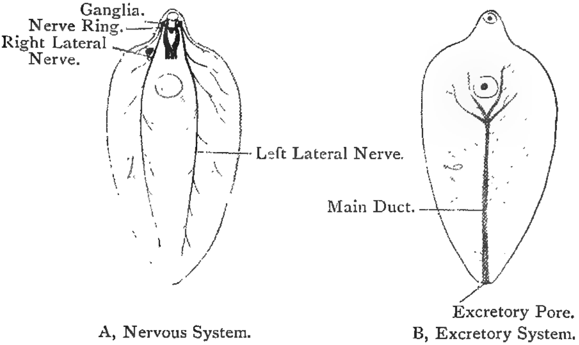
The animal creeps about slowly by muscular contractions. Under the cuticle are formed well-defined circular and longitudinal layers of muscles. The mouth leads into

**Alimentary.** a sucking pharynx with muscular walls. This opens backwards by a short *œsophagus* into a large *intestine.* The intestine forks into two main branches which run back to the hind end of the body. On their outer side they give off a great number of much-branched processes which end blindly at the edge of the body. Digestion appears to be purely intra-cellular. There is no anus.

**Excretory.** The excretory system consists of a median duct which opens by a pore at the posterior end. It is connected with innumerable branches which form a fine network all over the body. Each branch eventually terminates in a blind swelling, in the centre of which there depends a *flagellum*. The flickering motion of these flagella, doubtless causing currents towards the exterior, has given the name of *flame-cell excretory organs* to the whole system.

**Nervous.** There are no known sense-organs, but the nervous system consists of a ring round the pharynx with two lateral ganglia and a small ventral ganglion. From the lateral ganglia are given off two ventro-lateral nerves which pass to the hind end of the body.

Fig. 71.—STRUCTURE OF DISTOMUM.



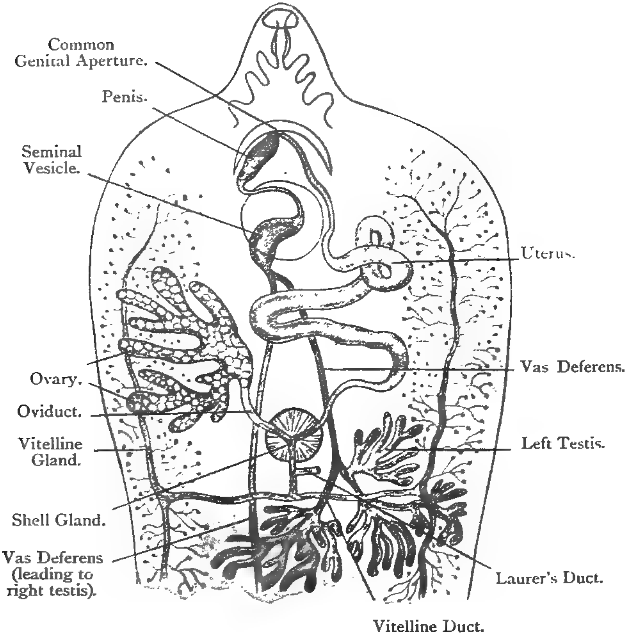
A, Nervous System. B, Excretory System.

**Vascular.** The cavity of the body between the muscle layers and the alimentary and reproductive organs is almost entirely filled up with a mass of cells, arranged in a mesh-work, to which the name of *parenchyma* has been applied. Small cavities between these cells represent the primitive vascular cavity or hæmocœle.

**Reproductive.** The reproductive organs are complex. *Distomum* is hermaphrodite. The female organs consist of a branched *ovary* on the right side of the animal, from which there passes an *ovarian* duct. Two large paired *yolk-glands* lie laterally and their *vitelline ducts* meet to form a median vitelline duct. This runs forward to meet the ovarian duct and from their junction there passes a median dorsal tube to the exterior, the so-called *vagina*. The junction is surrounded by a round *shell-gland* which secretes the shells of the eggs, and the united ducts lead towards the anterior end as a much-coiled *oviduct*. This opens to the exterior in the median ventral line between the two suckers.

Fig. 72.—VIEW OF LIVER-FLUKE (*Distomum*).

Showing the Reproductive Organs. (After SOMMER.)

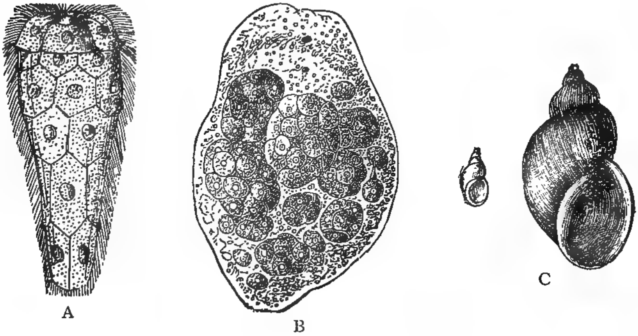


The male organs consist of a pair of branched *testes*, one behind the other. The *vasa deferentia* from them unite at the level of the posterior sucker to form a *seminal vesicle.* In front of the seminal vesicle lies the protrusible *penis* along which there runs an *ejaculatory duct* from the former. Penis and seminal vesicle lie in a cavity called the *cirrus-sac.* A small *prostate-gland* encircles the ejaculatory duct. There may possibly be self-fertilisation.[*]

**Development.**

The small ovoid eggs (about $\frac{1}{180}$ inch in length) accumulate in the oviduct and are enveloped in hard shells. They are discharged down the bile-duct into the intestine and thence to the exterior. The eggs, which are laid in the neighbourhood of water, hatch by detaching a circular cap and set free a small ciliated larva not unlike an adult in shape.

Fig. 73.—Development of Distomum Hepaticum.



A, Ciliated Larva; B, Sporocyst with contained embryos; C, *Limnæus truncatulus* (natural size and magnified), the host of the Sporocyst.

It has an outer layer enclosing a solid mass of cells. There are two small pigment spots which may serve as eyes. It lives actively for a few hours, and if successful during that time in finding a water-snail (*Limnæus truncatulus*), it is said to rotate rapidly with its pointed anterior end against the body of the snail and bore its way therein. In the tissues of the snail it loses its cilia and grows to about five times

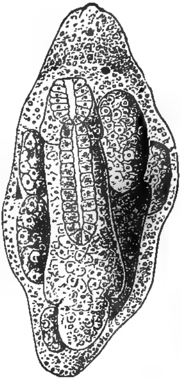
---

[*] A small duct leads dorsally from the median vitelline duct to the exterior. It is called Laurer's duct, and its use is not definitely known.

its length into a large two-layered sac called the *sporocyst*. The inner layer buds cells into the internal cavity, which develop into organisms called *rediæ* through a *morula* and *gastrula* stage. A *redia* has an elongated body with mouth at the anterior end, a pharynx and simple intestine. Externally it has a *collar* or thickened ridge round the anterior end, behind which is a small pore into the body-cavity, and a pair of processes towards the hind end. It also has excretory tubules. A redia when developed bursts through the brood-sac or sporocyst and eats its way through the snail. Eventually it produces, by budding of its internal cells, a number of *cercariæ* which are young or larval flukes. The *cercaria* escapes by the genital pore of the redia and out of the snail into the water. It has a rounded body and vibratile tail. Two suckers, a mouth, pharynx, and simple bilobed intestine can be distinguished, and there is also a flame-cell excretory system. The surface is dotted with *cystogenous* cells which produce the cyst. The cercaria works its way to the edge of the pond (the snail may be in grass already), up a blade of grass or other plant and there loses its tail, encysts and remains dormant. Should the cyst be introduced into the stomach of the sheep the cercaria escapes, passes up the bile-duct, and develops in a few weeks into a young fluke.

We have to add that the sporocyst may produce fresh sporocysts by binary fission and that the redia may give rise to fresh generations of rediæ.

Fig. 74.—SPOROCYST.



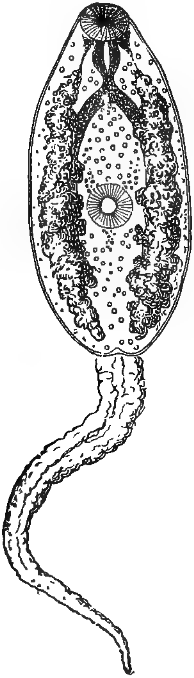
Sporocyst containing Rediæ.

Fig. 75.—A REDIA.

Young Redia. Notice the mouth and alimentary canal, and two lateral processes.

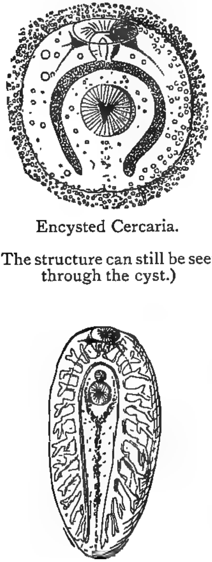
*Distomum* is a type of the *Digenous Trematoda*, or those with two or more generations in their life-cycle, which alternate in their environment between two hosts, as in *Distomum*. It also illustrates several adaptations due to a somatic endoparasitic habit (see Chapter IX.). The high fecundity, the complex sexual organs, and the absence of sense-organs should be here noted.

Fig. 76.—A CERCARIA.



Notice tail, suckers, bilobed intestine and dotted cystogenous cells.

Fig. 77.—CERCARIA AND DISTOMUM.



Encysted Cercaria.

(The structure can still be seen through the cyst.)

Young *Distomum*.

*Distomum* belongs to the phylum **PLATYHELMINTHES** because of its flattened unsegmented body, its simple alimentary canal with no anus, and its mesodermic parenchyma with flame-cell excretory organs. It belongs to the class TREMATODA because of its parasitic habit with suckers, thick hooked cuticle and complex sexual organs.

## II.—TÆNIA.

| | |
|---|---|
| PHYLUM | PLATYHELMINTHES. |
| CLASS | CESTODA. |

**Tænia solium** is a common tape-worm inhabiting the intestine of the human subject. It is of great length (often nine to ten feet) and flattened dorso-ventrally. The anterior end is extremely small, terminating in a knob called the head. The body enlarges gradually backwards, and it is broadest at the extreme hind-end. It is produced anteriorly into a process or *rostellum* which bears a ring of (22-32) hooks and behind them there are four large suckers. A little way behind the head there appear transverse constrictions running across the body. These get wider apart and deeper towards the hind-end, and partially divide the body into a series of sections known as *proglottides*. There may be about 850 proglottides, of which the broadest are about $\frac{1}{3}$ inch across.

**External Features.**

There is no mouth, no alimentary system, and no sensory organs, but the nervous and excretory systems are well developed. There is a nerve-ring in the head with two lateral ganglia giving branches to the suckers. There pass backwards from them a pair of lateral nerves which run throughout the length of the body.

**Nervous.**

The excretory system has also a ring in the head and four longitudinal ducts. The dorsal and ventral pair do not proceed far, but the lateral ducts pass down the entire length of the body just inside the nerves. In the posterior part of each proglottis they are connected by a transverse duct, and in the last proglottis this duct opens medially through a contractile vesicle to the exterior. Numerous secondary branches break up in the parenchyma and terminate in "flame-cells."

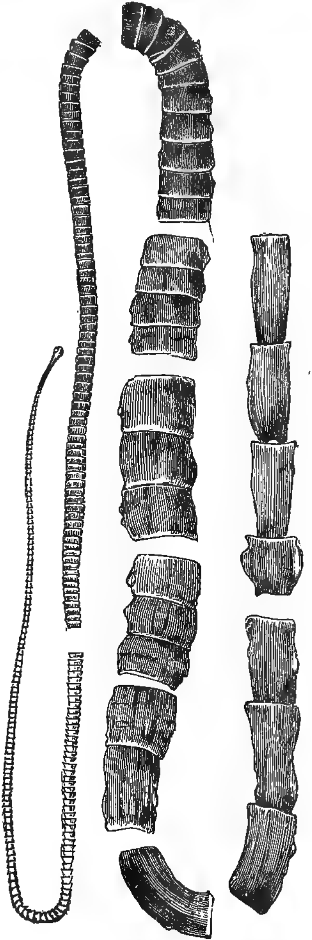
**Excretory.**

There is a very thin cuticle and a rather indefinite layer of ectoderm which merges into the parenchyma. In this tissue are small calcareous bodies. The muscles are arranged in a transverse series and a scattered longitudinal series outside it.

**Reproductive.**

In the parenchyma are found the complex reproductive organs. *Tænia*, like *Distomum*, is hermaphrodite, and the sexual organs are repeated in each proglottis. They mature gradually, hence the front proglottides show an earlier stage than the hind ones. Those front proglottides which show sexual organs have male organs only. The middle ones show both sets of organs and the "ripe" hind ones show a portion of the female organs only. The common sexual opening is found on the right side in one proglottis, on the left in another. The *testis* is a branched organ opening by a *vas deferens* to a *penis*. The paired *ovaries* lead by *ovarian ducts* into a median *oviduct*. This oviduct first receives the opening of the sperm-duct and then passes through the *shell-gland* to the *uterus*. In the shell-gland it receives the *vitelline duct* from the yolk-gland. The sperm-duct opens at its other end into a *seminal receptacle*, a chamber in which

Fig. 78.—TÆNIA SAGINATA.
(After LEUCKART.)



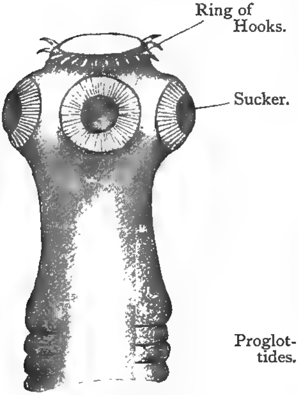
Selected portions from a single specimen.

the sperms are stored. It communicates with the exterior by a vagina, opening close to the penis.

Eggs pass down the oviduct, are fertilised by sperms from the seminal vesicle, receive yolk from the yolk-glands and a shell from the shell-gland, and then pass into the uterus. Here they accumulate in enormous numbers, and a "ripe" proglottis contains a large branching uterus with eggs; the remainder of the sexual organs have atrophied. The eggs are at first surrounded by an oval vitelline membrane filled with albumen, but later this ruptures and the egg has merely a thick shell.

The ripe proglottides are shed one by one and pass to the exterior. The eggs are set free in millions on introduction of the proglottis into the stomach of a pig. The embryo is spherical and has three pairs of hooks. By these, combined

Fig. 79.—HEAD OF TÆNIA SOLIUM.
(After LEUCKART.)



Note the ring of hooks on the rostrum, the four suckers, and the commencing proglottides.

Fig. 80.—TRANSVERSE SECTION OF A PROGLOTTIS OF TÆNIA.
(After SHIPLEY.)

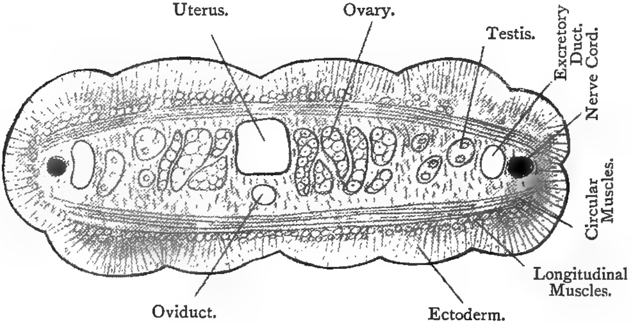


Fig. 81.—Semi-diagrammatic View of a Single Proglottis of a Tænia.

(Mainly after Leuckart.)

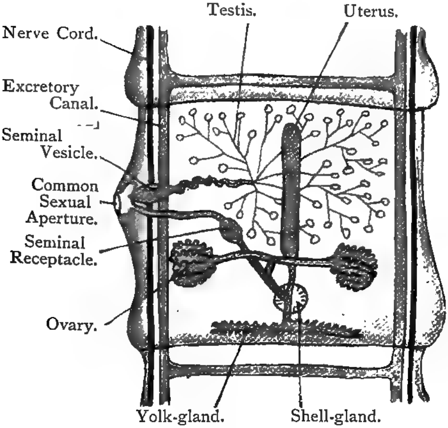


Fig. 82.—Proglottis of Tænia Saginata.

(After Leuckart.)

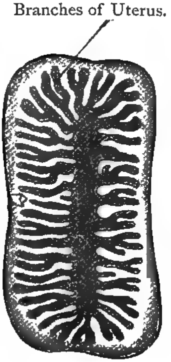
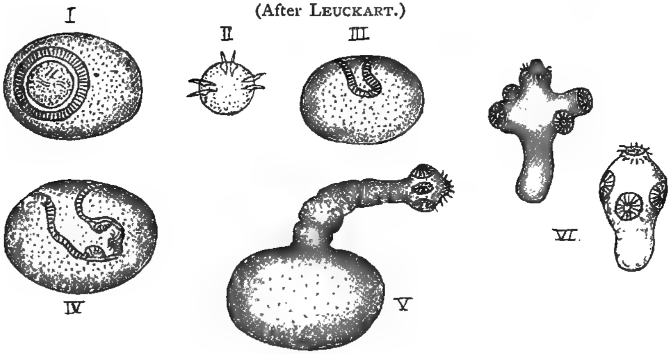


Fig. 83.—Development of Tænia Solium.

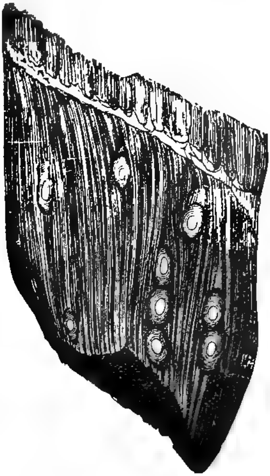
(After Leuckart.)



I, The egg in its vesicular vitelline membrane and shell. II, The free egg with three pairs of hooks. III, The cystic stage, with developing head. IV, A later stage of same. V, The bladder-worm, with head evaginated. VI, Young Tænia from intestine of a rabbit.

with the muscular movements of the host, the embryo is worked into the blood-vessels of the pig, along which it is carried into the muscles. Here it loses its hooks and becomes a hollow vesicle or cyst. The wall of the oval cyst is invaginated at one side and forms a pocket. On the wall of the pocket are found suckers and hooks, and it is later evaginated to form the cestoid worm. Pork containing such cysts is known as "measly." This is known as the *cystic* stage or *bladder-worm*, and the cysts of *Tænia solium* were known by the separate name of *Cysticercus cellulosæ* before their true nature was determined. The completed bladder-worm shows a large bladder, depending from which is the "body" of the worm. On being introduced, still alive, into the human subject the bladder, and with it the greater part of the body, is lost, and the head alone survives as a creeping worm, fixes itself and grows into the tapeworm.

Fig. 84.—"MEASLY" PORK.



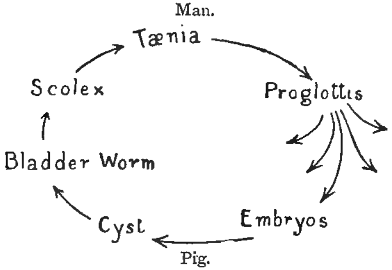
The oval bodies are cysts.

We may note that there is *no true metagenesis*, since the fission into proglottides can hardly be regarded as a method of reproduction. In some allied forms, however, the cyst or cystic stage produces several scolices, in which cases metagenesis is evident.

*Tænia solium* is only found in man, and is chiefly dangerous owing to a liability of the cystic stage being also passed through in man, often in the brain.

*Tænia* is a striking instance of the effects of endoparasitism, especially of the enteric type. (See Chapter IX.)

The life-history may be illustrated diagrammatically :—



## PHYLUM PLATYHELMINTHES.

**The Platyhelminthes**, or flat-worms, form a well-defined group of the affinities of which little is known. The two types given, *Distomum* and *Tænia*, represent the two "parasitic" classes of the phylum.

1. TREMATODA.—The *Trematoda* are all parasites, the *Monogenea* are mostly ectoparasites with one host, and the *Digenea* are endoparasites with two hosts.

2. CESTODA.—The *Cestoda* illustrate enteric parasitism with entire loss of alimentary canal. They usually alternate between two hosts and show a cestoid and cystic stage. *Tænia saginata* is a common type found in the ox and man. It has no hooks and is larger than *Tænia solium.* In these the cystic stage has only one head and is called a *cysticercus*, but in some, such as *Tænia cœnurus*, alternating between the dog (cestoid) and sheep (cystic), the cystic stage has many heads and is called a *Cœnurus.* It produces "sheep-gid"

or "sturdy" by pressure on the brain. Another small tapeworm of the dogs, *Tænia echinococci*, has enormous cysts, with secondary cysts and many "heads" (*Echinococci*), which may occur in man, sheep or pigs.

The members of the third class, or *Turbellaria*, are not parasites, but are terrestrial, marine, or freshwater. In a number of characters they resemble the other classes. The body is usually flattened dorso-ventrally. There is no anus. There are neither vascular nor respiratory organs. The excretory organs are of the "flame-cell" type, there is a brain with two lateral nerves, and the sexual organs are hermaphrodite and complex. On the other hand, the *Turbellaria* usually have simple sense-organs and the body is usually ciliated.

In the *Platyhelminthes* we see a distinct advance in structure when compared with the *Cœlenterata*. The axial or, at most, bi-plano-symmetry of the latter has given way to plano-symmetry. The mesoglœa of the *Cœlenterata*, with or without a few scattered cells, has given place to a definite mesoderm formed into muscles, gonads and parenchyma, and drained by a definite excretory system.

## PHYLUM PLATYHELMINTHES.

1. Three-layered metazoa with bilateral symmetry (plano-symmetry) and flattened body.
2. Alimentary canal, when present, has no anus.
3. Mesoderm with no definite cavity and fills the space between skin and alimentary canal (parenchyma).
4. Excretory organs consisting of ducts opening to exterior and blind branches containing "flame-cells."
5. Nervous system usually with two lateral cords and an anterior paired brain.
6. No vascular nor respiratory systems.
7. Mostly hermaphrodite.

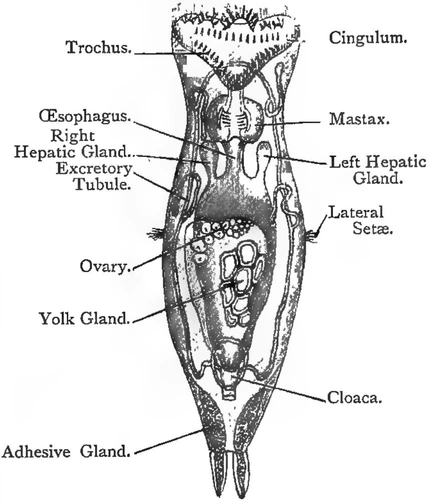
| Class I. | Class II. | Class III. |
|---|---|---|
| CESTODA. | TREMATODA. | TURBELLARIA. |
| *Type—Tænia.* | *Type—Distomum.* | *Type—Mesostoma.* |
| 1. Elongated flat-worms with thin cuticle. Hooks and suckers on head. | 1. Oval flat body with cuticle bearing fine hooks and suckers. | 1. Oval flat body with cilia and rhabdites. |
| 2. No mouth nor alimentary canal. | 2. Anterior mouth, racemose intestine. | 2. Ventral mouth, simple or branched intestine. |
| 3. Life-history of two phases—the cestoid and the cystic. | 3. Life-history often of two phases. | 3. Life-history simple. |
| 4. No sense-organs. | 4. No sense-organs. | 4. Paired eyes. |
| 5. Endoparasitic. | 5. Endoparasitic or ectoparasitic. | 5. Free—aquatic and terrestrial. |

# III.—HYDATINA.

PHYLUM ROTIFERA.

**Hydatina senta** is a small microscopic animal very commonly found in freshwater ponds and streams. Its body is transparent and elongated. At the blunt or *oral* end is a ciliated funnel-like depression, the *vestibule*, at the bottom of which is the *mouth*. The edge of the vestibule is fringed with a band consisting of specially long cilia, which is known as the *cingulum*. Further towards the centre of the vestibule is a broken row of longer cilia, called the *trochus*, whilst the *groove* between trochus and cingulum is raised into several lobes bearing *styles*. This complex apparatus is often called the *wreath* and serves for locomotion and for ingestion of food. The aboral end is tapering and terminates in a bilobed *foot* endowed with a pair of *adhesive glands*. The body is enveloped in a thin delicate cuticle covering a simple ectoderm. The mouth leads into a *mastax* which is a complex grinding apparatus containing chitinous teeth. From this an *œsophagus* is continued into a large digestive *stomach* followed by an *intestine*. The intestine terminates in an *anus*, situated not at the aboral end but on one surface, usually termed *dorsal*. Two *salivary glands* open into the mastax, and two *hepatic* or *digestive glands* discharge their fluid into the stomach.

Fig. 85.—VENTRAL VIEW OF HYDATINA SENTA × 40.
(After PLATE).



The alimentary canal hangs freely in the cavity of the body, which is filled with colourless fluid. This body-cavity is traversed by connective tissue and muscle fibres, but has no cœlomic lining. Throughout its course, laterally to the alimentary canal, is a pair of excretory tubules which bear branches terminating in closed flame-cell sacs. Each tubule opens behind into the *urinary bladder* with a single aperture to the exterior near the anus, forming a *cloaca*. Anteriorly the two tubules anastomose in front of the mouth. The brain is a large mass lying dorsally to the mouth; it supplies nerves to various parts of the body. Ventral to the stomach is a single *ovary* with a large *vitelline gland* and an *oviduct* opening into the cloaca.

The male *Hydatina* is much smaller in size and has no alimentary system.

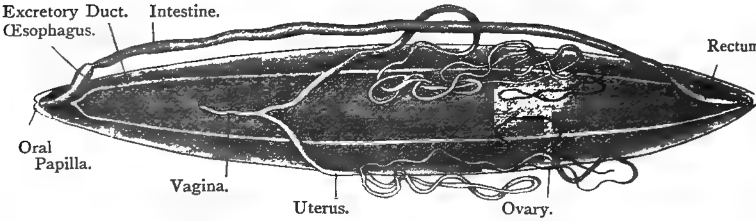
## PHYLUM ROTIFERA.

The **Rotifera** are an important phylum of common microscopic animals. They are marine and freshwater in habit, and they may be active, sedentary, tubicolous or ectoparasitic. They are interesting in their diversity of external form, their sexual dimorphism (with small and degenerate males), their summer and winter eggs and their power of resisting drought. They are three-layered in structure, but they have no cœlom; the cavity of the body is an archicœle and there are no nephridia, excretion being conducted by flame-cell tubules. These and other characters indicate a relationship to the *Platyhelminthes. Hydatina* is fairly typical but for the exceptional absence of eyes or other simple sense-organs. In other *Rotifera* there is great diversity in the form of the wreath and of the foot.

## IV.—ASCARIS.

| | |
|---|---|
| Phylum | Nemathelminthes. |
| Class | Nematoda. |

Fig. 86.—Dissection of Female Ascaris Megalocephala from the Dorsal Side. (*Ad nat.*)

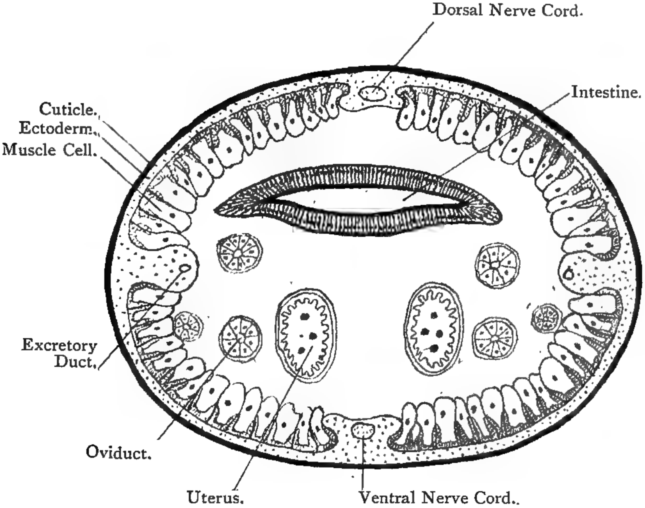


**Ascaris megalocephala** is a large nematode worm found commonly in the stomach of the horse. It is usually known as the "maw-worm." The body is long and cylindrical, tapering at each end. The female may be one foot or more in length; the male is usually less. In addition,

**External Features.**

the hind-end of the male is slightly coiled, and has a pair of minute bristles or *anal setæ* protruding from the anal aperture. The body is of a whitish colour, and it has four lines (a dorsal and ventral and two lateral) along its surface.

Fig. 87.—Diagrammatic Transverse Section of Ascaris Megalocephala. (*Ad nat.*)



The mouth is at the anterior end, surrounded by a dorsal and two lateral lips which bear sense-papillæ, probably tactile. The anus is a little distance from the posterior end on the ventral surface. Some little way behind the mouth is a minute median ventral pore, the excretory opening. On dissection we find a definite body-cavity* in which lie freely the alimentary and reproductive organs. The mouth leads into a *pharynx* with muscular walls lined by chitin. The suctorial pharynx opens into a long *intestine* terminating in the *anus*. The intestinal epithelium is said to secrete on both surfaces a delicate *cuticle*.

---

* This cavity may be a modified cœlom or may be an archicœle : the structure of the excretory organs points to the latter.

**Integumentary.** The outer surface of the body is covered by a thick cuticle, underneath which is a layer of *ectoderm* in which the cell-walls are said to be absent. This ectoderm is thickened in the mid-dorsal, mid-ventral, and the two lateral lines, corresponding to the four external lines. **Motor.** Below the ectoderm is a single layer of longitudinal muscle-cells, divided into four sections by the four ridges of ectoderm. Each muscle-cell has an outer muscular part with longitudinal striation and an inner protoplasmic part with a nucleus. As in *Hydra*, only a portion of the muscle-cell is differentiated into contractile tissue.

**Nervous.** The nervous and excretory systems are best seen in sections. The former consists of a nerve-ring round the front of the pharynx which is thickened dorsally and ventrally. Six small nerves run forwards and six others run backwards. Of these the four lateral soon become very thin, but the dorsal and ventral run the whole length of the body, embedded in the ectodermal ridges. They are connected by alternate lateral commissures.

**Excretory.** In the lateral ectodermal ridges there runs a pair of excretory ducts which apparently end blindly behind, but meet in front to open by the median ventral pore a little behind the mouth.

The male sexual organs consist of a single long coiled tube. The blind and tapering end forms the *testis*, the middle part the *vas deferens*, and the lower part swells out to form the *seminal vesicle.* This opens by a small duct into the intestine close to the anus. A small *setal gland* secretes the anal setæ. The female organs consist of a pair of long coiled tubes. The inner part of each forms the *ovary*, the middle portion the *oviduct* which swells out to form the *uterus.* The two uteri join in a common *vagina* to open to the exterior by a median ventral opening towards the *anterior* end of the body.

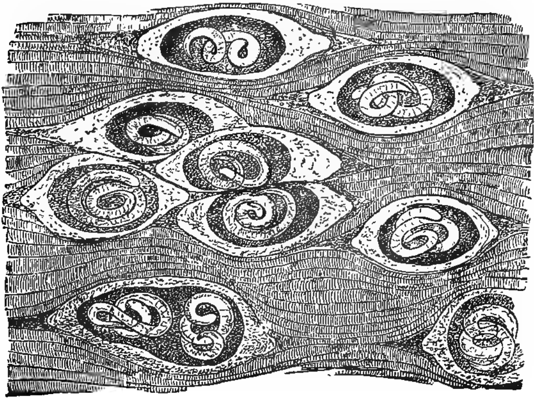
**Development.** The fecundity is enormous, many thousands of fertilised and encapsuled eggs being discharged daily from the uteri. These pass out of the body of the host, but their subsequent history is unknown. It is said that, as in the case of liver-rot, the maw-worm is acquired by feeding on damp pasture.

*Ascaris* is a fair type of the numerous NEMATODA or threadworms which infest the body of the higher animals. Its characters belonging to the class are the unsegmented body, the absence of appendages and the characters of the body-wall, excretory and reproductive systems.

## PHYLUM NEMATHELMINTHES.

This phylum contains a great number of free and parasitic worms forming the class *Nematoda*, and another divergent class of parasitic worm called *Acanthocephala*. The latter have a hooked anterior process and no alimentary canal, showing a complete adaptation to enteric parasitism, but the former show few similar modifications. Some appear to be only occasionally parasitic and some are entirely free. *Trichina spiralis* infests the pig, the muscles of this animal with encapsuled *Trichina* being known as *trichinosed* pork. Introduced into the human subject, they give rise to *trichinosis*. The *Filaridæ* also produce dangerous diseases, and the eel-worms or *Anguillulidæ* cause great destruction to crops.

Fig. 88.—MAGNIFIED VIEW OF "TRICHINOSED" PORK. THE NEMATODE WORMS (TRICHINA SPIRALIS) ARE SEEN ENVELOPED IN THEIR CAPSULES.



# CHAPTER XV.

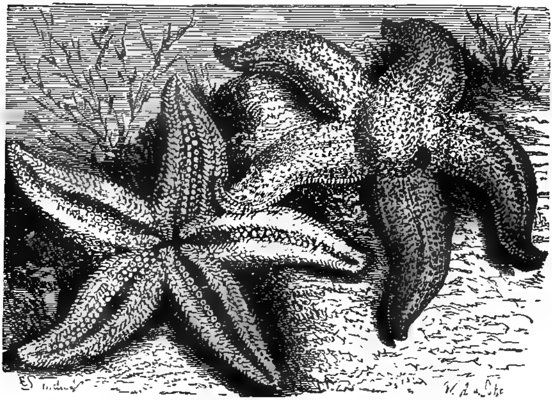
## *ARCHICŒLOMATA.*

ASTERIAS. BALANOGLOSSUS. LOPHOPUS. SAGITTA. WALDHEIMIA.

## I.—ASTERIAS.

| | |
|---|---|
| PHYLUM | ARCHICŒLOMATA. |
| SUB-PHYLUM | ECHINODERMATA. |
| CLASS | ASTEROIDEA. |

Fig. 89.—ASTERIAS RUBENS × ¼.

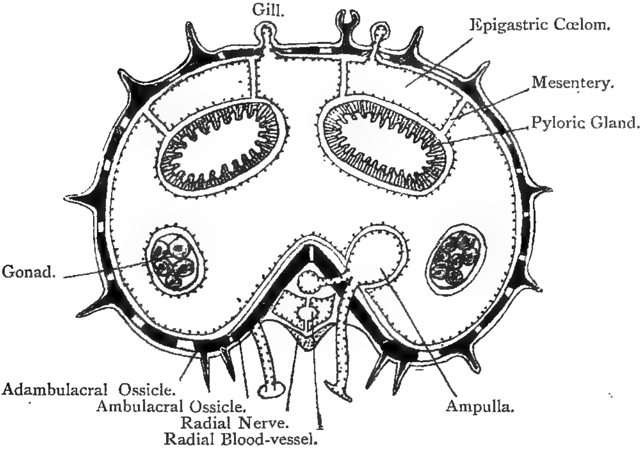


On the left the oral surface is seen with the five ambulacral grooves and tube-feet ; on the right is the aboral surface with the madreporite between the two lower arms.

**External Features.**

**Asterias rubens** (the starfish) is one of the commonest marine littoral animals. The body is of a dull yellow-red colour, flattened and produced into five equal-sized arms. This gives an external appearance of axial symmetry, but it will be seen that it is really plano-symmetric. For purposes of description, the five axes of the arms are termed *radii* and the five radii between them are called the *inter-radii.* In the middle of the upper surface is a minute aperture, the *anus*, and placed eccentrically in one inter-radius is a round, slightly convex, perforated plate called the *madreporite*. The line drawn through anus and madreporite and continued on either side gives the direction of the perpendicular plane of symmetry. The whole upper surface of the body is covered with a scattered mass of *ossicles*, calcareous nodules which can be seen and felt *through* the extremely thin and delicate *ectoderm*.

Fig. 90.—TRANSVERSE SECTION OF THE ARM OF ASTERIAS RUBENS. (Diagrammatic.)



The general cavity is the hypogastric cœlom.

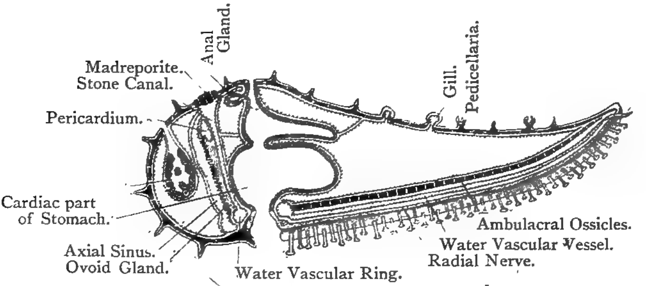
On the under or oral side of the starfish the *mouth* is situated in the centre. Along the centre of each arm there runs a deep groove, the *ambulacral groove*. This is filled with two double rows of *ambulacra* or tube-feet, a number of small processes terminating in suckers. They form the locomotive organs of the animal. If the double rows be pressed aside from the middle line, there can be seen a delicate *radial* nerve in the middle of the groove. Further, if the tube-feet be cut away it will be noticed that they really emerge from small holes between the *ambulacral ossicles* arranged in a row on each side. These ossicles form the walls of the grooves. At the edges of the grooves are rows of calcareous spines, and a few extra large ones, the *oral spines*, project inter-radially or towards the mouth. At the tip of each arm is a small *eye-spot*.

If the upper surface be entirely removed the alimentary organs are brought into view. The mouth leads into a

**Alimentary.**

spacious *cardiac* part of the stomach which is radially lobed. A constriction leads into the *pyloric* portion which is pentagonal in shape, the angles projecting radially. From each angle there runs a duct which bifurcates into two long *pyloric glands* in each arm. The intestine is very short and has a pair of small branched *anal glands*. It will easily be seen that the pyloric glands are attached to the aboral wall by paired mesenteries, and that the cardiac part of the stomach is attached to the oral wall by *retractor* muscles. The cardiac portion is often protruded (*e.g.*, into oyster-shells) and prey is obtained in this way. The pyloric glands are said to be digestive in function and the anal glands mainly excretory.

Fig. 91.—MEDIAN LONGITUDINAL SECTION THROUGH THE STARFISH IN THE PLANE OF ITS SYMMETRY.



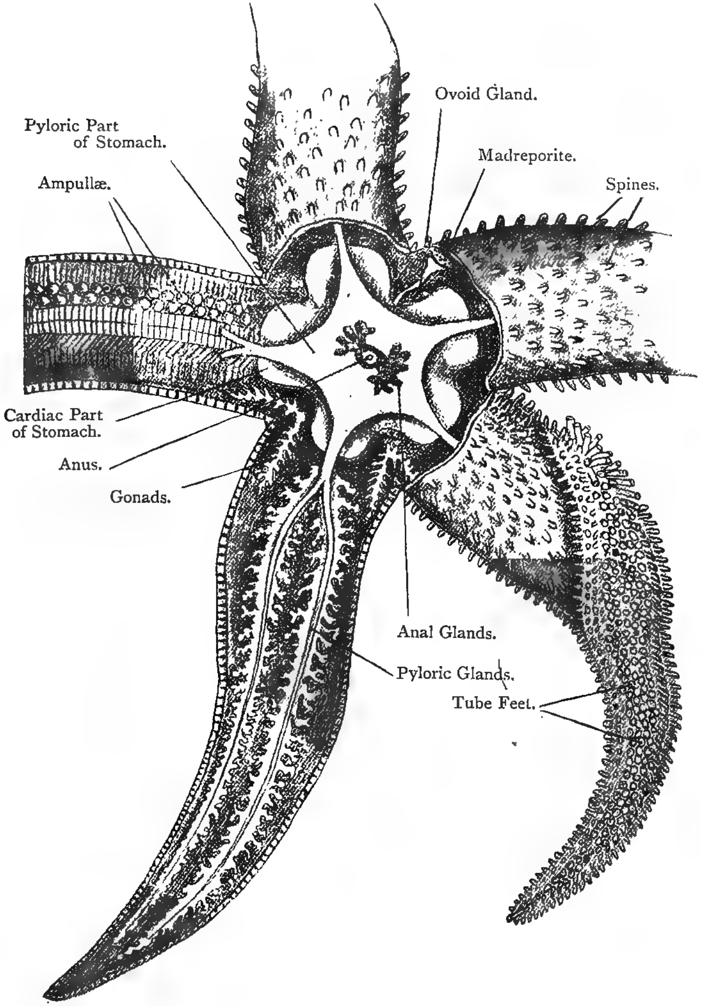
(If *exactly* median the section would cut the median mesentery and not the gonad.)

The cœlom is spacious and is cut into during dissection.

**Vascular.**

It is divided into several separate parts. The most important is (1) the water-vascular system (or ambulacral system). This is a part of the cœlom in which is concentrated the motor function found elsewhere

Fig. 92.—ABORAL DISSECTION OF A COMMON STARFISH. (*Ad nat.*)

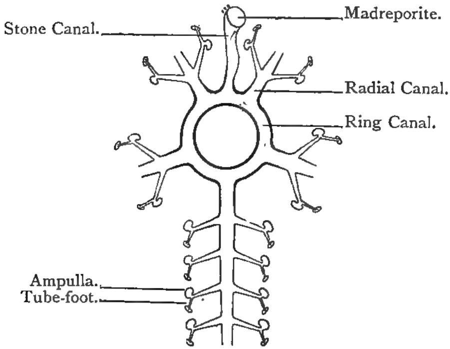


The lower right arm is turned over to show the oral surface; the lower left arm has its aboral wall removed and the upper left arm has the pyloric glands removed.

(*e.g.*, *Arenicola*) as a general feature of the whole cœlom. It consists mainly of a ring-canal round the mouth, five radial vessels just below the heads of the ambulacral ossicles, and a single inter-radial *stone-canal* running in the median mesentery to the madreporite, through which it communicates with the exterior. Each radial canal gives off paired

Fig. 93.—DIAGRAM OF THE WATER-VASCULAR SYSTEM OF THE COMMON STARFISH.

(Altered from GEGENBAUR.)



lateral canals which lead to the round vesicles or *ampullæ* seen as a double row on the inside of the ambulacral ossicles. These ampullæ communicate with the tube-feet, which, as noticed before, protrude into the ambulacral groove, between the ambulacral ossicles. The walls of this system are muscular, and it works as a hydraulic system by means of the tube-feet.

The rest of the cœlom is formed by (2) a large and spacious cavity, the *hypogastric* cavity, surrounding the lower part of the stomach, produced into the arms and forming a median mesentery in the madreporic inter-radius. (3) Aboral to this, lying on the stomach and produced into each arm along the aboral surface of the pyloric glands, is the *epigastric* cavity. Its walls form, with those of the hypogastric cavity, the two mesenteries along each hepatic cæcum. The hypogastric cavity is produced along the oral surface of each arm, inside the radial nerve, to form a pair of perihæmal cavities. The inner walls of these cavities form a median mesentery, in which is contained the radial blood-vessel. (4) Alongside of the stone-canal and opening into the madreporite is a long but small cavity called the *axial sinus.* Part of its wall appears to form the so-called *ovoid gland.*

The walls of the cœlom form muscles and the paired gonads which are situated inter-radially, opening dorsally to the exterior by fine pores. Scattered over the aboral surface are pores through which the cœlomic wall protrudes, as small vesicles or *branchiæ.* The blood-vascular system of the starfish is represented, as in *Balanoglossus*, by sinuses in the mesenteries and possibly by a central heart.

The radial nerves are connected with a nerve-ring round the mouth. Throughout its course the nervous system is an integral part of the ectoderm. An aboral nervous system has also been described.

**Development.**

The eggs are fertilised in the water ; segmentation is total and equal, producing a blastula and gastrula larva. The gastrula is further differentiated into a free-swimming pelagic *Bipinnaria.* This larva has a pre-oral and a post-oral ciliated band coiling over the surface of the body, and is *perfectly* plano-symmetric. Its mesoderm is early segmented into five principal parts, one pre-oral and two post-oral pairs. The adult grows like a large wart on the left side of the larva.

This development is important, for it shows that the apparently axo-symmetric *Echinodermata* are descended from plano-symmetric forms, with an archimeric segmentation like that of the other *Archicœlomata.*

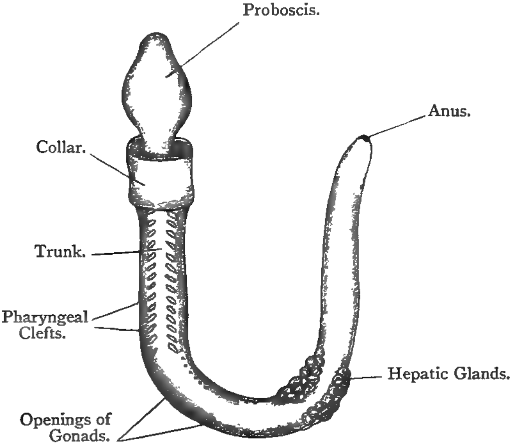
## II.—BALANOGLOSSUS.

| | |
|---|---|
| PHYLUM | ARCHICŒLOMATA (p. 170). |
| SUB-PHYLUM | ARCHICHORDA (p. 171). |

**External Features.**

**Balanoglossus** is a long worm-like animal of a burrowing habit. It has the body divided into three segments. The anterior, or *proboscis*, lies in front of the mouth (or is pre-oral) and can be expanded or contracted at the will of the animal. The second segment or *collar* encircles the body immediately behind the *mouth* which is in the median ventral line. The third part or *trunk* is long and forms the remainder of the body. At its extreme end opens the *anus.* In the constricted neck between proboscis and collar there open dorsally two small pores, the *proboscis pores*, which lead into the cavity of the proboscis. A similar pair of pores (the *collar pores*) lead out from the collar at its hind end. In the front region of the trunk, opening dorso-laterally into a long dorsal groove, there are two rows of small slits which open downwards into the alimentary canal. They are numerous and are known as the *pharyngeal clefts*. Lying outside the pharyngeal clefts, and also continued backwards behind them, are two rows of *genital pores*.

Fig. 94.—Semi-Diagrammatic View of Balanoglossus from the Dorsal Surface.



The ectoderm consists of a simple ciliated epithelium with unicellular mucous glands.

**Alimentary.**

The mouth leads into an elongated pharynx. The extreme anterior wall of this pharynx is pushed forwards into the proboscis as a diverticulum, the *sub-neural gland*.* The epithelial cells, forming the wall of this organ and that of the anterior part of the pharynx, are metamorphosed into *chordoid tissue* (see Chapter XXIV.). Their protoplasm is almost entirely replaced by vacuoles with walls and scattered nuclei, amongst which there may be small glands. This structure converts

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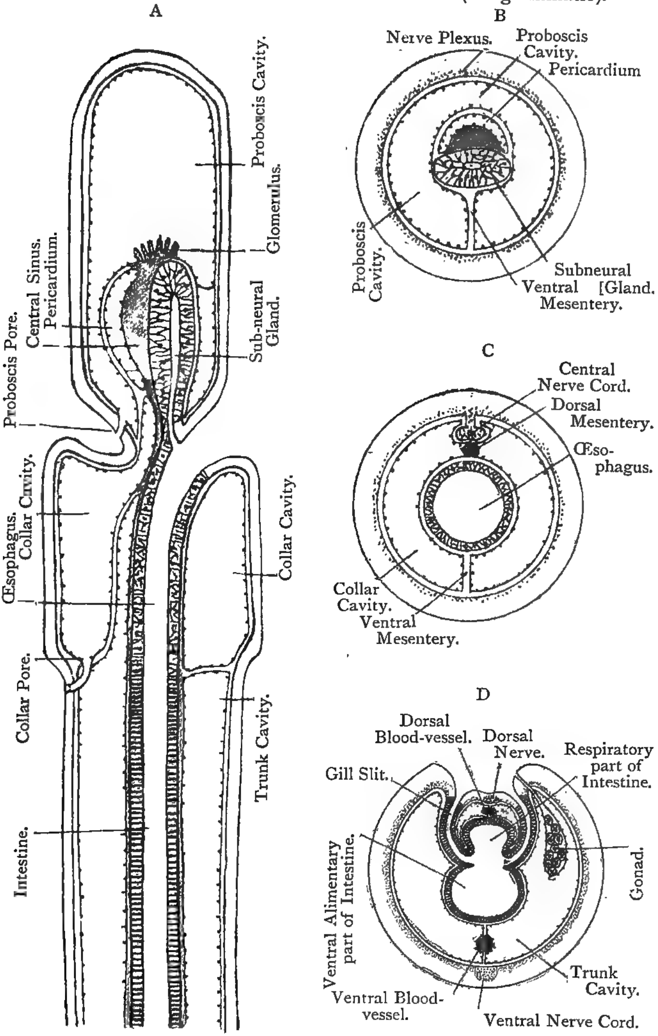
* This organ is also known as the "notochord" or "stomochord."

Fig. 95.—ANATOMY OF BALANOGLOSSUS (Diagrammatic).



A, Median sagittal section. B, Transverse section of proboscis. C, Transverse section of collar. D, Transverse section of trunk.

the pharyngeal wall into a stiff body. Hence the subneural gland serves to support the proboscis, and the pharyngeal wall with the mouth are permanently rigid and open. The posterior portion of the pharynx becomes almost divided into a dorsal and ventral part, each of which is ciliated. The pharyngeal clefts open into the dorsal portion, which is often called the respiratory part, the ventral being distinguished as the nutritive portion. Water, mud and nutritive particles pass in at the mouth through the pharynx. The water is said to pass out dorsally by the pharyngeal clefts The mud and food pass ventrally into the intestine in which digestion is effected. In many species numerous *hepatic glands* open dorsally into the intestine. The intestine runs to the end of the trunk and terminates in the *anus*.

**Cœlom.**

The external segments of the body are found to correspond to cavities of the mesoderm. The proboscis has a single cœlomic cavity, opening behind by a single or, in some cases, two *proboscis-pores*. The walls of the cavity form complex muscles for the movements of the proboscis.

In the collar there are paired cœlomic cavities separated by dorsal and ventral mesenteries which suspend the pharynx. Each opens to the exterior by a *collar-pore*. The trunk also has a pair of cavities with dorsal and ventral mesenteries. The walls form a well-developed system of *longitudinal muscles* and paired *gonads*. The trunk-cavities are produced forwards into the collar by two dorsal (or *perihæmal*) and two lateral (or *peripharyngeal*) processes. The cœlom is filled with a network of connective tissue.

**Nervous.**

The nervous system consists of a central nerve-mass in the dorsal region of the collar, a nerve-ring round the hind end of the collar, and a median dorsal and median ventral nerve along the trunk. Nerves pass forwards on to the proboscis.

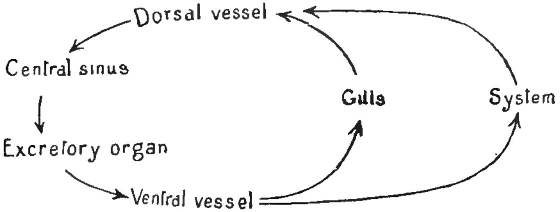
Except in the dorsal collar-region, the nerves are still parts of the ectoderm and are connected in all directions by a diffuse nerve-plexus.

The blood-vascular system consists of sinuses or vessels between the constituent layers of the dorsal and ventral

**Blood Vascular.**

mesenteries — the dorsal and ventral vessels. The dorsal vessel runs forward to the "central sinus" which lies just over the subneural gland — partly surrounded by the contractile *pericardium.* In its course through the trunk the dorsal vessel receives *efferent branchials* from the pharyngeal slits. The blood appears to leave the central sinus and pass forwards to a paired *glomerulus.* This is a glandular excretory organ formed from the wall of the proboscis-cœlom. From this it finds its way into the ventral vessel round the pharynx. The ventral vessel takes the blood back to the body.

The course of the blood is thus as follows :—



**Development.**—The sexes are separate and the sexual products are shed into the water. There are two types of development. In one there is a larval development with a free-swimming pelagic larva called *Tornaria;* in the other there is a *demersal* larva with direct development. The main facts in the direct development are as follows :—

1. Total equal segmentation to form blastula larva.
2. Invagination to form a ciliated gastrula which escapes from egg-membrane.
3. The hypoblast gives off five archenteric pouches to form the five segments of the mesoderm, one pre-oral and two pairs of post-oral segments. The exterior of the elongated larva becomes marked off into proboscis, collar and trunk.
4. Mouth and anus are broken through, the latter at the same spot as the closed blastopore.
5. The subneural gland grows forward from the front end of the pharynx and pharyngeal clefts appear.

The larva *Tornaria* is a transparent pelagic form with three complex ciliated bands, a pre-oral, a post-oral, and a peri-anal. The last is motor and the two former are mainly trophic. It has a complete alimentary system from the first and differs mainly from the demersal larva in the large size of the hæmocœle, the small mesodermic segments, the early formation of the pericardium and the presence of eye-spots. The pharynx of *Tornaria* appears to have paired chordoid areas (pleurochords) found in adult allies.

*Balanoglossus* is an important type of the *Archicœlomata* and is additionally interesting as having in its anatomy a foreshadowing of certain organs found in the *Chordata* (see *Chordata*).

It belongs to the *Archicœlomata*, chiefly because of its archimeric segmentation of the mesoderm and the *Archichorda* from the presence of chordoid structures and pharyngeal clefts.

## III.—LOPHOPUS.

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|---|---|
| PHYLUM | ARCHICŒLOMATA (p. 170). |
| SUB-PHYLUM | BRYOZOA (p. 177). |

**Lophopus** is a small freshwater organism common in rivers and streams. It is a colony of individuals or polypes which are embedded in a common gelatinous investment. The whole colony executes slow creeping movements.

Each individual has a crown of tentacles or *lophophore* which is in the form of a horseshoe. It bears a row of tentacles the whole way round the edge of the horseshoe, the row on the outer or convex edge being continuous round the ends with that on the inner or concave edge. A web unites the bases of the tentacles. In the centre of the horseshoe, between the rows of the tentacles, is situated the *mouth*. This is overhung by a small flap or process, the *epistome*, between it and the inner row of tentacles. In the concavity of the lophophore, and hence *outside* the tentacles, opens the *anus*. When undisturbed, the animal spreads the tentacles apart and the cilia covering them cause currents with food-particles to pass towards the mouth. On stimulation the polype retracts itself and the tentacles are withdrawn.

In the interior of the animal we find that the mouth leads to an œsophagus and a lobular stomach, from which the intestine runs forward to the anus. The whole alimentary canal is therefore flexed into a **U**.

The ectoderm is simple and secretes the gelatinous investment. Between it and the alimentary canal is the spacious cœlom lined by mesoderm. In the epistome is a pre-oral portion, the epistomial cavity, which communicates on either side with a lophophoral cavity produced out into each arm of the horseshoe and separated from the spacious trunk-cavity by a *transverse septum*. The trunk-cavity is lined by a thin layer of mesoderm which extends over the alimentary canal and inside the ectoderm. At the aboral end it is differentiated into circular muscles called the *parietal* muscles. These on contraction compress the cœlomic fluid and force the oral part of the polype upwards. From the base of the stomach there runs a band or *funiculus* which attaches the alimentary canal to the aboral end and a *retractor* muscle runs beside it. The mesoderm upon the funiculus gives rise to testes and ovaries and the animal is *hermaphrodite*. The main nerve-ganglion lies between mouth and anus just under the epistome. It gives off a ring round the œsophagus and other branches.

In allied species the trunk-cœlom opens by paired ciliated canals to the exterior near the anus.

Fig. 96.—View of Entire Colony of Lophopus. (After Allman.)

*Lophopus* is an annual and dies down on the approach of winter. It produces, however, before this event, a number of encapsuled buds called *statoblasts* which give rise to a fresh colony in spring. These are not found in its marine allies. (See page 61.) The colony is produced by asexual budding from a single individual, hence metagenesis occurs as in hydroid zoophytes.

Many bryozoan colonies have a close superficial resemblance to the hydroid colonies, hence it should be noted that the bryozoan polype is a far more highly organised animal than the hydroid. The possession by the former of mesoderm and a cœlom and a definite nervous system may be specially emphasised.

## IV.—SAGITTA.

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|---|---|
| PHYLUM | ARCHICŒLOMATA (p. 170). |
| SUB-PHYLUM | CHÆTOGNATHA (p. 177). |

**Sagitta,** the arrow-worm, is a free-swimming pelagic animal of elongated body and may be about ¾ inch in length. It is one of the simplest and best types of the pelagic *nekton.* Its body is of a glassy transparency, cylindrical in transverse section and perfectly planosymmetric. The anterior end is formed into a head, with mouth surrounded by tufts of setæ or bristles which act as jaws. The posterior end bears a bifid caudal or tail-fin and two pairs of lateral fins protrude from the body.

Three parts of the body can be distinguished. The *head,* the elongated *trunk* and the *tail.* The mouth leads into a *pharynx,* which passes into a simple intestine, terminating in an *anus,* situated ventrally between trunk and tail. Corresponding with the three segments are the three mesodermic segments. The head segments have their walls largely modified into jaw-muscles; the trunk segments also form dorsal and ventral longitudinal muscles and a pair of spacious cœlomic cavities. The walls of these form dorsal and ventral mesenteries supporting the intestine. In the tail the segments are very similar, but as there is no intestine in this part the mesentery is continuous and median.

In the trunk the cœlomic walls form paired lateral *ovaries*; in the tail they form *testes.* Each of these lead, by paired oviducts and vasa deferentia respectively, to the exterior near the anus. The animal is therefore hermaphrodite. Transverse septa are found between the three segments.

The nervous system consists of a *dorsal brain* in the head with paired connectives round the neck to a large subœsophageal mass on the ventral surface of the trunk. The brain supplies nerves to a pair of simple eyes on the head and certain sense-papillæ.

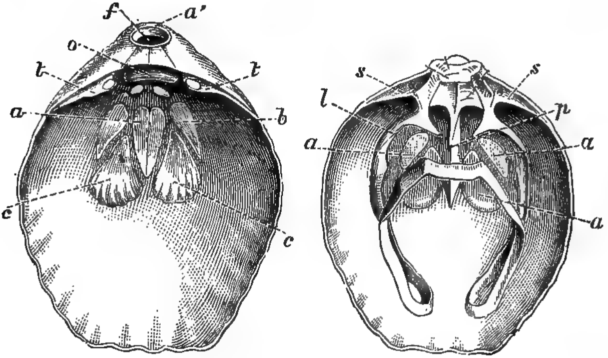
*Sagitta* reproduces only sexually. The eggs and larvæ are pelagic and transparent, though demersal eggs and larvæ are known in the sub-phylum.

## V.—WALDHEIMIA.

| | |
|---|---|
| PHYLUM | ARCHICŒLOMATA (p. 170). |
| SUB-PHYLUM | BRACHIOPODA (p. 177). |

**Waldheimia** is a small marine organism enveloped in two shells. They are roughly circular in outline and convex externally. The so-called *ventral* shell is produced behind the other or *dorsal* into a process. Through a hole in this process there projects a *peduncle* which fastens the animal to a foreign body, such as a rock. A side view of the two shells recalls the appearance of a Roman lamp, with the peduncle as a wick ; hence the *Brachiopoda* are sometimes termed *Lamp-shells.* The two shells are hinged upon each other at the posterior end (towards the peduncle) and can be widely opened anteriorly. The shells and the animal are plano-symmetric, about a perpendicular plane passing through the middle line of each shell. (The bivalve *Mollusca* are plano-symmetric, about a plane passing *between* the shells, which are therefore *right* and *left*, not dorsal and ventral.)

Fig. 97.—Ventral (A) and Dorsal (B) Shell of *Waldheimia Australis.* (After Davidson.)



A

B

*a*, Adductor.
*a'*, Apex.
*b*, Ventral Adjustor.
*c*, Divaricator.
*f*, Foramen.
*o*, Peduncular Muscles.
*t*, Teeth.

*a*, Adductor.
*l*, Loop.
*p*, Septum.
*s*, Socket.

Inside the dried dorsal shell can be seen a complex calcareous skeleton in the form of a twisted loop. The growth of the shell is like that of bivalves. The cavity inside the shells is lined by a soft double flap of the body called the *mantle*, enclosing the *mantle-cavity.* Its edge is fringed with *setæ.*

The most conspicuous part of the body is the *lophophore*, which consists of a pair of coiled arms carrying a great number of ciliated tentacles. A ridge lying dorsal to the mouth, the *epistome*, is continued round the lophophoral arms. The mouth leads into a short œsophagus, a swollen stomach, and a short intestine which ends blindly. There is a pair of large racemose *digestive glands*, with ducts leading into the stomach. The cœlom is spacious, and the same parts of the mesoderm can be recognised as in other *Archicœlomata*. Thus there is an unpaired epistomial cavity, a pair of lophophoral cavities and a large trunk-cavity partially divided up by a ventral mesentery and certain bands. The trunk-cavity opens by paired tubes or *nephridia* into the mantle-cavity. Its walls also form the muscles and the gonads. The muscles are numerous and well developed, mainly for moving the shells and peduncle. The gonads and the trunk-cavity spread into the mantle.

There seems a somewhat indefinite blood-system with a contractile *heart* situated dorsal to the stomach. The nervous system is a ring round the œsophagus with dorsal brain and ventral subœsophageal ganglia, which latter are the larger. Numerous nerves supply the parts of the body.

The sexes are separate and the development is larval. Most brachiopod larvæ are pelagic and have three segments.

## PHYLUM ARCHICŒLOMATA.

The five preceding types represent the five most important divisions of this diverse phylum. The phylum includes the most primitive and simplest representatives of the truly cœlomate animals. They are usually described as *unsegmented*, but there can be discerned in them, with more or less clearness, a primitive *archimeric* segmentation into three parts. The first is anterior to the mouth or pre-oral, and the other two are post-oral. They may be called the *protomere*, *mesomere*, and *opisthomere*. They are probably represented in the segmented worms by the *prostomium*, the *peristomium*, and the rest of the body respectively; hence these differ from the *Archicœlomata* in having the opisthomere divided into a great number of segments or *metameres*, or metamerically segmented.

In addition the *Archicœlomata* usually have a nervous system, often in continuity with the ectoderm, a dorsal brain, an œsophageal nerve-ring and usually a ventral pair of ganglia. The cœlom retains its primitive relationships and any of the segments may have ciliated tubes to the exterior. The vascular system, if present at all, is a series of hæmocœlic sinuses and the archimeric heart is, if present, dorsal to the alimentary canal.

All have more or less primitive methods of feeding; they are mostly pelagic, sedentary or burrowing, and are modified accordingly.

In their development there is, in the majority of cases, an equal segmentation, a blastula, gastrula and a pelagic larva; in fact, a typically larval development throughout. The cœlom in most cases arises by pouches from the hypoblast.

SUB-PHYLUM I.—ARCHICHORDA. — *Balanoglossus* is the burrowing vermiform representative of this sub-phylum, but there are also sedentary relatives. They have special interest as they appear to be allied to the ancestors of the metamerically segmented *Chordata.* Thus the sub-phylum shows a dorsal nervous system, pharyngeal clefts and chordoid portions of the pharynx. This relationship will be mentioned in the *Chordata.*

*Cephalodiscus* is a small deep-sea form which lives in sedentary communities. There is only a single pair of pharyngeal clefts and two pleurochords. Others approximate in habits to the *Polyzoa.*

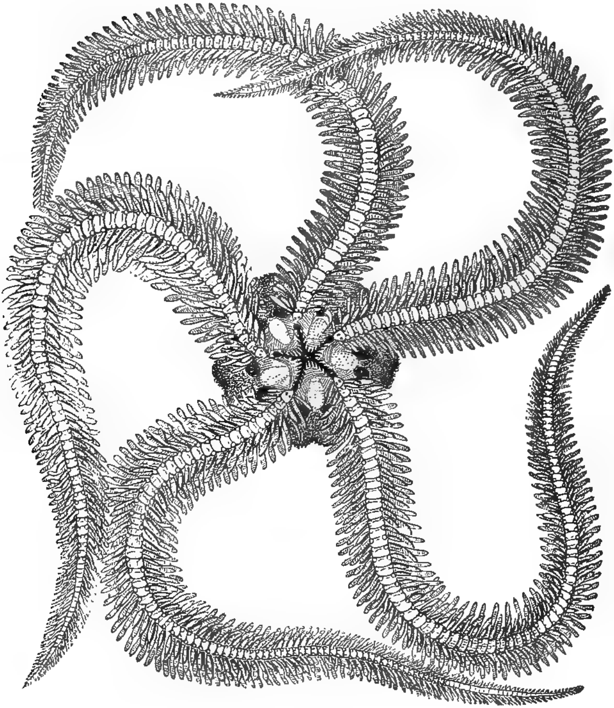
SUB-PHYLUM II.—ECHINODERMATA.—*Asterias* is a fair representative of this large sub-phylum. They all show plano-symmetric larvæ, which go through a metamorphosis into the adult. Their special features are the great development of a mesodermic calcareous skeleton and a modification of part of the cœlom into a water-vascular (or ambulacral) system. The larvæ show the archimeric segmentation of the *Archicœlomata.* The peculiar axial symmetry is usually supposed to be due to a sedentary or fixed habit in the past. Like most *Archicœlomata*, they are well represented in early epochs.

There are five classes of the *Echinodermata* :—

CLASS I.—*Asteroidea*, of which *Asterias* is a type.

CLASS II. — *Ophiuroidea* (the brittlestars).—These are five-rayed, but the arms are almost entirely filled by the enlarged ossicles and are sharply distinguished from the central disc. The greater flexibility of the arms enables them to be largely used as motor organs and the tube-feet are correspondingly reduced. There is no anus and the madreporite appears to have become shifted to the ventral surface. They differ in several other points from the *Asteroidea.*

Fig. 98.—A BRITTLESTAR (Natural size).



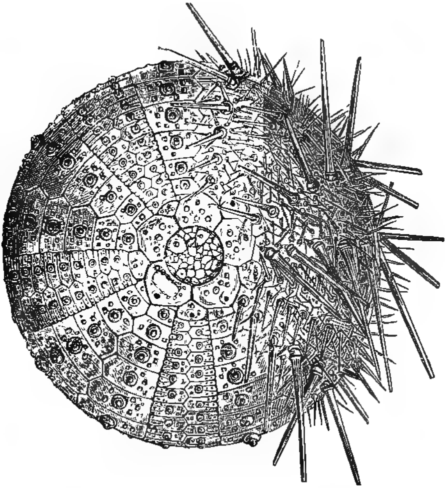
View of oral surface showing mouth and genital pores. Notice the jointed arms.

CLASS III.—*Echinoidea* (Sea-urchins).—These are spherical or oval in shape, and the calcareous skeleton forms a continuous mass of plates bearing spines. The anus opens at one pole and is surrounded by five *genital* plates which are inter-radial. One forms the madreporite and a genital opening is situated on each. Between these there lie the smaller *oculars*. They bear the simple eyes and are radials. From these ten plates there run down orally ten double rows of plates. Those below the oculars are called the *radials* or ambulacrals as they bear rows of tube-feet. Those between them are *inter-radials* or antambulacrals.

The mouth opens in the middle of a *buccal membrane* and is armed with five teeth. These are borne by a beautiful calcareous structure often called *Aristotle's lantern.*

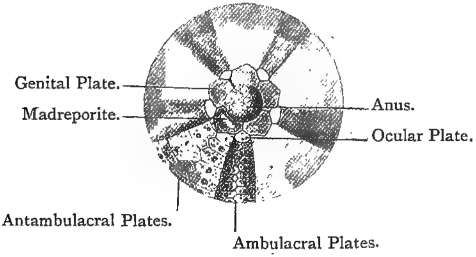
Fig. 99.—A COMMON SEA-URCHIN (*Echinus Microstoma*).

Natural size (After WYVILLE THOMSON).



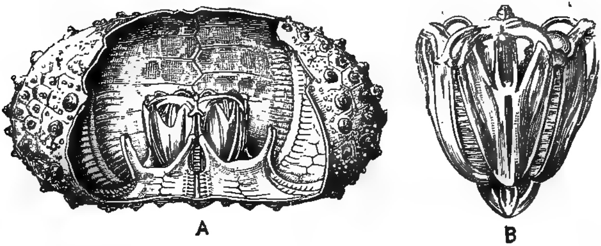
The animal is seen from the aboral surface, from the left half of which the spines have been removed. The plates can be identified from the next figure.

Fig. 100.—DIAGRAM OF DORSAL VIEW OF ECHINUS SHOWING THE PLATES.



In the sand-dwelling types, or Heart-urchins, such as *Spatangus*, there are no *lantern* nor *teeth*, and the body becomes planosymmetric.

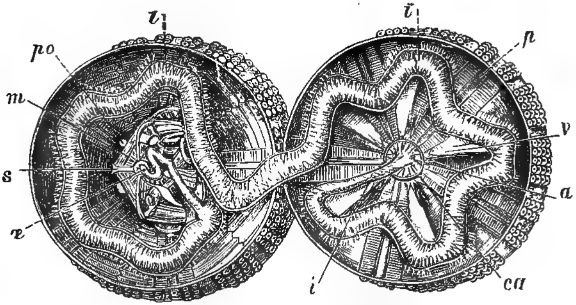
Fig. 101.—View of *Echinus Microstoma.*
(After Wyville Thomson.)



A, Internal View of the Skeleton showing Aristotle's Lantern in position.
B, Aristotle's Lantern or Dental Pyramid.

Class IV.—*Crinoidea.*—The Crinoids have five jointed arms which bifurcate at the base, forming ten. Each has a number of pinnæ or small processes containing the gonads. The crinoids are fixed by a long stalk or axis to the sea-floor either throughout life or for the earlier part of it. They are known as the stone-lilies and are mostly deep-sea forms.

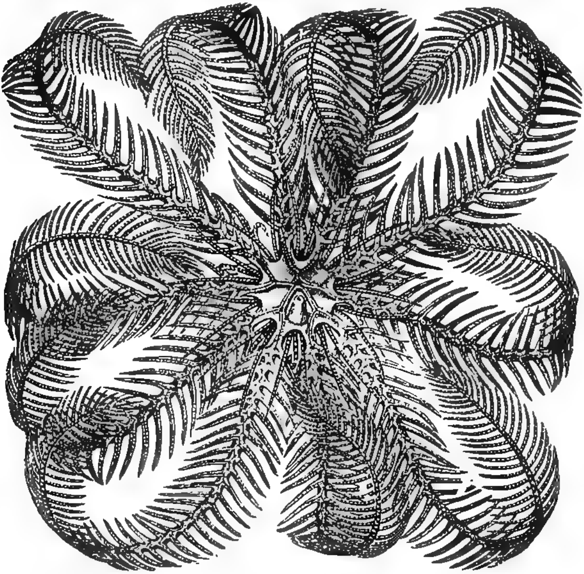
Fig. 102.—View of Interior of Bisected Sea-Urchin (*Echinus Lividus*).
Note the long coiled intestine suspended to the body-wall by mesentery.



*æ*, Gullet.
*l*, First coil of intestine.
*m*, A jaw-muscle.
*po*, Cut end of a radial vessel.
*s*, Part of the dental pyramid.
*a*, Anus.
*ca*, Ocular plate.
*i*, Intestine.
*l*, Second coil of intestine.
*p*, Radial water-vascular vessel.
*v*, Ovary.

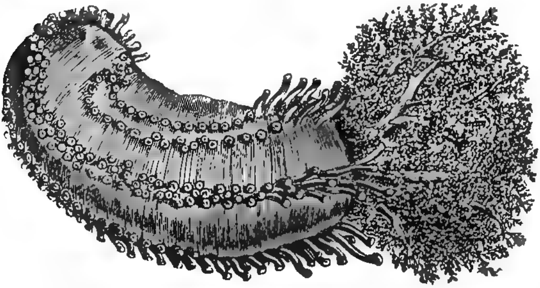
Class V.—*Holothuroidea* (the Sea-Cucumbers).—These have the body elongated in an oral-aboral direction, in some cases simulating a "worm." The ambulacra run in five rows down the sides of the body and, in addition, there is a ring of branching tentacles round the mouth. They have scattered calcareous spicules in the body-wall which give it a tough but flexible consistency.

Fig. 103.—The Rosy Featherstar *(Antedon Rosacea)*.



Natural size. View of oral surface. The ten arms are pinnate, and from their bases pass five ciliated grooves to the mouth in the centre of the disc. The anus is situated on an inter-radial papilla (seen below the mouth in the figure).

Fig. 104.—A Holothurian *(Cucumaria Planci)* × 2.



Note the oral tentacles and the elongated body with five rows of tube-feet.

## SUB-PHYLUM ECHINODERMATA.

1. Cœlomate metazoa with pentamerous axial (radial) symmetry.
2. A calcareous mesodermic skeleton.
3. A well-developed cœlom, part of which forms a water-vascular system, mainly locomotive.
4. Develop from pelagic larvæ with bilateral symmetry.
5. Marine.

| Class I.<br>ASTEROIDEA.<br>*Type—Asterias.* | Class II.<br>OPHIUROIDEA.<br>*Type—Amphiura.* | Class III.<br>ECHINOIDEA.<br>*Type—Echinus.* | Class IV.<br>CRINOIDEA.<br>*Type—Antedon.* | Class V.<br>HOLOTHUROIDEA.<br>*Type—Cucumaria.* |
|---|---|---|---|---|
| 1. Flattened dorso-ventrally with five or more arms. | 1 Flattened dorso-ventrally with five arms and central disc. | 1. Round or globular. | 1. Disc with branched arms and a dorsal stalk. | 1. Elongated dorso-ventrally. |
| 2. Ambulacra in ventral grooves of the arms. | 2. Ambulacra lateral and no ventral groove. | 2. Ambulacra in five rows down the body. | 2. Ambulacra mainly sensory tentacles. | 2. Ambulacra in five rows down body, and tentacles round the mouth. |
| 3. Cœlom and hepatic cæca continued into arms. | 3 Arms nearly filled with large ambulacral ossicles. | 3. No arms. | 3. Arms jointed and bearing lateral pinnules. | 3. No arms. |
| 4. Madreporite dorsal. | 4. Madreporite ventral. | 4. Madreporite dorsal. | 4. No true madreporite. | 4. No madreporite, stone canal opens into cœlom. |
| 5. Anus dorsal. | 5. No anus. | 5. Anus dorsal. | 5. Anus ventral. | 5. Anus dorsal. |
| 6. Gonads at base of arms and inter-radial, open dorsally. | 6. Gonads in central disc and inter-radial, open ventrally. | 6. Gonads inter-radial, open dorsally. | 6. Gonads in pinnules. | 6. Single gonads open ventrally near mouth. |
| 7. Scattered calcareous skeleton with spines. | 7. Dense calcareous skeleton with spines. | 7. Continuous skeleton with spines. | 7 Jointed skeleton. | 7. Spicular skeleton. |
| 8. Larva *bipinnaria*. | 8. Larva *pluteus*. | 8. Larva *pluteus*. | 8. Oval larva with no mouth, and five ciliated bands. | 8. Larva *auricularia*. |

SUB-PHYLUM III.—BRYOZOA.—The *Bryozoa* are marine and freshwater colonial forms. They are all practically sedentary and in many types there is great physiological division of labour, some polypes degenerating into mere vibratile processes or snapping pincers.

The class *Phylactolœmata* (with horseshoe-shaped lophophore) are all freshwater types and the polypes are better developed.

The *Gymnolœmata* (with circular lophophore) are nearly all marine and have more modified polypes. Their skeletons may be calcareous or chitinous and are, as in the case of the hydroid zoophytes, constructed upon the same principles of branching as plants.

SUB-PHYLUM IV.—CHÆTOGNATHA.—This is a small group for *Sagitta* and its allies. *Sagitta* is practically typical of the sub-phylum. It is important, showing the possibilities in the *Archicœlomata* of an active progressive type.

SUB-PHYLUM V.—BRACHIOPODA.—These are like *Waldheimia*, all two-shelled, and are divided into the hinged and those without hinges. They are like the rest of the *Archicœlomata* of ancient origin and some types, such as *Lingula*, with a long peduncle used as a motor organ, appear to have remained constant in structure from the earliest geological times.

## PHYLUM ARCHICŒLOMATA.

1. Cœlomate tridermic metazoa with plano-symmetry.
2. No metameric segmentation, but a distinct archimeric segmentation into three parts.
3. Cœlom well developed and divided more or less into parts corresponding with the segmentation.
4. Nervous system simple, with dorsal brain, circumœsophageal ring and cords, often retaining its connection with the ectoderm.
5. A simple blood-vascular system of hæmocœlic sinuses.
6. Usually have a free larval pelagic development.
7. Mostly marine and pelagic, sedentary or burrowing.

## PHYLUM ARCHICŒLOMATA.

| Sub-Phylum I.<br>ECHINODERMATA. | Sub-Phylum II.<br>ARCHICHORDA. | Sub-Phylum III.<br>BRYOZOA. | Sub-Phylum IV.<br>BRACHIOPODA. | Sub-Phylum V.<br>CHÆTOGNATHA. |
|---|---|---|---|---|
| An axial symmetry superposed, body stellate. | Plano-symmetric, body worm-like. | Mainly plano-symmetric, compact, enclosed in zoœicum. | Plano-symmetric, body compact, enclosed in two shells. | Plano-symmetric, bod elongated. |
| Alimentary canal short and in shorter axis. | Alimentary canal in long axis and straight. | Alimentary canal **U**-shaped. | Alimentary canal **U**-shaped. | Alimentary canal straight. |
| Protomere vestigial, mesomere forms branched tentacles (ambulacra). | Protomere forms large proboscis, mesomere may have tentacles. | Protomere vestigial (epistome), mesomere with crown of tentacles (lophophore). | Protomere vestigial (epistome), mesomere with tentacles (lophophore). | Protomere forms head, no tentacles to mesomere. |
| A calcareous mesodermic skeleton. | A slight mesodermic skeleton of chondroid material. | An exoskeleton of chitin but no mesodermic skeleton. | A mesodermic skeleton of chondroid material and an exoskeleton of calcareous and chitinous shells. | No skeleton, but chitinous jaws. |
| Mainly creeping but some sedentary. | Creeping, gregarious or colonial. | Sedentary and colonial. | Sedentary but never colonial. | Free-swimming and pelagic. |

# CHAPTER XVI.

## *ANNULATA.*

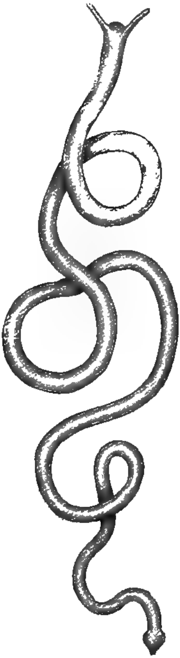
POLYGORDIUS. ARENICOLA. HIRUDO. LUMBRICUS.

## I.—POLYGORDIUS.

PHYLUM - ANNULATA (p. 237).
SUB-PHYLUM - ANNELIDA (p. 238).
CLASS - ARCHIANNELIDA (p. 239).

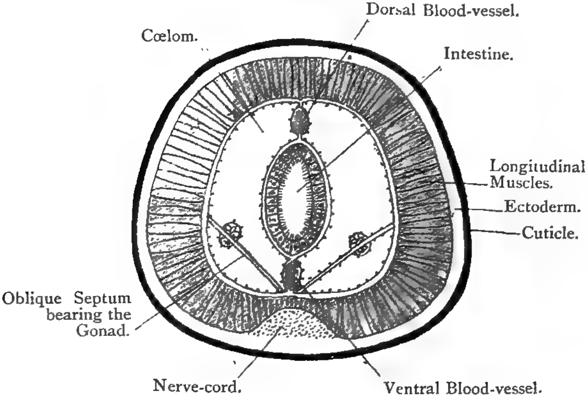
*Polygordius neapolitanus* is a small delicate marine (1½ inch) worm, of elongated body, found in the sand at moderate depths. It is of a pale pink hue. At the anterior end are a pair of small tentacles, the prostomial tentacles, covered with fine setæ. They are parts of the *prostomium*, a lobular process lying anterior and dorsal to the *mouth*. Immediately behind the mouth is the *peristomium*, a large and well-defined segment. The rest of the body is divided externally and internally into a series of segments. The terminal or anal segment is swollen and bears the *anus*. On its broadest part this segment bears a ring of papillæ. The mouth leads into an œsophagus which continues as a simple intestine terminating in the anus. The ectoderm is a simple epithelium with unicellular glands; it secretes a thin *cuticle*. Below it the mesoderm forms a well-developed system of longitudinal muscles. Inside them is the delicate cœlomic epithelium, lining a spacious cœlom. This is divided by dorsal and ventral mesenteries, in which are simple blood-vessels, and by transverse septa between each segment. Each segmental part of the cœlom opens by simple paired tubes (or *nephridia*) to the exterior. The nervous system is still part of the ectoderm. It consists of a brain in the prostomium,

Fig. 105.—POLYGORDIUS NEAPOLITANUS.



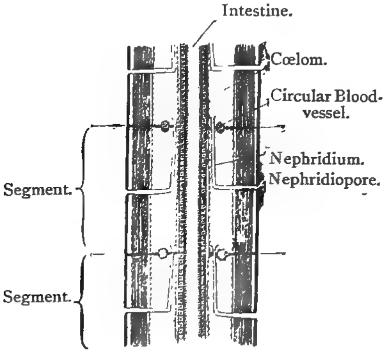
Entire animal seen from dorsal aspect × 5. (After FRAIPONT.)

Fig. 106.—Transverse Section of Polygordius, Semi-Diagrammatic. (After Fraipont.)



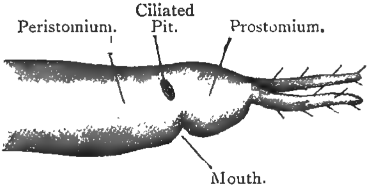
a ring round the œsophagus and a ventral nerve-cord, swollen into ganglia in each segment. Immediately behind the prostomium and placed laterally are a pair of ciliated pits which are probably sensory.

Fig. 107.—Coronal Longitudinal Section of Polygordius (Highly Magnified).



The sexes are separate and the testes and ovaries arise on two diagonal muscular bands intersecting the cœlom.

Fig. 108.—LATERAL VIEW OF FRONT END OF POLYGORDIUS. (After FRAIPONT.)



The sexual products escape by rupture of the body-wall. The following points in the development may be noted :—

1. Fertilisation external.
2. Total equal segmentation to form a *blastula.*
3. Invagination to form *gastrula* and closure of the blastopore.
4. Elongation of the larva and invagination of anterior œsophagus and posterior hind-gut, forming mouth and anus.
5. Production of *trochophore*, with three bands of cilia, pre-oral, post-oral and peri-anal, paired larval "kidneys" consisting of branching blind tubes opening externally, an apical plate, with pigment spot, and mesoblastic pole-cells laterally to the hind-gut.
6. Elongation and growth of the posterior region to form the body (except prostomium and peristomium) of the worm. Splitting and segmentation of the mesoblastic bands to form the cœlom, whilst the walls form muscles. Formation of nerve-cord from epiblast cells.
7. Loss of ciliated bands and pelagic habit. Growth of prostomial tentacles and nephridia. The young worm assumes the creeping burrowing habit of adult.

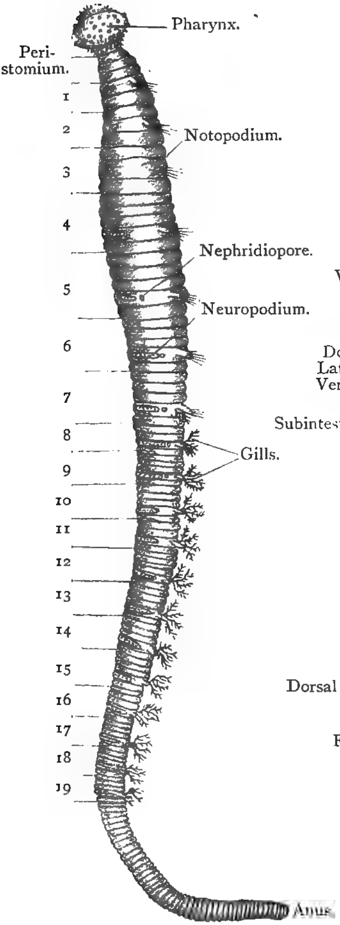
## II.—ARENICOLA.

| | |
|---|---|
| PHYLUM | ANNULATA (page 237). |
| SUB-PHYLUM | ANNELIDA (page 238). |
| CLASS | POLYCHÆTA (page 239). |

**Habits.**

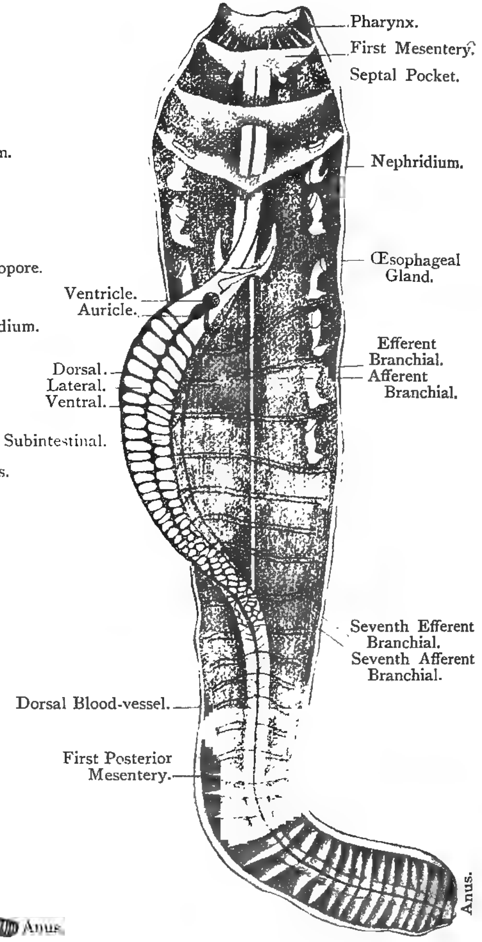
**Arenicola marina** is a worm, usually about 8 inches long, found very commonly burrowing in the sand between tide-marks. Its burrow is U-shaped, and from one to two feet in depth. At one end the sand is thrown up at the surface in small coils or casts, which have been ejected from the animal, whilst at the other end is a conical depression in the sand, below which rests the head of the worm. The burrow is lined with a mucous layer secreted by the skin.

Fig. 109.—LATERAL VIEW (LEFT SIDE) OF THE LOBWORM *(Arenicola Marina). (Ad nat.)*



The pharynx is protruded.

Fig. 110.—DISSECTION OF ARENICOLA. *(Ad nat.)*



The body-wall is cut down the median dorsal line and pinned down on each side.

The animal is plano-symmetric, with a *mouth* at the anterior and an *anus* at the posterior end. The *pharynx* is protrusible and is used by the animal for "rolling" sand and food into the alimentary canal. In the living animal its action may often be seen. It is covered with rough papillæ on its front part and with hooks further back.

**External Features.**

The body is differentiated by its structure into three portions:—

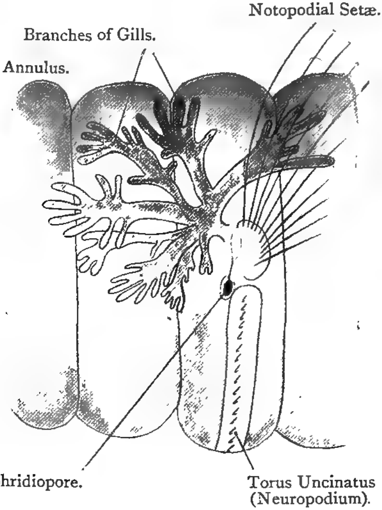
(1) The anterior region with appendages but no gills.
(2) The middle part with gills and appendages.
(3) The posterior region or tail with neither gills nor appendages.

The whole body is marked off by a great number of rings or *annuli*, but these should be carefully distinguished from the far less numerous *metameric segments.* In the greater part of the body there are five annuli to each segment. The number of segments, at least in (1) and (2), can be counted by enumeration of the appendages or the gills.

The class of *Polychæta* has each segment typically provided with a pair of lateral appendages, called feet or *parapodia*, and each parapodium usually has two parts—a dorsal portion or *notopodium* and a ventral part or *neuropodium.* Each part bears a tuft of *setæ* or *bristles.* In the active, swimming allies of *Arenicola* these feet are well developed, but in burrowing forms they tend to become reduced in size. Thus in *Arenicola* the notopodium is reduced to a small process with setæ, and the neuropodium to a long pad with a single row of short hook-shaped setæ. *Arenicola* has nineteen pairs of these appendages, and they are all similar except for the reduced size of the *neuropodium* in the first few segments. In the anterior region (1) the mouth is overhung by a small dorsal process, the *prostomium*, and immediately behind this is the *peristomium* which differs from the true segments in having no appendages. Then follow six true segments, each having appendages, and the last three of which have, just above the *neuropodium*, a minute excretory pore or *nephridiopore.*

The middle portion (2) has thirteen segments, each having a pair of appendages, and the first three also have nephridiopores. All bear gills (or *branchiæ*) which project dorso-laterally and are beautifully branched delicate organs of respiration. Through their thin walls the blood and outside water interchange carbonic acid and oxygen. The posterior part (3) consists of a great number (about 30) of compressed segments, on none of which are there any appendages or gills.

Fig. 111.—A Magnified Gill-Segment of Arenicola. (After Ashworth and Gamble.)



**Integumentary.** The body is covered by a fine but definite cuticle secreted by the simple underlying ectoderm in which there are unicellular glands.

If the animal be cut open down the median dorsal line the whole internal anatomy is exposed, for *Arenicola* is a cœlomate animal and all the internal organs lie in contact with the cœlom.

The cœlom is spacious, as in *Polygordius*, but it is not completely divided up into compartments. The front part

**Cœlom.** is divided by three transverse *septa*,* between the first, second, third and fourth segments, which

---

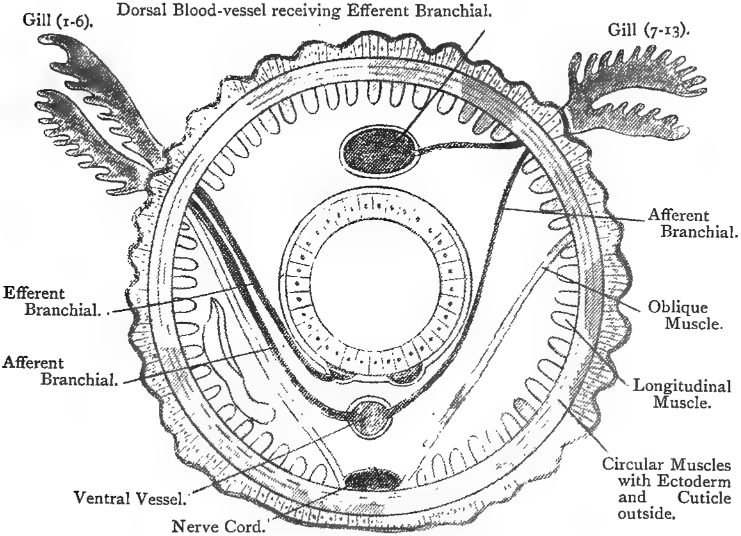
* The first septum has a pair of hollow *septal pockets* which are muscular, and probably assist in protrusion of the pharynx.

hold the front part of the alimentary canal in position. There is no dorsal nor ventral mesentery, but in the "tail" region, from segment 20 backwards, there are regular transverse septa. Hence the alimentary canal, from segment 4 to segment 19 inclusive, is free to move in the cœlom.

**Alimentary.**

The pharynx leads into a long *œsophagus* which widens out into the *stomach.* Just before the commencement of the latter there is a pair of *œsophageal glands* or pockets, the lumen of which opens into the œsophagus. They are probably digestive glands. The stomach is wide, and is covered with *yellow-cells*, intersected by a network or plexus of blood-vessels. At about the level of the seventh pair of gills the stomach passes into the *intestine* which terminates in an *anus.*

Fig. 112.—TRANSVERSE SECTION OF ARENICOLA (Diagrammatic).



On the left is seen the arrangement of the first six branchial segments; on the right the last seven.

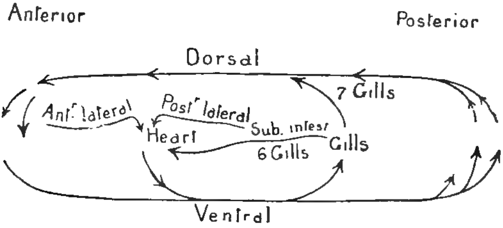
*Arenicola* is perpetually employed in passing quantities of sand and food-particles through its alimentary canal, digesting the latter and egesting the former.

**Blood Vascular.**

The blood-system is complex. The blood is respiratory in function and is said to contain hæmoglobin, giving it a red colour. The vessels lie between the cœlomic epithelium and the alimentary canal or the body-wall, as the case may be. Along the whole length of the alimentary canal runs a median *dorsal* vessel in which the blood runs forwards. It supplies branches to the alimentary canal throughout its course, and it receives ærated blood from the *last seven* pairs of gills by paired *efferent branchials.* Below the alimentary canal, but hanging free from it, runs the median *ventral* vessel. Its chief branches are thirteen pairs of *afferent branchials* taking blood *to* the gills and some to the nephridia. In this vessel the blood flows backwards, and it drains the regions of the alimentary canal supplied by the dorsal vessel. At the commencement of the stomach there are a pair of *hearts.* Each is two-chambered, consisting of an *auricle* and a *ventricle.* On contraction of the ventricles on each side the blood from the heart is driven into the ventral vessel.

Over the stomach is a plexus of vessels, of which we may discern the two *posterior lateral* vessels and two *subintestinals* in the ventral wall of the stomach.

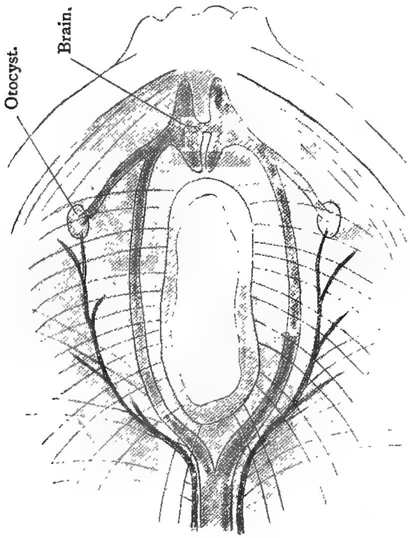
The subintestinals receive blood from the first six pairs of gills by six efferent branchials on each side. The subintestinals communicate through small vessels with the posterior laterals, which carry the blood forwards and, together with paired *œsophageals* on the œsophagus, fall on each side into the auricle of the heart. On contraction of the heart the blood is driven through the ventricles and thence into the ventral vessel. We may summarise this rather complex arrangement by a diagram—



It should be noticed (1) that the hearts are paired, two-chambered and independent in action; (2) that the hearts are not on the main outer circle formed by the dorsal and ventral vessels, but merely force blood into this current; (3) that the hearts pump blood to the gills and the body, and hence they are not definitely either respiratory or systemic.

Fig. 113.—VIEW OF NERVE-RING AND BRAIN OF ARENICOLA.

(After ASHWORTH and GAMBLE.)



Note the Œsophagus cut across leaving a hole round which the nerve-ring connects the brain with the ventral nerve-cord.

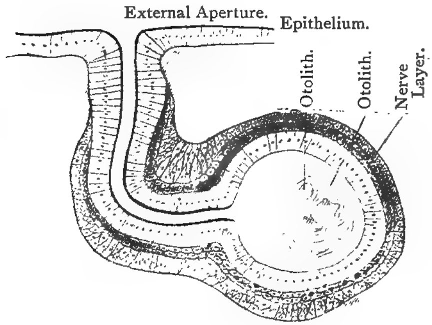
**Nervous.** The nervous system in *Arenicola* consists of a paired brain in the prostomium, a ring round the pharynx in the peristomium and a ventral nerve cord running in the median ventral wall of the body. There are no ganglia. *Arenicola* has no eyes but is endowed with

**Sensory.**

a pair of *otocysts*. These are situated laterally on the peristomium and are supplied by nerves from the brain. They consist of spherical sacs communicating with the exterior by fine ducts. The cells lining the sac are sensory and the cavity contains a number of loose concretions or *otoliths* which appear to be sand-grains.

Fig. 114.—Section through the Otocyst of Arenicola.

(After Ashworth and Gamble.)



On the prostomium is a ciliated pit called the *nuchal-organ*, a probable sense-organ allied to the paired ciliated pits of *Polygordius*. *Arenicola* has no prostomial tentacles, but the prostomium is produced into two *lobes* which are also probably sensory.

**Muscular.**

The muscular system is well developed and consists of a circular layer under the ectoderm and a longitudinal layer inside it. There are also diagonal fibres running from the lateral lines to the mid-ventral line.

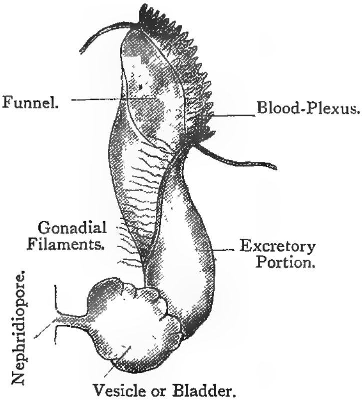
Nearly all the animals usually called "worms" move by the system of circular and longitudinal muscles. The body of the "worm" which contains cœlomic fluid acts much like an elongated bladder or sausage-skin filled with fluid. When the circular muscles contract they press on the cœlomic fluid which forces out each end and hence elongates the worm, reducing its calibre. When the longitudinal muscles contract the body is shortened, the cœlomic fluid at the same time forcing the walls outwards. Hence the alternate movements of the two muscular series enable the animal to lengthen or shorten its body, like a concertina. But this by itself would not effect movement of the whole body. Further provision is usually found in hooks, suckers, or setæ, which catch the ground or surrounding medium and prevent movement in *one* direction, usually backwards. By this means all the expansion or lengthening and shortening or contraction must take place forwards and progress is therefore rapid. We may emphasise in this arrangement the motor function performed by the cœlom and its fluid, which may be compared with the more specialised condition in the proboscis of *Balanoglossus* and the ambulacral system of *Asterias*.

**Excretory.**

The excretory organs consist of six pairs of *nephridia* (in segments 4 to 9 inclusive). These are wide tubes which open into the cœlom by large funnels or *nephrostomes* and to the exterior by small nephridiopores. A patch of cœlomic epithelium covering each of the nephridia, except the first, gives rise to the sexual elements, which lie free in the nutritive cœlomic fluid and pass to the exterior by the nephridia. *Arenicola* is diœcious and breeds in spring and summer. It develops by a free larval form allied to the trochophore.

Fig. 115.—A Nephridium of Arenicola.

(After Ashworth and Gamble.)



**Reproductive.**

[Table.

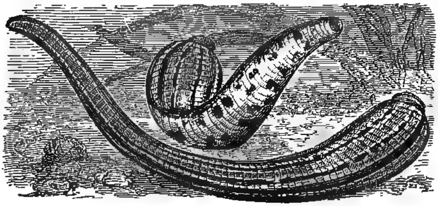
ARENICOLA.

| SEGMENTS. | APPENDAGES. | NERVOUS SYSTEM. | EXCRETORY SYSTEM. | APERTURES. | GILLS. |
|---|---|---|---|---|---|
| Prostomium. | | Brain. | | Mouth. | |
| Peristomium 1 | | Nerve ring. | | Otocyst. | |
| 2 | Parapodia. | | | | |
| 3 | " | | | | |
| 4 | " | | Nephridium 1 | Nephridiopore 1 | |
| 5 | " | | " 2 | | |
| 6 | " | | " 3 | " 2 | |
| 7 | " | | " 4 | " 3 | |
| 8 | " | | " 5 | " 4 | Gill 1 |
| 9 | " | | " 6 | " 5 | " 2 |
| 10 | " | | | " 6 | " 3 |
| 11 | " | | | | " 4 |
| 12 | " | Nerve cord. | | | " 5 |
| 13 | " | | | | " 6 |
| 14 | " | | | | " 7 |
| 15 | " | | | | " 8 |
| 16 | " | | | | " 9 |
| 17 | " | | | | " 10 |
| 18 | " | | | | " 11 |
| 19 | " | | | | " 12 |
| 20 | " | | | | " 13 |
| Tail, &c. | | | | Anus. | |

## III.—HIRUDO.

| | |
|---|---|
| PHYLUM - | ANNULATA (p. 237). |
| SUB-PHYLUM | ANNELIDA (p. 238). |
| CLASS - | HIRUDINEA (p. 239). |

Fig. 116.—THE MEDICINAL LEECH (*Hirudo medicinalis*).



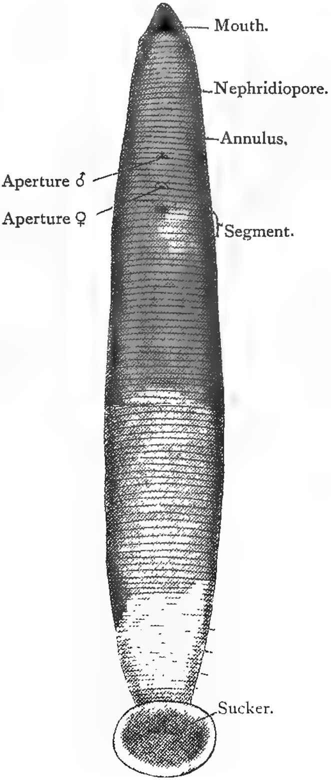
The more tapering end is anterior. The centre individual is seen in the action of swimming.

The common leech (*Hirudo medicinalis*) is an elongated, slightly-flattened worm of freshwater habitat. It is found commonly in ponds and is usually of a dark greenish tint with yellow lines and spots. The ventral surface is darker, sometimes black. Like *Arenicola*, it is plano-symmetric. The mouth is at the anterior end in the centre of a sucker. It is triangular and armed with three chitinous teeth. At the hind end is a large *posterior sucker* and the *anus* is situated *dorsal* to it.

**Habits.**

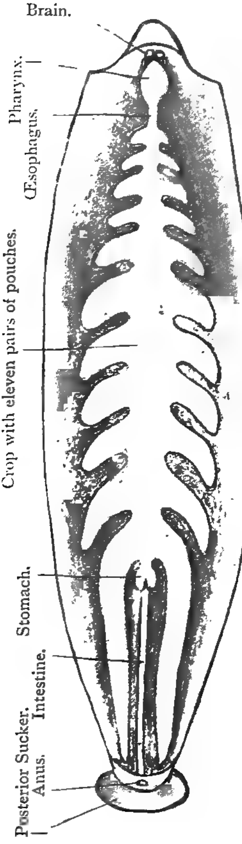
**External Features.**

Fig. 117.—VENTRAL VIEW OF THE LEECH. (Natural size.) (*Ad nat.*)



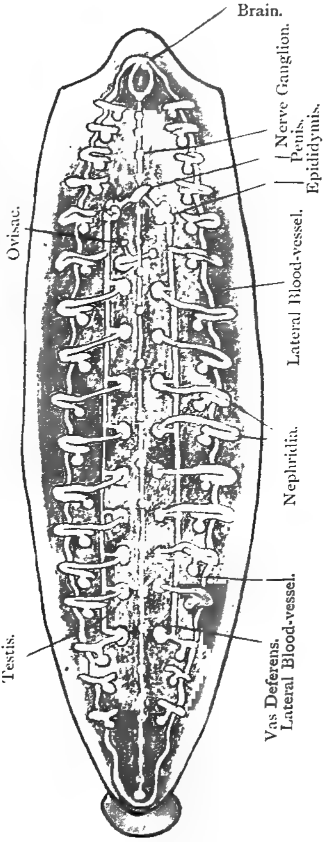
As in *Arenicola*, we can see a great number of *annuli* or rings, of which about five are contained in each true segment, but there is a marked absence of gills and appendages. *Hirudo* breathes by the skin and the suckers take the place of appendages in locomotion. The segments can be made out by the presence on the first annulus in each of paired rows of sense-organs. In this way there can be found twenty-six segments, and development indicates that the posterior sucker is formed from seven segments fused together. Hence the body of the leech consists of thirty-three segments.

Fig. 118.—FIRST DISSECTION OF LEECH (*Hirudo*).
(*Ad nat.*)



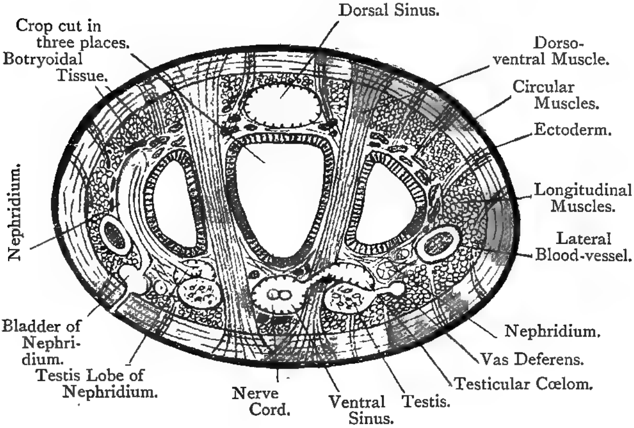
The body-wall is cut open along the mid dorsal line and pinned back.

Fig. 119.—SECOND DISSECTION OF LEECH (*Hirudo*).
(*Ad nat.*)



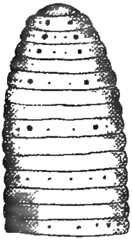
The alimentary canal is picked out, and the nervous, blood-vascular, genital and excretory organs are exposed.

Fig. 120.—TRANSVERSE SECTION THROUGH THE LEECH (*Hirudo medicinalis*). (Mainly after BOURNE.)



On the last annulus of each segment, from segment 6 to 22 inclusive, there open on the ventro-lateral line paired *nephridiopores.*

Fig. 121.—DORSAL VIEW OF THE ANTERIOR END OF A LEECH. (After WHITMAN.)



The small dots are the sense-organs, of which five pairs are large and formed into eyes.

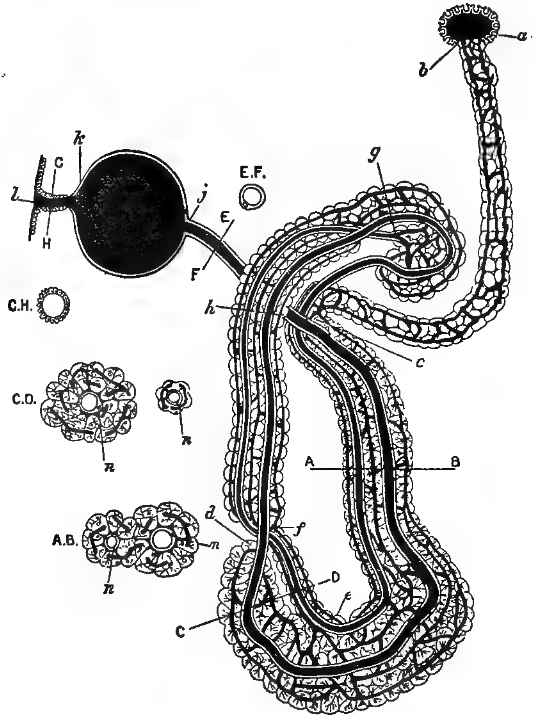
**Integumentary.**

On the first five segments one of the sense-organs on each side is enlarged into an eye; thus there are five pairs of eyes. In the median ventral line the unpaired male genital aperture is found in segment 10 and the female in segment 11. The body is flexible and is enveloped in a thin cuticle secreted by the simple ectoderm.

**Alimentary.**

The mouth leads into a sucking *pharynx*, the walls of which contain unicellular salivary glands and can be pulled out by radiating muscles. A short *œsophagus* connects it with the *crop.* This is a thin-walled but spacious sac which extends laterally as eleven pairs of pockets, of which the eleventh is the longest. The crop opens into a small bilobed *stomach* and from this the *intestine* passes to the anus.

Fig. 122.—A NEPHRIDIUM OF THE LEECH.
(After BOURNE.)



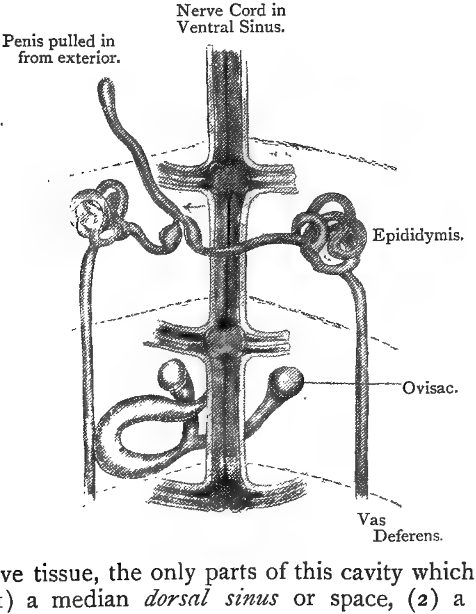
*a*, The funnel; *l*, the nephridiopore; *k*, the bladder; *c*—*h*, various parts of the excretory portion. The cross lines AB, CD, EF and GH indicate the cross-sections shown on the left.

The three jaws rasp a hole in the skin of the victim; the pharynx sucks the blood and passes it into the crop (the saliva is said to delay clotting of the blood). From the crop the blood is slowly passed into the stomach and digested as required.

**Cœlom**

The student will have noticed already in cutting open the leech (by a dorsal incision) that the interior is very different from that of *Arenicola*. There is no spacious cœlomic cavity; the organs have to be picked out and the skin peeled off. This is due to the fact that the cœlom is filled up almost entirely by connective tissue, the only parts of this cavity which are left being (1) a median *dorsal sinus* or space, (2) a median *ventral sinus* surrounding the nerve-cord, and (3) a few small spaces lying immediately over the testes.

Fig. 123.—Magnified View of Two Consecutive Segments of the Leech (10th and 11th). (*Ad nat.*)



**Blood-Vascular.**

The blood-vascular system is complex and the blood-vessels have definite walls. There are two main *lateral* vessels which give off numerous smaller branches. These communicate with a complex system of fine vessels called the *botryoidal tissue.* Through the medium of this tissue the blood-vascular and cœlomic systems are said to communicate.

**Nervous.**

The nervous system is on the annelid plan, but somewhat concentrated. A double brain lies on the pharynx, from which there passes a pair of commissures round the pharynx, meeting below to form the double ventral nerve-cord along the body. On this cord there are twenty-three ganglia which are segmentally arranged. The first is larger than the rest and forms a subœsophageal mass consisting probably of *five fused ganglia.* The last, supplying the sucker, is said to contain *seven fused ganglia,* the sucker itself being supposed to represent seven fused segments.

**Muscular.**

The muscles consist of powerful circular and longitudinal series and a number of dorso-ventral muscles as well. The leech not only progresses by its suckers, but it can swim rapidly by undulating motion of the whole body. (See Fig. 116.)

**Excretory.**

There are seventeen pairs of nephridia found in segments 6 to 22 inclusive. A typical nephridum has (1) an internal branched but *closed* funnel which rests in a small cavity of the cœlom, (2) a much-coiled excretory portion with a ciliated duct, and (3) a bladder or vesicle opening to the exterior by the nephridiopore. The first four nephridia are without the funnel.

The leech is hermaphrodite and the male organs are segmented. They consist of nine pairs of *testes* in segments 12 to 20 inclusive. Each opens inwards by a *vas efferens* into a *vas deferens* on each side. These are coiled into *epididymes* in segment 10 and then unite and pass down the *penis;* at the base of the penis is a small *prostate gland.*

The female organs are in segment 11 and are formed by paired *ovisacs,* containing in their cavities the *ovaries,* which unite to form an *oviduct* swollen at its distal end into a *vagina* and opening to the exterior on the same segment.

Fertilisation is mutual and the eggs are laid in a cocoon, usually in damp places. They have yolk and pursue an embryonic development.

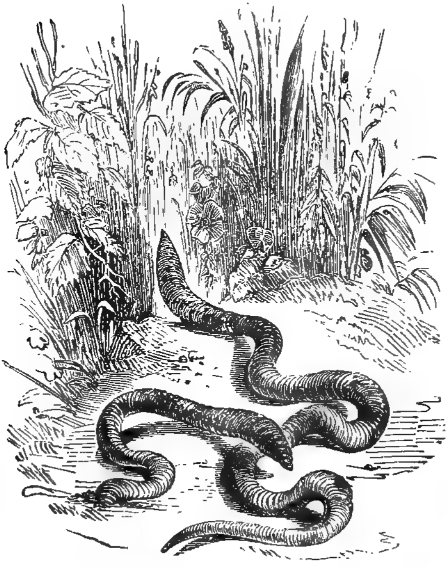
## LEECH.

| SEGMENTS. | NERVOUS SYSTEM. | EXCRETORY SYSTEM. | REPRODUCTIVE SYSTEM. | SENSE-ORGANS. | APERTURES. |
|---|---|---|---|---|---|
| Prostomium | Brain | | | | Mouth. |
| 1 | Sub-œsophageal mass. | | | Eyes | |
| 2 | | | | " 2 | |
| 3 | | | | " 3 | |
| 4 | | | | " 4 | |
| 5 | | | | " 5 | |
| 6 | Ganglion 1 | Nephridium 1 | | Sense-organs. | |
| 7 | " 2 | 2 | | " | |
| 8 | " 3 | 3 | | " | |
| 9 | " 4 | 4 | | " | |
| 10 | " 5 | 5 | | " | ♂ ap. |
| 11 | " 6 | 6 | Ovisacs. | " | ♀ ap. |
| 12 | " 7 | 7 | 1 Testis. | " | |
| 13 | " 8 | 8 | 2 " | " | |
| 14 | " 9 | 9 | 3 " | " | |
| 15 | " 10 | 10 | 4 " | " | |
| 16 | " 11 | 11 | 5 " | " | |
| 17 | " 12 | 12 | 6 " | " | |
| 18 | " 13 | 13 | 7 " | " | |
| 19 | " 14 | 14 | 8 " | " | |
| 20 | " 15 | 15 | 9 " | " | |
| 21 | " 16 | 16 | | " | |
| 22 | " 17 | 17 | | " | |
| 23 | " 18 | | | " | |
| 24 | " 19 | | | " | |
| 25 | " 20 | | | " | |
| 26 | " 21 | | | " | |
| 27 | " 22 | | | | |
| 28 | Posterior ganglion (23) | | | | |
| 29 | | | | | |
| 30 | | | | | |
| 31 | | | | | |
| 32 | | | | | |
| 33 | | | | | Anus. |

## IV.—LUMBRICUS.

| | |
|---|---|
| PHYLUM - | ANNULATA (p. 237). |
| SUB-PHYLUM | ANNELIDA (p. 238). |
| CLASS | OLIGOCHÆTA (p. 239). |

Fig. 124.—THE COMMON EARTHWORM
*(Lumbricus terrestris).*



The darker end is anterior.

**Habits.** The common earthworm has a shape and appearance familiar to all. A full-grown specimen may be eight or nine inches long. The anterior end is usually of a dark purple colour which becomes lighter further down the body to a dull pink. The animal lives in self-constructed burrows in the earth, though at times it emerges from these and creeps on the surface.

Like all other *Annelida*, the earthworm is plano-symmetric, though the absence of appendages makes this less evident than in other classes.

**External Features.**

The body is constricted throughout into a series of about 150 *segments*, but there are no annuli. The segments, from about 29 to 35,* have a swollen appearance and a yellowish colour. They form the *clitellum*. The *mouth* is at the anterior end, overhung by a prostomium and bordered by the *peristomium*. At the extreme posterior end is the *anus*.

As in the leech, there are neither gills nor appendages. If the body of the worm be drawn through the fingers from tail to head it will rasp with some resistance to the fingers. This is due to the presence of minute *setæ* which are found on each segment. The setæ are in pairs and are arranged in two ventral and two lateral rows. Each segment, therefore, has eight setæ. They naturally project backwards and aid the locomotion of the worm in the same way as the appendages of *Arenicola*. In the mid-dorsal line is a row of median *dorsal pores*, occurring between each segment from about the 9th backwards and communicating with the cœlom. A pair of minute nephridiopores open on the ventral surface of each segment (except the first two), but they are too small to be recognised without the aid of a lens. On the 15th segment there is a pair of ventral openings with tumid lips, the male *genital* openings, and on the segment (14th) in front are the two female genital apertures. Between segments 9, 10 and 11 there are the two paired openings of the *spermathecæ*.

**Integumentary.**

The body is covered by a cuticle with simple ectoderm, forming a flexible but firm envelope. Scattered throughout the ectoderm are numerous unicellular glands, specially abundant in the region of the clitellum.

**Sensory.**

There are no eyes nor otocysts, but the prostomium has sense-organs for perception of contact and perhaps of taste. The alimentary canal is exposed by making a median dorsal incision along the body of the worm. The mouth passes into the muscular *pharynx*, from

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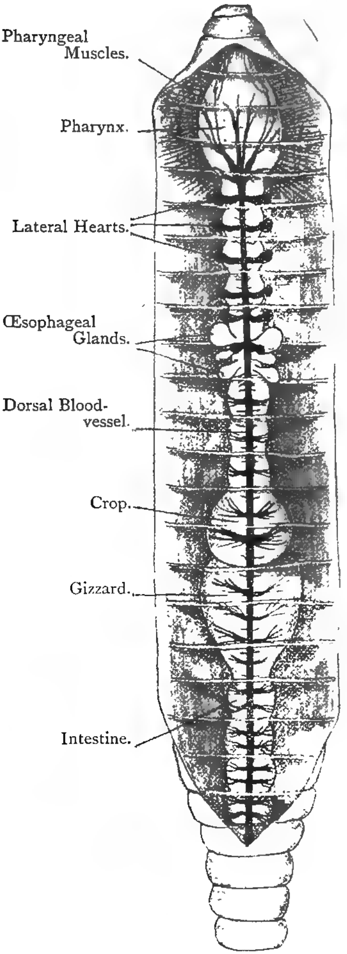
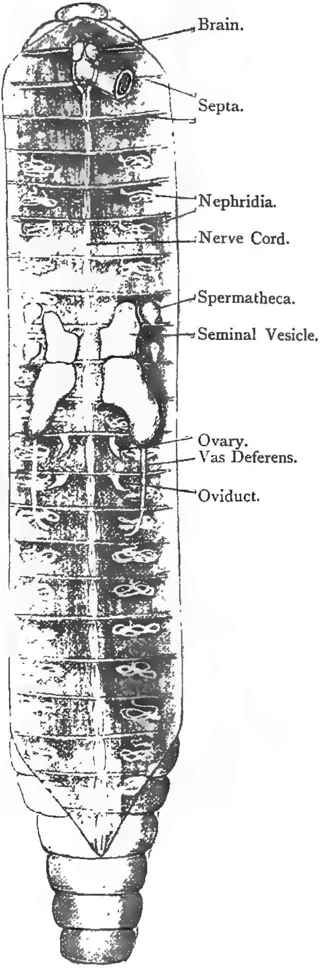
* There is great variation in the position of the clitellum.

Fig. 125.—FIRST DISSECTION OF THE EARTHWORM. (*Ad nat.*)



The body is cut open along the dorsal line and the body-walls pinned down.

Fig. 126.—SECOND DISSECTION OF THE EARTHWORM. (*Ad nat.*)

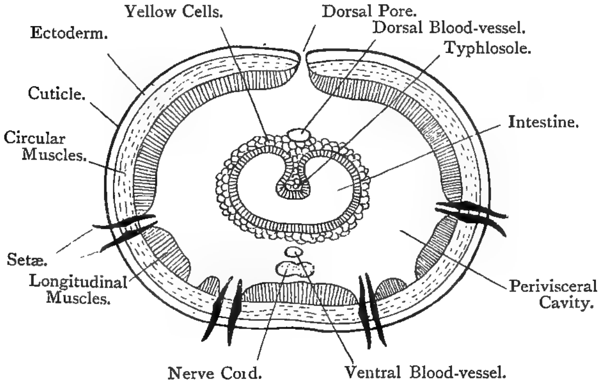


The alimentary canal is cut through and removed, exposing nervous, excretory and genital organs

**Alimentary.**

which a long thin *œsophagus* passes back to the thin-walled *crop*. Upon the œsophagus are three pairs of pouches, the two hinder pair being known as *calciferous glands*. The crop leads into the muscular *gizzard*, which has a small opening into the long *intestine*. A fold of the dorsal wall, called the *typhlosole*, projects into the lumen of the intestine. The alimentary canal is held in position by a complete series of *transverse septa* dividing the cœlom into compartments. Each septum has an aperture by which cœlomic fluid can pass from one segment to the other.

Fig. 127.—Transverse Section of an Earthworm in the Intestinal Region. (Semi-diagrammatic.)



**Muscular.**

Under the ectoderm is a layer of connective tissue beneath which lies a series of *circular muscles*. Inside this there is a *longitudinal series*. These function very much as in *Arenicola*.

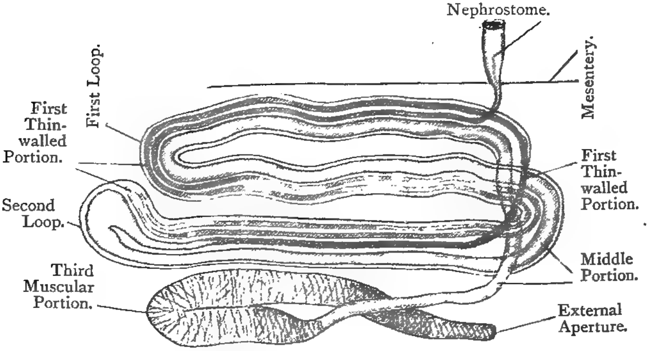
**Blood-Vascular.**

The cœlomic fluid is nutritive and the *cœlom* is spacious. The cœlomic wall covering the intestine is thickened into a mass of excretory *yellow cells*. The blood-vascular system is easy to see, for the blood (mainly respiratory) is bright red from the presence of *hæmoglobin* (*cf. Arenicola*). There is a main *dorsal vessel* running forwards and a *ventral* backwards. These are connected by numerous *circular* vessels, of which six at the anterior end are specially contractile and form the *lateral hearts*. The dorsal vessel is also contractile.

**Nervous.** The *brain* lies in the prostomium, with a *nerve-ring* round the pharynx and a *double nerve-chain* along the ventral surface. The nerve-chain has double ganglia in each segment.

**Excretory.** The *nephridia* are numerous, a pair occurring in nearly every segment. They are complex coiled tubes with an internal funnel, a coiled excretory part and a small bladder or vesicle leading to the exterior. The funnel always opens into the cœlomic compartment in front of the one in which the bulk of the nephridium lies.

Fig. 128.—A Nephridium of Lumbricus.



**Reproductive.** Respiration appears to be carried on by the skin. The worm is hermaphrodite. The male organs consist of two pairs of *testes* lying in the 10th and 11th segments. They are enveloped in the large branching *seminal vesicles*, from each of which there passes a *vas deferens* backwards to open on the 15th segment. The pair of *ovaries* lie in the 13th segment, and the *oviducts*, with funnels opening into the same segment, run through the septum and open to the exterior on the 14th segment.

Two pairs of *spermathecæ* or small spherical sacs open between 9 and 10 and between 10 and 11 on each side.

The eggs are laid in cocoons and undergo an embryonic development. The cocoons are secreted by the clitellum.

LUMBRICUS (1st twenty segments).

| SEGMENTS. | APPENDAGES. | NERVOUS SYSTEM. | EXCRETORY SYSTEM. | REPRODUCTIVE SYSTEM. | APERTURES. |
|---|---|---|---|---|---|
| Prostomium. | | Brain. | | | Mouth. |
| Peristomium 1 | | Nerve-ring. | | | |
| 2 | Setæ. | Ganglion. | | | Nephridiopores (same as nephridia). |
| 3 | " | " | | | |
| 4 | " | " | Nephridium 1 | | |
| 5 | " | " | " | | |
| 6 | " | " | " | | |
| 7 | " | " | " | | |
| 8 | " | " | " | | |
| 9 | " | " | " | Spermatheca. | Spermathecal. |
| 10 | " | " | " | Sperm. Testis. | Spermathecal. |
| 11 | " | " | " | Testis. | Dorsal pore. |
| 12 | " | " | " | | " |
| 13 | " | " | " | Ovary. | " |
| 14 | " | " | " | Oviducts. | " |
| 15 | " | " | " | | " |
| 16 | " | " | " | | ♀ ap. " |
| 17 | " | " | " | | ♂ ap. " |
| 18 | " | " | " | | " |
| 19 | " | " | " | | " |
| 20 | " | " | " | | " |
| &c. | | | | | |

(For the general characters of the Sub-Phylum *Annelida*, see page 238.)

# CHAPTER XVII.

## *ANNULATA—Continued.*

NEPHROPS. BLATTA. PERIPATUS. EPEIRA.

## I.—NEPHROPS.*

| | |
|---|---|
| PHYLUM | ANNULATA (p. 237). |
| SUB-PHYLUM | ARTHROPODA (p. 240). |
| CLASS | CRUSTACEA (p. 241). |

**Habits.**

The Norway Lobster (*Nephrops norvegicus*) is a very common kind of lobster found, amongst other places, in the Firth of Forth. It is caught in great numbers in the trawl and is apparently gregarious in its habits. It is a ground-feeder and is fond of shell-fish, but will eat almost any marine animal of a sufficiently small size. It is rather smaller than the common lobster, and is at once distinguished by its pale yellow and red colour and its more angular outline.

**Integumentary.**

The body is perfectly plano-symmetric and is encased in a hard calcareous exoskeleton. As in the *Annelida*, the whole body is enveloped in a chitinous cuticle secreted by the underlying ectoderm (or epidermis), but this cuticle is greatly thickened over certain areas, and is, in addition, converted into a hard plate by the deposition of calcareous matter in the chitin. The hard plates are called *sclerites*, and the soft cuticular parts between them which make movements possible are called the *arthrodial membranes.*

**External Features.**

We can distinguish the body and the appendages, as in many *Annelida.* In the body the largest sclerite is the *carapace.* This rests like a saddle on the anterior half (or more) of the body. The front end is produced into a sharp *rostrum*, and on either side it hangs down as a lateral *branchial plate.* The branchial plate can be broken off, and the gills are then exposed in the branchial chamber which is plainly only a

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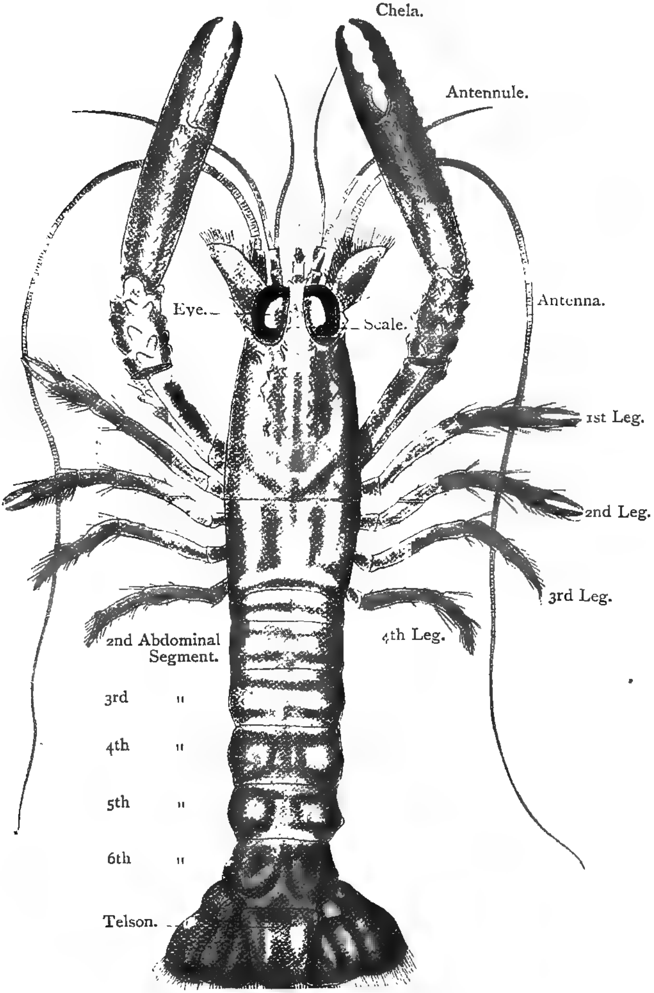
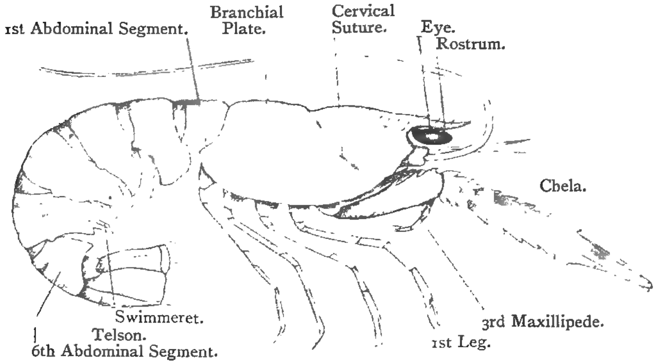
* The following description, except in the case of the gills, will apply equally well for the crayfish (*Astacus*), the lobster (*Homarus*), or the shrimp (*Crangon*), and with very little modification for the crab (*Carcinus*).

Fig. 129.—THE NORWAY LOBSTER *(Nephrops norvegicus).*
Dorsal aspect. *(Ad nat.)*



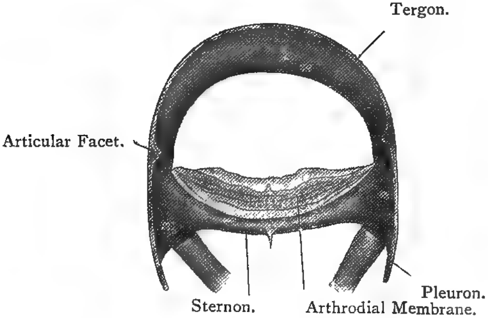
part of the exterior partially shut in. In many *Crustacea* the part of the body here covered by the carapace is divided into *head* and *thorax*, and in *Nephrops* the line of junction is shown by a *cervical suture* passing down laterally and obliquely from the mid-dorsal line.

Fig. 130.—Lateral View of Norway Lobster (Right) × $\frac{2}{3}$.
*(Ad nat.)*



The third portion of the body, behind the carapace, is called the *abdomen.* In this region there are several sclerites movable on each other and they are found to correspond with the metameric segments of the body. Each abdominal sclerite is roughly in the form of a ring. The dorsal part is called the *tergon*, the ventral narrow part is the *sternon*, and from the junction there hangs down laterally the *pleuron.* Just inside the pleuron there is an appendage on each side. Each abdominal sclerite is fastened to its fellows in front and behind by dorsal and ventral arthrodial membranes and laterally by a pair of ball-and-socket joints, which allow of movement only around the axis through them. The sclerites overlap dorsally those behind them. The last (7th) abdominal sclerite is flattened and bears no appendages: it is called the *telson.* The appendages of the abdominal sclerites are termed *swimmerets* for they are mainly used for swimming. They consist typically of a basal piece, the *protopodite*, bearing two paddles, the outer one called the *exopodite* and the inner termed the *endopodite*. Hence they are termed *biramous* appendages. The abdomen of *Nephrops*, therefore, resembles that of a polychæte annelid in that it is divided into a number of segments, each of which bears a pair of biramous swimming appendages. In the part in front of the abdomen the segmentation cannot be traced by the sclerites for they are united, at least dorsally and laterally, into one sclerite, but the appendages still enable us to determine the number of segments which have become fused. From these we find that the thorax consists of eight segments and the head of five, which, with seven abdominal, gives a total of twenty segments. The telson having no appendages, there are only nineteen pairs of appendages.

Fig. 131.—An Abdominal Segment of Nephrops × $\frac{3}{2}$. (*Ad nat.*)



Glancing at the thoracic and cephalic (head) appendages, we see that there are four pairs of legs preceded by a pair of pincers; these are succeeded by a pair of foot-jaws, inside which there are no less than five more pairs of jaws; and, lastly, in front of the mouth there are two pairs of feelers.

We can recognise at once that the appendages have altered considerably in form and function if they all were at one time of a common type. The evidence of development and of comparative anatomy leads us to suppose that the ancestors of lobsters had simple biramous appendages to each segment. All were used as swimming organs, but when walking on the sea-floor became the vogue, the swimmerets in the neighbourhood of the centre of gravity became modified for bearing the weight of the body. In this case the *endopodites* evidently form the main axis of support, being nearest the perpendicular through the centre of gravity, and the exopodites, being superfluous, disappear. A "leg" or a chela therefore consists of *protopodite* and especially *endopodite.* Both parts become jointed for further movement, so the protopodite acquires two sclerites and the endopodite five.

On the other hand, the appendages near the mouth naturally take part in the ingestion of food. In this the basal part or *protopodite*, being nearest the mouth, becomes the *gnathobase* or jaw-element. Hence the jaw-elements always consist largely of *protopodite*, the endopodite and exopodite becoming subsidiary. These three axioms should be held in mind :—

1. Swimming organs at the hind end, retaining their primary functions, retain the primitive biramous condition with *equal endopodite and exopodite.**

2. Walking organs, round the centre of gravity, lose the exopodite and have a large and complex *endopodite.*

3. Eating organs, round the mouth, lose the exopodite and reduce the endopodite, but have a large *protopodite.*

4. Tactile organs, at the anterior end, may be specially modified, with or without reduction.

5. Organs between these, with ill-defined functions, such as foot-jaws, *may* retain all the parts more or less modified.

(It will be found convenient to remove the appendages from the last leg forwards as the jaws overlie each other forwards.)

If the four legs be removed we can at once contrast them. The two first have pincers at their ends, or are *chelate;* whereas the two last are non-chelate. Each has two joints to the protopodite and five to the endopodite. This completes the last leg, but the three in front of it bear a long hairy pad called an *epipodite*, and attached to its base is a filamentous *gill.* If the specimen be a male, the genital aperture will be found on the basal joint of the last leg, whereas, if a female, the genital aperture

---

* In a few cases, as in the sixth abdominal, the *exopodite* is the larger.

will be on the basal joint of the anti-penultimate leg. In front of the legs are the *chelæ*, or pincers, usually asymmetric, as one is modified for cutting and the other for crushing. They are evidently large legs and do not differ essentially from a typical leg.

Fig. 132.—A CHELA OF NEPHROPS (9th appendage). *(Ad nat.)*

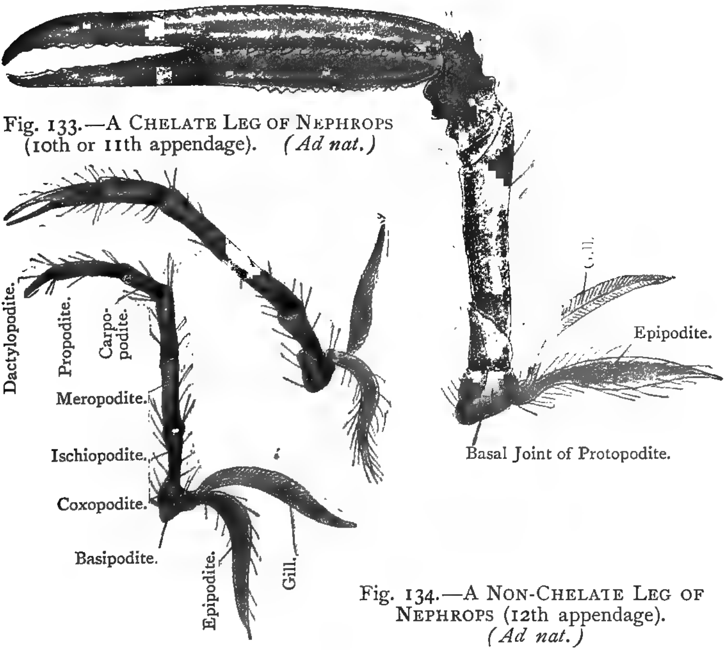


Fig. 133.—A CHELATE LEG OF NEPHROPS (10th or 11th appendage). *(Ad nat.)*

Fig. 134.—A NON-CHELATE LEG OF NEPHROPS (12th appendage). *(Ad nat.)*

In front of the chelæ are three pairs of *maxillipedes* or foot-jaws. The second maxillipede may be examined first. It has a leg-like five-jointed endopodite, a two-jointed protopodite and a long filamentous exopodite Finally there is a long epipodite, but no gill.* The third maxillipede is like it, but can be easily distinguished by the *serrated*

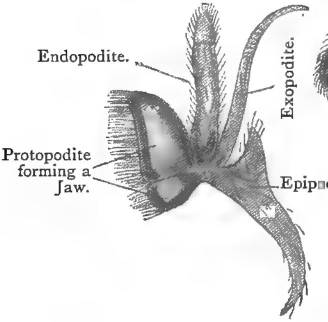
---

* In *Astacus* there is a gill on this appendage.

*(or toothed) edge* on the basal joint of the endopodite and by the *presence of a gill.* The first maxillipede, on the other hand, has a small *two-jointed endopodite* and the protopodite is produced into a jaw.

Fig. 135.—THE FIRST MAXILLIPEDE (left) OF NEPHROPS.

Enlarged. (*Ad nat.*)



Note the jaw formed of protopodite and the two-jointed endopodite.

Fig. 136.—THE SECOND MAXILLIPEDE OF NEPHROPS.

Enlarged. (*Ad nat.*)

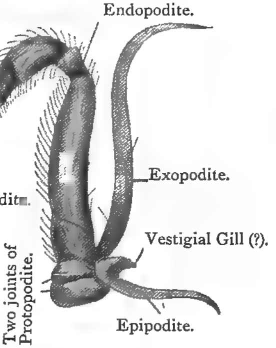
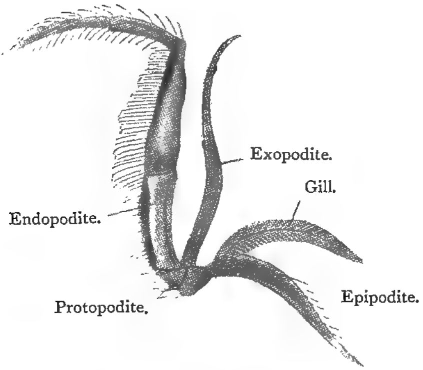


Fig. 137.—A THIRD MAXILLIPEDE OF NEPHROPS. (*Ad nat.*)

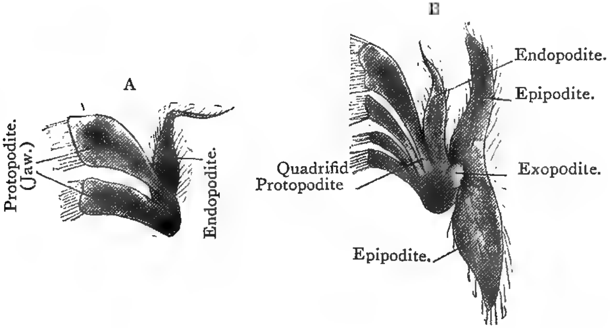


These eight appendages complete the thorax.

Still passing forwards on to the head we find two small foliaceous *maxillæ:* The second maxilla (the first to be removed) has a *quadrifid* jaw-like protopodite, a thin unjointed endopodite and a scoop-shaped epipodite (called the *scaphognathite*). The exopodite may possibly be represented by a small process.

The first maxilla is the smallest of all the appendages. It has a bifid jaw or protopodite and a small unjointed endopodite.

Fig. 138.—A, First Maxilla, and B, Second Maxilla of Nephrops. *(Ad nat.)*



The mouth is guarded by a pair of powerful biting jaws, formed by the protopodite of the *mandibles*, the little endopodite being three-jointed and forming the *palp*. Passing in front of the mouth we reach the large *antennæ.* On the ventral surface of the basal protopodite of these appendages is an aperture, the *excretory pore.* The endopodite is produced into a long tactile feeler, and the exopodite forms a small semi-circular *scale.* The *antennule* has a small aperture in the protopodite leading to the otocyst. It has no exopodite, and the endopodite is formed into two filamentous feelers.

If we now return to the swimmerets we find that they are not all alike. The first swimmeret has, in the female, only one "paddle" (or the endopodite, borne on a small protopodite), whereas, in the male, the protopodite alone

Fig. 139.—THE ANTENNULE OF NEPHROPS. (*Ad nat.*)

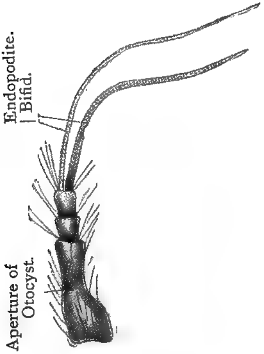


Fig. 140.—THE MANDIBLE OF NEPHROPS × 2. (*Ad nat.*)

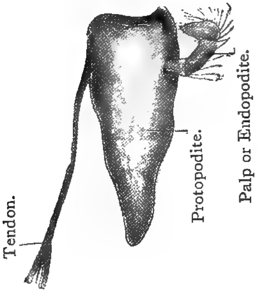
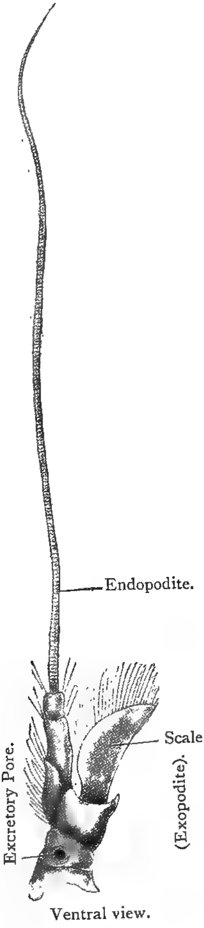


Fig. 141—LEFT ANTENNA OF NEPHROPS. (*Ad nat.*)



remains as a long, grooved spike, which apparently acts as an accessory organ of reproduction.

In the female the next four are normal, but in the male the second one has a process of the protopodite which gives the whole appendage the appearance of being triramous. The other three are normal.

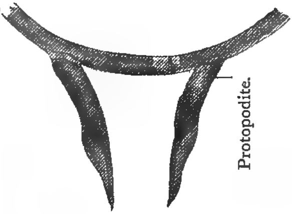


Fig. 142.—The First Pair of Swimmerets in Nephrops (♂). (*Ad nat.*)

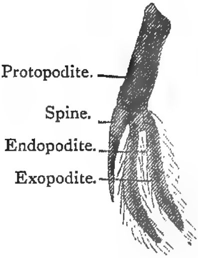


Fig. 143.—The 2nd Swimmeret of Nephrops (♂). (*Ad nat.*)

Note the spine on the Protopodite.

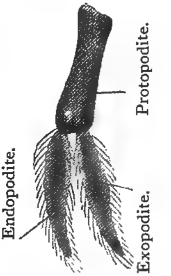


Fig. 144.—A Typical Swimmeret of Nephrops. (*Ad nat.*)

In both sexes the sixth swimmerets are of large size, the *exopodite* being jointed. These "paddles," together with the median *telson*, form the tail which, on flexion of the abdomen, strikes the water forwards resulting in a rapid backward motion of the whole body.*

**Sensory.** At least four senses can be recognised in *Nephrops*. (1) The *eyes* are paired and situated just below the rostrum upon eye-stalks. They are called *compound* eyes.

Compound eyes are characteristic of *Arthropoda* and have throughout the group a characteristic structure. They are called compound because they consist of an aggregate of elements called *ommatidia*, each of which has its own

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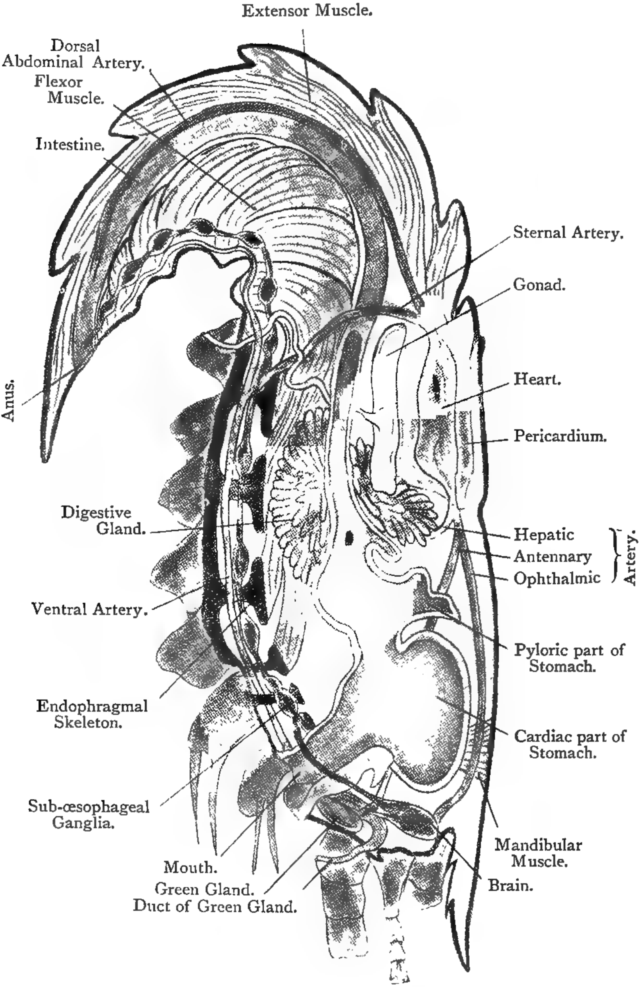
* The swimmerets in *Astacus* have the paddles (or exopodite and endopodite) differentiated into a basal unjointed and an upper filamentous portion. In *Carcinus* the swimmerets are vestigial (♂) or very reduced (♀).

Fig. 145.—A MEDIAN SAGITTAL SECTION THROUGH NEPHROPS (Semi-diagrammatic).



complete optical apparatus. The ommatidia are arranged radially, converging to the centre of the eye towards the optic ganglion, and their outer ends are covered by a thickened cuticle divided into *facets*. Each ommatidium or eye-element consists of (*a*) an outer layer of cells which secrete a long, lens-like body, the *crystalline cone;* (*b*) an inner layer of cells, called *retinulæ*, which secrete in their common inner space the *rhabdomes*, or rod-like bodies. From these there pass fine nerves to the optic ganglion, which in its turn communicates with the brain. The crystalline cones form the dioptic apparatus, and the retinulæ and rhabdomes are the sensory apparatus. Between the ommatidia, cells loaded with pigment grow up from the connective-tissue layers below. They serve to isolate the ommatidia and shut out cross-rays.

(2) The otocysts consist of paired hollow cavities in the base of the antennule. Each communicates with the exterior by a minute aperture. The cavity contains a few sand-grains, and its wall has sensitive "hairs" projecting into the cavity, supplied by fibres from the antennulary nerve. (3) A number of the "hairs" on the antennule are sensory and are said to have an *olfactory* sense. (4) *Crustacea*, with a hard exoskeleton, can hardly have the tactile sense distributed all over the surface like some other animals, but they have numerous sensory or *tactile hairs.* These should be carefully distinguished, on the one hand, from mammalian hairs, and, on the other, from annelid setæ. The seta is a cuticular bristle formed of chitin throughout, but the lobster's "hair" consists of a delicate cuticle on the surface and a living protoplasmic axis connected by sensory nerve to the nerve cord.

**Alimentary.**

The mouth, as we have seen, passes from the anteroventral mid-line past the mandibles through a short *œsophagus* into the spacious *stomach.* This is divided by a constriction into two parts, the so-called *cardiac* and *pyloric* chambers. The pyloric chamber leads into a short *mesenteron*, into which open the paired ducts from a large *digestive gland*, and thence into an intestine to the *anus* on the ventral surface of the telson.

Development teaches us that the whole of the alimentary canal, except the mesenteron, arises from ectoderm, and, in accordance therewith, it is lined with a chitinous cuticle. In addition the cuticle in the stomach has a number of hard sclerites which form the *gastric mill.* This apparatus has a median tooth and two lateral teeth worked by powerful muscles. Further, the aperture between the cardiac and pyloric portions is guarded by strainers, or small processes, covered with "hairs." Digestion of the food is apparently confined to the region of the mesenteron.

**Muscular.**

The sclerites of the lobster are moved by a complex series of muscles lying inside the body or limbs. There are two series of muscles—(1) the *flexors* which by contraction bend the abdomen or the limb; (2) the *extensors* which straighten it. In the limbs, at least, these are attached to the arthrodial membranes by tendons, but in some cases to the edge of the sclerite. A cross-section of the abdomen shows the powerful flexors, the contractions of which bend the tail and drive the lobster backwards through the water, and above them the much thinner *extensors.*

The anterior flexors are attached in the thorax to the *endophragmal* skeleton, which consists of parts of the ectoderm with cuticle; these have grown in from the ventral surface during development. Hence the endophragmal skeleton does not constitute an *endoskeleton.*

The lobster can swim gently forwards by the action of the swimmerets, it can creep in any direction by its legs and it can shoot rapidly backwards by contraction of the tail.

**Skeletal.**

The skeleton being an exoskeleton, it has already been noticed in the external features. We need only emphasise the tucking of the ectoderm into the stomach and into the ventral region of the thorax, the sclerites in each case forming the gastric mill and the endophragmal skeleton.

**Vascular.**

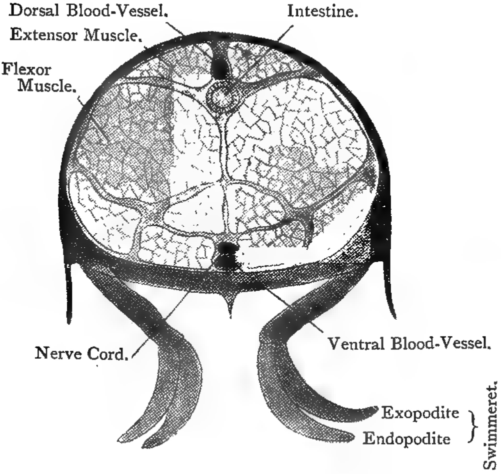
The vascular systems of the lobster are in a peculiar condition. In the *Annelida* and *Archicœlomata* we could distinguish two vascular systems. The larger and more spacious, contained *within* the mesoderm, was called the cœlom and was mainly nutritive and motor; the smaller consisted of fissures and small sinuses lying *between* the three primary layers, was called the blood-vascular or hæmocœlic system, and was usually respiratory and excretory.

In the *Arthropoda* this condition is reversed. The cœlom is reduced to a few small spaces *within* the mesoderm, such as the cavity of the gonads and of green gland, is either indifferent or excretory, and has lost its motor function, whereas the blood-vascular or hæmocœlic system is spacious and forms the main cavities of the body. It is divided by a median horizontal *pericardial septum* in the thorax into an upper cavity, the *pericardial sinus*, and a lower cavity which forms the general body-cavity. The *body-cavity of the lobster* is therefore purely hæmocœlic, mostly a large venous cavity, but partly a small arterial* pericardial cavity. The *heart* lies dorsally in the pericardial sinus, *with which it communicates by six valves;* on contraction it drives the blood forwards and backwards by main arteries. Forwards there is a median *ophthalmic* artery, paired *antennary* and

**Cœlom.**

**Blood-Vascular.**

Fig. 146.—Section across the Abdomen of Nephrops × 2. *(Ad nat.)*



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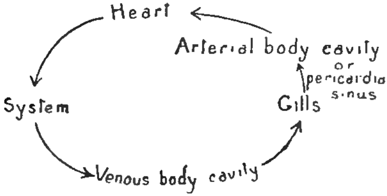
[*] Arterial in containing ærated blood; structurally it is a part of the venous system.

paired *hepatic* arteries. Posteriorly the heart gives off a *dorsal abdominal* backwards, and a *sternal* artery downwards which, on reaching the ventral surface, divides into a *ventral thoracic* forwards and an *abdominal* backwards.

All these arteries supply the organs with pure blood, and the impure venous blood accumulates in the cavity of the body whence it passes out to each gill by an *afferent branchial.* After æration in the gills, it is collected by *efferent branchials* and passed by *branchio-cardiac canals* up the sides of the thorax into the pericardial sinus.

The heart of the lobster is thus *systemic*, and the course of the blood is as follows :—



The special point to notice is the hæmocœlic body-cavity converting the venous system into a number of large sinuses or spaces, the arterial vessels alone having definite walls.

**Nervous.**

The nervous system is constructed on essentially the same plan as that of the *Annelida*, but there are more concentrations of the ganglia. If the lobster were a simple annelid we might expect to find a dorsal brain over the anterior end of the alimentary canal, a ring round it to the ventral surface, and a double nerve-chain to the hind end, with double ganglia in each segment; but in reality matters are rather different. The *brain* of the lobster has the true brain portion supplying sensory nerves to the eyes, but, in addition, it has the two next pairs of ganglia belonging to the antennules and antennæ fused with it. The antennules and antennæ are really post-oral appendages, but they move forward in development to the adult position in front of the mouth. The ganglia corresponding to them follow suit and fuse with the primary brain to form one mass.

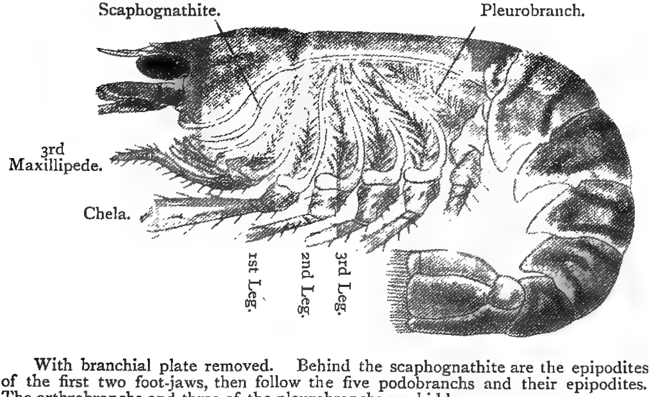
In a similar manner the ganglia of the next six appendages, which are all jaws or foot-jaws, fuse to form one large *sub-œsophageal mass.* After this follow the *five thoracic ganglia* of the chelæ and the legs, and, lastly, the *six abdominal ganglia.* The last supplies both the sixth segment and the telson, and thus *may* be two (6th and 7th) fused ganglia.

In this way the primitive chain of twenty ventral ganglia is reduced in number by fusions at each end till twelve only remain.

**Excretory.**

The lobster excretes nitrogenous waste products by a pair of *green glands* in the head, which *may* be a pair of much modified nephridia. Each consists of a complex excretory tube leading to a bladder, which opens to the exterior by the excretory pore on the ventral side of the antenna. The excretory products are thus discharged into the stream of water emerging from the branchial chamber (see below). We may notice that the tubes have no internal nephrostome, for there is no cœlomic body-cavity into which they can open.

Fig. 147.—Lateral View of Nephrops. (*Ad nat.*)



With branchial plate removed. Behind the scaphognathite are the epipodites of the first two foot-jaws, then follow the five podobranchs and their epipodites. The arthrobranchs and three of the pleurobranchs are hidden.

**Respiratory.**

There are nineteen pairs of gills. They are situated along the sides of the thorax and are protected by the branchial plate of the carapace. The branchial chamber so formed communicates freely with the exterior between the legs and at the hind end, but the principal aperture (the *cervical canal*) lies at the front end and opens beside the mouth.

In this there lies the *scaphognathite* of the 2nd maxilla which is said to bale or scoop the water *out* of the branchial chamber, fresh water coming in from behind and between the legs. Each gill consists of a central axis with lateral branches, covered with a very thin cuticle, ectoderm and mesodermic layer. In its interior the blood circulates from afferent to efferent branchials.

Five of the gills are fixed to the bases of the third maxillipede, chela and first three legs. They are termed *podobranchs*. To the arthrodial membrane of each of the same appendages is attached a pair of small *arthrobranchs*; whilst higher up, on the side-wall of the thorax, are found four large *pleurobranchs*, which are supposed to correspond to the four last segments.* The epipodites lie between each set of gills in each segment and force the incoming water to pass the whole way up the gills instead of taking a short cut to the cervical canal.

It is possible that the primitive arrangement was that of a podobranch, two arthrobranchs and a pleurobranch to each segment of the thorax, making a total of thirty-two, but this number persists only in numbers 5, 6 and 7, where the thorax is broadest. The cavity has become narrower in front and behind, hence the last leg loses its podobranch and its two arthrobranchs, and the pleurobranchs all disappear in front of number 5: so also do the arthrobranchs and podobranchs in the first two segments. With a loss of ten gills in front and three behind, the thirty-two is reduced to nineteen. This will be clear after an inspection of the diagram.†

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* It is probable that *all* the gills arise on the basal joint of the thoracic appendages, but the pleurobranchs and arthrobranchs migrate during development to their final positions.

† In *Astacus* there is a podobranch on the second maxillipede and one arthrobranch above it, but only the last pleurobranch remains; thus it possesses only 18 pairs of gills, *i.e.*, podobranchs (6), arthrobranchs (11) and pleurobranchs (1).

The testes are a pair of organs lying in the dorsal part of the thorax. They lead by paired tubes, the *vasa deferentia*, continuous with the testicular cavity, to the exterior on the last leg. The *ovaries* are also paired, and in a similar way lead to the exterior by paired tubes, the *oviducts*, on the anti-penultimate leg.

**Reproductive.**

The eggs are shed in great numbers and adhere to the swimmerets of the female. In this condition the female is known as a "berried" lobster, and swimming is at that time impracticable. The male discharges the male element upon the eggs and development takes place within the egg-membrane.

The full development of the Norway lobster has not been followed, but its close ally the crayfish has been well studied.

The chief points of special importance in the development are as follows:—

1. The egg has a large amount of yolk arranged symmetrically and the segmentation is equal and superficial. (See page 49.)

2. Invagination takes place at one spot, resulting in a sac of endoderm pushing into the yolk, the blastopore closing.

3. The endoderm cells ingest the yolk within themselves and thus come to lie close under the ectoderm.

4. From the middle line (future ventral surface) the ectoderm invaginates to form stomodæum and proctodæum, which open into the archenteron and form the gullet and stomach and the intestine respectively.

5. Paired thickenings of the ventral surface form the head, the thorax and abdomen and the paired appendages.

6. The first three pairs of appendages to appear are the antennules, antennæ and mandibles, the embryo at this stage being somewhat comparable to the *nauplius* larva of some other *Crustacea*. (See page 242.)

7. The paired appendages then appear gradually in order backwards and the young crayfish hatches, with a cephalothorax distended dorsally with yolk.

[TABLE.

NEPHROPS.

| SEGMENTS. | | APPENDAGES. | NERVOUS SYSTEM. | APERTURES. | GILLS. | | |
|---|---|---|---|---|---|---|---|
| | | | | | Podobr. | Arthobr. | Pleurobr. |
| Prostomium. | | | Primary brain. | | | | |
| Head. | 1 | Antennule. | Brain. | Otocyst. | | | |
| | 2 | Antenna. | | Excretory pore. | | | |
| | 3 | Mandible. | Sub-œsophageal mass. | Mouth. | | | |
| | 4 | 1st Maxilla. | | | | | |
| | 5 | 2nd " | | | | | |
| Thorax. | 6 | 1st Maxillipede | | | | | |
| | 7 | 2nd " | | | | | |
| | 8 | 3rd " | | | 1 | 2 | |
| | 9 | Chela. | Gangl. 1. | | 1 | 2 | |
| | 10 | 1st Leg. | " 2. | | 1 | 2 | 1 |
| | 11 | 2nd " | " 3. | ♀ ap. | 1 | 2 | 1 |
| | 12 | 3rd " | " 4. | | 1 | 2 | 1 |
| | 13 | 4th " | " 5. | ♂ ap. | | | 1 |
| Abdomen. | 14 | 1st Swimmeret | " 6. | | | | |
| | 15 | 2nd " | " 7. | | | | |
| | 16 | 3rd " | " 8. | | | | |
| | 17 | 4th " | " 9. | | | | |
| | 18 | 5th " | " 10. | | | | |
| | 19 | 6th " | Post. gangl. 11. | | | | |
| | 20 | | | Anus. | | | |
| (Telson.) | | | | | | | |

## II.—BLATTA.

| | |
|---|---|
| PHYLUM - | ANNULATA (page 237). |
| SUB-PHYLUM | ARTHROPODA (page 240). |
| CLASS | INSECTA (page 246). |

The common cockroach—*Blatta (Periplaneta Orientalis)*—is of a dark brown colour except when young and is usually about one inch in length. The American species (*Blatta Americana*) is considerably larger and is thus preferable for dissection.

The male cockroach is winged and the female has no wings.* The cockroach is found most frequently in places with a high temperature, such as kitchens, laundries, or bake-houses, hence it is typically terrestrial. It is an omnivorous feeder and thrives in

**Habits.**

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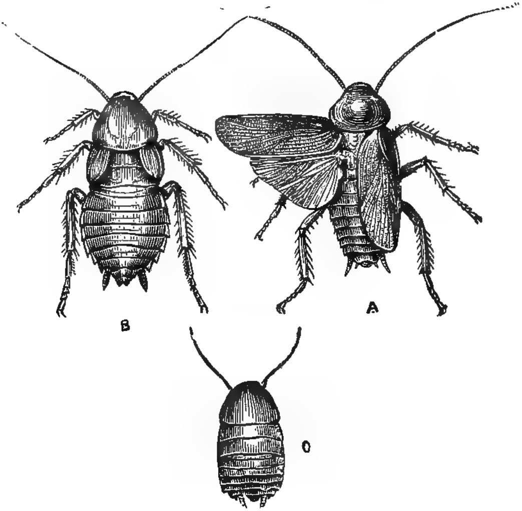
* Both sexes are winged in the case of *B. Americana.*

confinement upon bread. The body is plano-symmetric, and is encased in a hard exoskeleton. This consists of a chitinous cuticle secreted by the ectoderm, but it differs from that of the lobster in the absence of calcareous matter. Hence the exo-skeleton is tough and somewhat flexible, but not nearly so hard and thick as that of the latter. We can still distinguish chitinous *sclerites* united by softer *arthrodial membranes.*

**Integumentary.**

Fig. 148.—The Common Cockroach *(Blatta Orientalis).*
Natural Size.

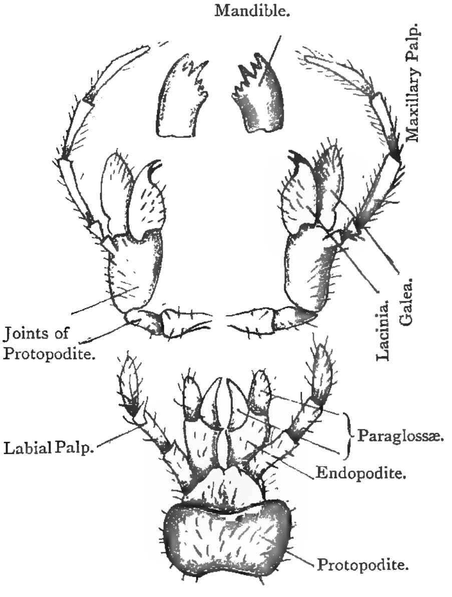


A, Male with wings expanded; B, Female with vestigial wings; C, Wingless young.

**External Features.**

The body is divided into three parts—the *head*, the *thorax* and the *abdomen.* Of these the head is not segmented, the thorax is partially so, but the abdomen is as clearly segmented as in the lobster. The head bears one pair of long *antennæ* at the anterior end, and close to them is a pair of compound eyes, not differing essentially from those of the lobster. The *mouth* lies on the ventral surface of the head and is surrounded by a *labrum* or upper lip anteriorly. It is a flat plate formed of the head shield, produced downwards, and is in no way related to an appendage. Posteriorly, the mouth is bounded by a *labium* or lower lip, formed by the fusion across the middle line of a pair of appendages, the *second maxillæ*. Between labrum and labium and *lateral* to the mouth lie a pair of *mandibles*, hard-toothed crushing organs with no palp, and a pair of *first maxillæ*. The first maxillæ, when dissected out, show a two-jointed basal portion *(protopodite)* which bears a double *endopodite*, the inner part of

Fig. 149.—THE MOUTH APPENDAGES OF THE COMMON COCKROACH × 9. (*Ad nat.*)



The mandibles are above the first maxillæ in the middle and the labium (2nd maxillæ) below.

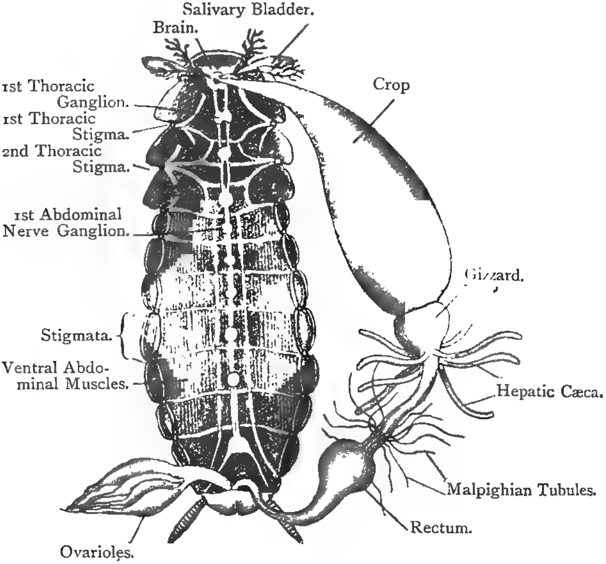
which is the *lacinia* or blade and the outer the *galea* or hood, and a long jointed *exopodite* usually known as the *maxillary palp*. The *second maxillæ* closely resemble the first maxillæ in structure, but the *labial palps* (or *exopodites*) are smaller and the protopodites are fused across the middle line, as noticed above, the two appendages forming the *labium*. The head is joined by a neck with small sclerites to the thorax. The thorax has three segments, called the *prothorax*, the *mesothorax* and the *metathorax*. These are freely movable. Each has a pair of *legs* on the ventral surface, hence the cockroach has three pairs of legs. Each has a basal piece or *coxa*, a small *trochanter*, a long *femur* and *tibia*, and a six-jointed *tarsus* terminating in two claws. On the dorsal surface of the male the mesothorax bears a pair of leathery wings (sometimes termed *elytra*), and the metathorax carries a pair of membranous wings.

The abdominal segments, like those of the lobster, are movable, and each has a *tergon* and *sternon*. There are *ten* abdominal segments. The terga overlap each other, and the 7th *completely* overlaps the small 8th and 9th; hence one can only count eight (1 to 7 and 10). The last or 10th is notched, and bears laterally a pair of many-jointed *anal cerci*. Of the nine sterna, the first is a mere rudiment and the 9th in the male bears a pair of small *styles*. In the female, the 7th is boat-shaped and envelopes the sterna behind it which are adapted for sexual functions. Hence in the female only seven sterna can be made out externally. At the hind end of the body the *anus* opens and below it is the opening of the genital organs. There are no excretory pores, but the respiratory organs or tracheæ open by ten paired apertures, the *stigmata*. Two of these open laterally between the thoracic segments, and the other eight lie between the terga and sterna of each of the first eight *abdominal segments*. Air is inhaled and exhaled through these stigmata by a rhythmic lengthening and shortening of the segments upon each other (caused by tergal and sternal muscles).

The external features show a marked contrast to those of the lobster. The principal differences are (1) the presence of only one pair of antennæ; (2) only three pairs of thoracic appendages; (3) the absence of abdominal appendages (except, perhaps, the anal cerci); (4) the presence of *stigmata* and absence of gills; and (5) the terminal position of the genital aperture.

**Sensory.** The antennæ are tactile and, like the antennules of the lobster, they are also said to possess *olfactory* hairs. The palpi are also tactile. The eyes have been already referred to.

Fig. 150.—DISSECTION OF COCKROACH FROM THE DORSAL SIDE. (*Ad nat.*)



The body-wall is removed and the alimentary canal pulled over to the right. The ventral tracheal system is seen as white tubes leading from the stigmata.

If the terga be gently cut off or freed by a scalpel the principal organs of the body are exposed. **Alimentary.** The *mouth* passes into a *buccal cavity* provided with a hard chitinous tongue. The paired *salivary glands*, with *salivary bladder*, open by ducts into this part. Thence a delicate *œsophagus* passes gradually into a large and spacious *crop*. At the hind end of the crop is the small thick-walled *gizzard*, provided with six chitinous *teeth* and *strainers*, as in the lobster.

The cavity of the gizzard is continued into that of the *mesenteron*, a comparatively short tube which leads into a still shorter and narrower intestine, terminating in a vesicular *rectum*. At the front end of the mesenteron are eight (or nine) *hepatic cæca* or hollow glandular processes, and at its hind end are six tufts of extremely fine long processes, called the *malpighian tubules*. They constitute the excretory organs of the cockroach. The rectum has six longitudinal folds. As in the lobster, the mesenteron alone is formed from endoderm, and absorption is confined to it. The parts in front and behind are formed of ectoderm and are lined by chitin. The digestive fluid from the cæca is said to pass forwards into the crop where it is mixed with the food. Here the food is digested or reduced to a soluble condition. The gizzard then relaxes and allows the digested food to pass on into the mesenteron, in which absorption is effected. The most important differences in the alimentary system from that of the lobster are (1) the presence of salivary glands (connected with the terrestrial habit); (2) the division of the "stomach" into a large storage crop and a small gizzard; and (3) the presence of excretory organs opening into the alimentary canal.

**Muscular.**

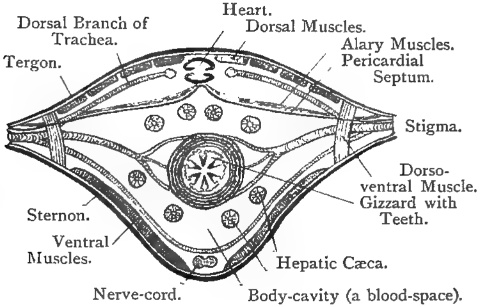
The cockroach has a complex system of muscles. In the abdomen the dorsal and ventral abdominal muscles are little modified. They serve to execute the respiratory movements, not to flex the abdomen. In the thorax the muscles are broken up into special limb muscles, moving the legs and wing-muscles for flight. The *alary* muscles run as a triangular band from the tergon of each segment towards the heart, spreading out under the pericardial septum and meeting its fellow below the heart. They may serve to move the pericardial septum.

As in the lobster, the muscles are attached to the exoskeleton but there is no endophragmal skeleton. The cavity of the body is largely filled up by the *corpus adiposum* or fat body, a mass of fat cells.

**Blood-Vascular.**

The heart is a long delicate tube running in the median dorsal line of the thorax and abdomen. It lies just under the terga. In each segment (three thoracic and ten abdominal) it opens by paired valves or ostia into the pericardial cavity surrounding it. On contraction of the heart the blood is driven forwards along the dorsal aorta, which terminates near the brain in a funnel opening into the body-cavity. The body-cavity is, therefore, a blood-space or hæmocœle in which the blood bathes all the tissues and eventually finds its way back to the heart. Immediately under the heart the *pericardial septum* stretches across the body-cavity, partially dividing it into a dorsal pericardial sinus and a ventral main cavity. The septum is a *fenestrated membrane*, being perforated by numerous apertures.

Fig. 151.—TRANSVERSE SECTION OF BLATTA. (Semi-diagrammatic.)



Passing through the anterior portion of the abdomen.

**Nervous.**

The brain lies in the head dorsal to the œsophagus. It has a paired anterior lobe which supplies the eyes and a posterior giving nerves to the antennæ. A ring round the œsophagus is completed by a sub-œsophageal mass, composed of three pairs of fused ganglia, belonging to the mandibular, maxillary and labial segments. This is followed by a double ventral nerve-chain with three thoracic ganglia and six abdominal.

The cockroach has a nervous system much like that of the lobster. As in the latter, we can recognise certain fusions. If we start with a brain and a chain with ganglia to each segment we get a total of five cephalic (of which the second has no appendages), three thoracic and ten abdominal ganglia, or eighteen in all. These are reduced to *ten* by the fusion of the first two to the brain, the fusion of the next three to form the subœsophageal mass, and the fusion of the last five to form the terminal abdominal ganglion. As in the lobster, the first two ganglia move forwards to the brain and the jaw-ganglia fuse together.

**Excretory.**

In the cockroach there is no trace of excretory glands opening at the base of any of the appendages. A different kind of excretory organ is found in the *Malpighian tubules* described above.

**Respiratory.**

The *tracheæ* are tubes, lined with chitin, thickened in a spiral, and passing inwards from the stigmata. They branch all over the body and pass into the wings. They appear in dissection like delicate silver tubes. In a general way, there pass inwards from each stigma a *dorsal*, a *ventral* and a *splanchnic* branch. The dorsal branches anastomose beside the heart, the ventral anastomose near the nerve-cord, and the splanchnic branch all over the viscera. The first stigma sends two large paired tracheæ forwards to supply the head.

**Reproductive.**

The male organs consist of a pair of minute *testes* in the dorsal part of the middle of the abdomen. They lead by small *vasa deferentia* into a "mushroom-shaped gland," a tufted organ which is really a paired *vesiculum seminalis;* an *ejaculatory duct* passes from these to the exterior.

In the female each of the paired *ovaries* consists of eight long tubes or *ovarioles*. They unite to form a pair of *oviducts* which open together on the 8th sternon. The short united portion is sometimes called the *uterus*. A pair of branched *colleterial glands* open into the uterus and a small sac or *spermatheca* opens on the 9th sternon. In both sexes there are *gonapophyses* or paired sclerites, modified to assist reproduction—in the male for copulation, in the female for deposition of the ova. In the female the 8th and 9th sterna are telescoped within the large 7th, producing a *genital pouch*. It should be noted that the female opening, as in the lobster, is two segments anterior to that of the male.

**Development.**

The eggs are laid in a capsule (one from each ovariole, making sixteen in all) formed by the *colleterial glands*. They have much yolk, and the segmentation is equal and superficial. A *ventral plate* is produced by a thickening of the cellular layer. This is invaginated, the walls meeting above and forming an *amnion*, a remarkable protective membrane, found also in land vertebrates. Some points of special interest in the subsequent development are the presence of a segment between that of the antennæ and that of the mandibles, and the presence of abdominal appendages which disappear later. These seem to point to the cockroaches having suppressed a head segment, probably corresponding to that bearing the antennæ in the lobster, and to their having in a similar way lost a number of abdominal appendages.

The mesoblast is present in the embryo as paired somites containing cœlomic cavities, separate from the hæmocœle or blood-space, part of which forms the heart. In later development, however, the mesoblast walls break up to form the muscles, connective tissue, gonads and walls of the heart; the cavities of the somites then become continuous with the hæmocœle. Thus there is no true perivisceral cœlom in the cockroach, a condition agreeing with other *Arthropoda.*

The young cockroach only differs from the adult by an absence of wings, and it grows gradually into the adult, passing through periodic *ecdyses* or shedding of its integument. Hence the cockroach is *ametabolic*, or developing without *metamorphosis.*

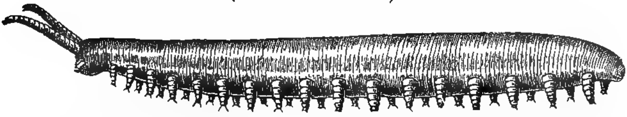
BLATTA.

| SEGMENTS. | | APPENDAGES. | NERVOUS SYSTEM. | APERTURES. |
|---|---|---|---|---|
| Prostomium. | | | Primary brain. | |
| Head. | 1 | Antennæ. | Brain. | Mouth. |
| | 2 | | | |
| | 3 | Mandibles. | Subœsophageal mass. | |
| | 4 | 1st Maxillæ. | | |
| | 5 | 2nd " | | |
| Thorax. | 6 | 1st Leg. | Ganglion 1 | |
| | 7 | 2nd " | " 2 | Stigma. |
| | 8 | 3rd " | " 3 | " |
| Abdomen. | 9 | | " 4 | Stigma. |
| | 10 | | " 5 | " |
| | 11 | | " 6 | " |
| | 12 | | " 7 | " |
| | 13 | | " 8 | " |
| | 14 | | Posterior ganglion 9 | " |
| | 15 | | | " ♀ ap. |
| | 16 | | | " " |
| | 17 | | | Anus, ap. |
| | 18 | Anal cerci. | | |

# III.—PERIPATUS.

| | |
|---|---|
| PHYLUM | ANNULATA (p. 237). |
| SUB-PHYLUM | ARTHROPODA (p. 240). |
| CLASS | PROTRACHEATA (p. 244). |

Fig. 152.—LATERAL VIEW OF PERIPATUS CAPENSIS. (After BALFOUR.)



Note the thick antennæ on the head, the long soft body with seventeen pairs of soft ringed legs, and the oral papillæ at the sides of the mouth.

**Peripatus capensis** is a small worm-like animal. The female may be 2½ inches in length and the male slightly smaller. The body is of a warm olive-green hue, shading off to light brown on the ventral surface. It is usually to be found hiding under stones or in the crevices of rocks, and occurs on Table Mountain.

The anterior end bears a pair of thick antennæ. Extending down either side of the body and protruding ventrally are seventeen pairs of stumpy legs terminating in two claws.

The *mouth* is on the under side of the head or anterior end and is covered laterally by a pair of *oral papillæ*, on which are the openings of the slime glands. They are apparently the first pair of post-oral appendages. Inside the mouth is a pair of chitinous jaws. At the hind end opens the *anus* which also has a pair of *anal papillæ*, probably the last pair of appendages. At the base of each leg, on the inner side, there is a *nephridiopore*. Immediately below the anus is the *genital aperture*.

The animal is strictly plano-symmetric. The body is soft and the cuticle is not thickened into sclerites, but there are a number of soft papillæ all over the surface which bear cuticular spines. Under the cuticle is a simple ectoderm covering the muscles.

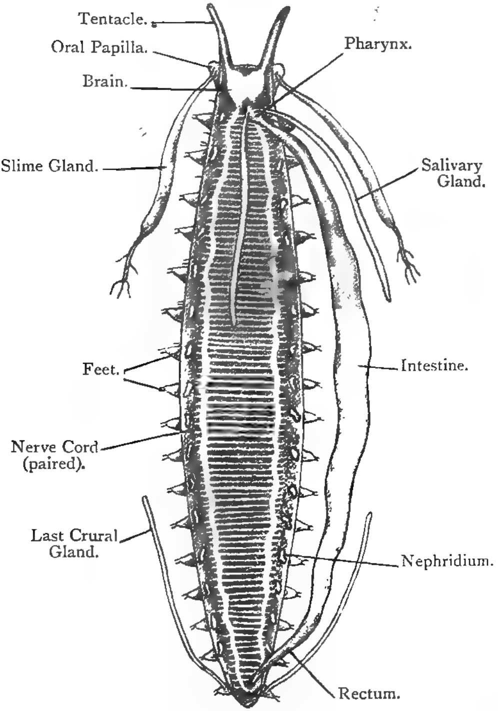
The antennæ are tactile and there is a pair of *simple* eyes at the base of the antennæ. The mouth, with its chitinous jaws, leads into a *pharynx*, into which there opens a large pair of *salivary glands*, said to be a modified pair of nephridia. A short œsophagus continues into a spacious but simple *stomach*. Quite at the hind end of the body the short *intestine* leads to the *anus*. The whole alimentary canal, as in the cockroach, lies in the cavity of the body and there are no mesenteries. Immediately below the ectoderm there is a thick layer of circular muscles, internally to which there is a series of longitudinal muscles, more or less broken up into dorsal, ventral, and lateral bands.

In addition, there are oblique bands running from the sides to the mid-ventral line.

*Peripatus* has little more skeleton than the *Annelida*, the scattered cuticular spines forming the nearest approach to an exoskeleton.

Fig. 153.—A Dissection of Peripatus Capensis from the Dorsal Surface.

(After Balfour.)



The cœlom is not present as a body-cavity, but is in the adult only represented by the cavities of the gonads and those of the nephridia. The actual body-cavity is a venous blood-space which thus contains blood and belongs to the blood-vascular system. Hence, as in the lobster and the cockroach, it leads directly into the dorsal heart by paired *ostia* or valves. The heart is itself a long tube lying dorsally, extending nearly the length of the body. It is surrounded by a *pericardial sinus*, as in the lobster.

The brain over the pharynx supplies the eyes and antennæ. A nerve-ring round the œsophagus unites it with the ventral nerve-chain. The two cords of this chain are widely apart and are connected by cross strands. At the hind end they communicate over the intestine. There are nineteen pairs of ganglia upon the cords, supplying the jaws, oral papillæ and the seventeen pairs of legs. There are seventeen pairs of nephridia (and the pair of salivary glands belonging to the segment of the oral papillæ). Each has a bladder or vesicle, leading to the exterior at the inner base of the leg, a coiled excretory portion and an internal nephrostome which opens into a small closed cœlomic space.

*Peripatus* breathes by tracheæ opening to the exterior by *stigmata.* Their arrangement is indefinite, though some are arranged in rows.

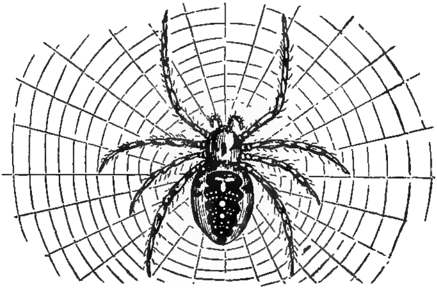
The sexes are separate. The male organs are a pair of testes lying over the stomach, leading to the genital pore by paired vasa deferentia. The ovary is unpaired and leads to the exterior by paired oviducts which are swollen to form *uteri.* The development takes place in the uterus, hence *Peripatus Capensis* is viviparous.

## IV.—EPEIRA.

| | | |
|---|---|---|
| PHYLUM | - - | ANNULATA (p. 237). |
| SUB-PHYLUM | - - | ARTHROPODA (p. 240). |
| CLASS | - - | ARACHNIDA (p. 258). |

Fig. 154.—A COMMON GARDEN SPIDER (*Epeira diademata*).

Resting in the centre of its web. Dorsal aspect and about natural size.



Note the four pairs of legs, the small leg-like pedipalpi, the cephalothorax and the large soft abdomen with white marks and dots.

*Epeira diademata* is one of the commonest of our British spiders. The figure is about the natural size of the female;

**Habits.**

the male is smaller and of more delicate build. The colour varies considerably in shades of brown, but is always mottled in blotches and irregular markings of white. The most characteristic of these is a T-shaped white mark on the abdomen, followed by two or more large white dots. The legs are barred.

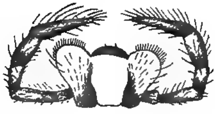
*Epeira diademata* lives in the centre of its vertical web. usually head downwards. The web is commonly suspended between branches of a shrub.

**External Features.**

The body is constricted by a "waist" into an anterior smaller part called the *cephalothorax*, and a large posterior globose part, the *abdomen.* Neither part shows any external indications of segmentation and the abdomen is soft to the touch. The abdomen bears no appendages but the cephalothorax has six pairs. The anterior of these are called the *cheliceræ.* They are two-jointed, and the distal joint is in the form of a sharp curved stylet connected with a *poison gland* in the proximal joint. The second pair are the *pedipalpi* or feelers; they appear like a pair of short legs and really function as arms. The basal joint is formed into a kind of jaw and the terminal joint in the adult male is modified into a swollen "palpal organ" for transferring the sperms into the seminal receptacle of the female. The next four appendages are *legs,* many-jointed and covered with numerous hairs.

Fig. 155.—The Two First Pairs of Appendages of Epeira Diademata. (*Ad nat.*) Magnified.

Cheliceræ.



Pedipalpi.

Note the non-chelate poison fangs (cheliceræ) and the fused pedipalpi with long palps, also non-chelate.

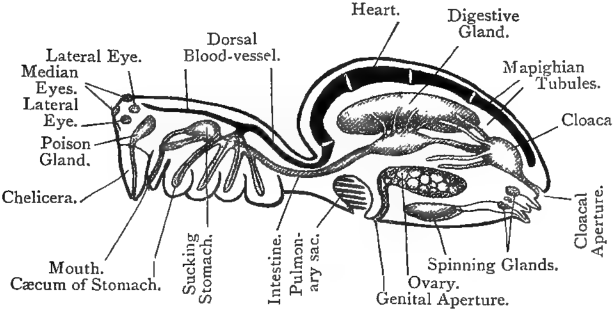
The spider, therefore, differs from the insect in having no pre-oral appendages or antennæ, and in possessing four pairs of legs instead of three.

The *mouth* is a minute ventral aperture between the two cheliceræ and the *anus* is at the tip of the abdomen. Immediately in front of the anus is a swollen process which is found to consist of four papillæ or *spinnerets,* at the tip of each of which there is a great number of minute apertures. These communicate with the *spinning glands* lying in the abdomen, a complex series of glands which produce threads of various kinds, according to the requirements of the spider. Further forward on the ventral line of the abdomen opens the *genital aperture* and on either side of it the single pair of *stigmata* leading into the *pulmonary sacs.* Lastly, just in front of the spinnerets there is a small median aperture leading into four *tracheæ.*

**Integumentary.**

The integument of the spider consists of a thin cuticle over the abdomen, thickened in the cephalothorax. The whole surface is more or less covered with fine hairs which extend down to the tips of the legs. The dorsal anterior surface of the cephalothorax

Fig. 156.—Longitudinal Sagittal Section through Epeira Diademata (♀). (Semi-diagrammatic, after Leuckart.)



is smooth and bears six eyes which are of the simple type. Four are arranged in a small square and the other two laterally.

**Alimentary.**

The mouth leads up a small tubular *pharynx* and a short *œsophagus* into the large "sucking" *stomach.* The walls of this organ can be drawn outwards by strong muscles, causing powerful suction. The true stomach is small and expands into long *cæca* which end blindly towards the bases of the legs. The intestine is narrow and leads through the "waist" into the abdomen. Here it swells into a sac, receiving the ducts of a large *digestive gland* and then is continued as the *rectum* into the *cloacal* sac. The spider kills its prey by its poison cheliceræ, bites it open with the cutting bases of the pedipalpi, and sucks its juices by means of its sucking stomach. The juices are stored in the stomach and its cæca and digested and absorbed in the intestine. We may note the absence of any crushing gastric mill, so characteristic of the lobster and cockroach. Again, we can observe a certain resemblance in the alimentary system of the spider to that of the leech, due to a similar method of feeding.

**Muscular.** The muscular system is much broken up into limb muscles and other special muscles, and it is difficult to recognise much trace of the annelid and protracheate arrangement.

**Cœlom.** The cœlom has much the same relationship as in the *Insecta*—that is, it is inferred that the perivisceral part is not represented. There is a pair of small and degenerate *coxal glands* which in some young spiders open by a duct at the bases of the legs. These are held to be vestigial excretory organs of the nephridial type, and in the young scorpion they are said to have internal openings into the cœlom.

The heart is a long dorsal tube surrounded by a *pericardial sinus* into which it opens by three pairs of ostia. The heart is continued forward into main arteries which finally open into the venous sinuses composing the body-cavity. Some of these communicate with the pulmonary sacs and thence pass to the heart. The pulmonary sacs are therefore in the same position in the blood circuit as are the gills of the lobster and similarly the heart is systemic.

**Nervous.** The nervous system is concentrated in the cephalothorax. It consists of a brain above the pharynx, supplying the eyes and the cheliceræ, and connected by a nerve-ring with a ventral nerve-mass formed of at least five pairs of fused ganglia. From it nerves are given off to the pedipalpi, the legs and the abdominal organs. *Epeira* shows a great degree of nerve-concentration and in this respect differs from some *Arachnida*.

The vestigial excretory organs, or coxal glands, have already been alluded to. The functional organs are four long coiled malpighian tubules opening into the cloaca. In addition to possessing two kinds of excretory organs, the spider also has two kinds of respiratory organs. The two pulmonary sacs are situated in the antero-ventral part of the abdomen and consist of large chambers containing a number of flat horizontal *lamellæ* with thin walls. Stigmata put their cavities in communication with the exterior. There are in addition four tracheæ opening, as stated, by a ventral aperture in front of the spinnerets. They do not differ essentially from the tracheæ of the insects. Hence the spider has two sets of breathing organs, pulmonary sacs and tracheæ.

**Excretory.**

**Respiratory.**

The *ovaries* are paired tubes uniting to form *oviducts* which open into a median *uterus.* The uterus opens into the genital pouch, into which also open two *seminal receptacles.* The pouch is provided with a kind of gonapophysis, called the *epigynium.* The *testes* are simple tubes with *vasa deferentia* uniting into a *sperm-sac* with a median aperture just behind the stigmata.

**Reproductive.**

The eggs are laid in holes and corners during the autumn, and are often enveloped in silky cocoons. They have a large amount of yolk, and the development is embryonic. They hatch in the spring, the young spider differing but little from its parent. The spiders form the order *Araneina* of the class *Arachnida.*

**Development.**

(For General Characters of Sub-Phylum Arthropoda, see page 240).

## PHYLUM ANNULATA.

The *Annulata* form one of the three great phyla of the *Metazoa.* They are typically elongated plano-symmetric animals. They always have three primary layers, the mesoderm filling more or less of the space between the ectoderm and endoderm. The whole body is segmented or made up of a number of segments or metameres, in which many organs are repeated. In the lower types there can be distinguished a pre-oral part, in front of the mouth, called the prostomium, and a segment immediately behind the mouth called the *peristomium* which differs in many respects from the segments behind it. In the great majority each segment carries a pair of appendages which may be parapodia, legs, jaws, and so on.

The nervous system consists of a dorsal brain in the prostomium, a circumoral ring round the front end of the gut and a double ventral nerve-chain with or without ganglia.

The heart, when present, is dorsal to the alimentary canal and may show traces of segmentation.

There are never true "shells," as in the *Mollusca*, but the body is enclosed in a thin cuticle or a thickened cuticular *exoskeleton*.

The phylum is divided into two sub-phyla:—(1) ANNELIDA and (2) ARTHROPODA.

## SUB-PHYLUM I.—ANNELIDA.

The *Annelida* is the sub-phylum of segmented worms, and in anatomical characters it is sufficiently definite. The most diagnostic characters of the sub-phylum are (1) the metameric segmentation. The body has a great number of segments, usually preceded by a prostomium and a peristomium. The nervous, blood-vascular, cœlomic and excretory systems are mostly repeated in the segments. (2) The nervous system always consists of a dorsal brain in or near the prostomium, a nerve-ring in the peristomium, and a long ventral chain, usually more or less segmented and showing a double origin. (3) The muscular system and *chief* method of locomotion are quite characteristic. The circular and longitudinal muscles, contained in a tough, flexible body-wall, work in conjunction with external organs (setæ, suckers) and with the internal vascular cœlomic fluids in the way described for *Arenicola*. (4) Highly developed nephridia are not confined to the sub-phylum, but are very characteristic of it.

The four classes are intimately connected by intermediate types but can hardly be further approximated.*

CLASS I.—ARCHIANNELIDA. From the type *Polygordius* it can be seen that this class contains the simplest

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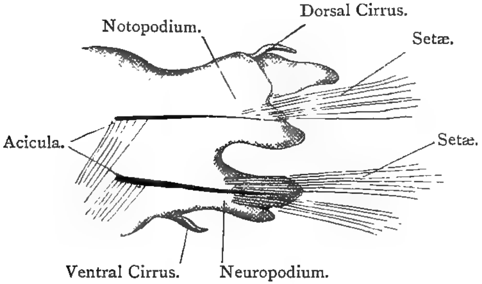
* The *Polychæta* and *Oligochæta* are often placed together as *Chætopoda*, with the presence of setaæ in common.

and most primitive of the *Annelida*, as is shown by the ectodermal nervous system, the persistence of radial septa and longitudinal mesenteries, the simple nephridia and the absence of appendages. It contains two or three other small worms.

CLASS II.—POLYCHÆTA. This class has a great number and variety of types. Many live in tubes and burrows and the anterior end bears a mass of tentacles and gills, whilst the free-swimming forms often have a great development of lateral appendages which are in many cases used for swimming. They are called *Polychæta* because they usually have great numbers of setæ.

Fig. 157.—FOOT OR PARAPODIUM OF A NEREIS. (*Ad nat.*)



CLASS III.—OLIGOCHÆTA. As in *Lumbricus*, the body is usually without appendages or gills and has only comparatively few setæ. They are usually divided into the mud dwelling (freshwater) forms and the terrestrial. Their hermaphrodite and complex sexual organs and protected embryonic development are characteristics.

CLASS IV.—HIRUDINEA. In many respects this class resembles the last, especially in the absence of appendages, the hermaphrodite sexual organs and the development. It is, however, clearly characterised by the reduced condition of the cœlom and its continuity with the blood-vascular system, by the suckers and the mode of life.

The most important features of the sub-phylum and the classes are summarised in the subjoined table :—

## SUB-PHYLUM ANNELIDA.

1. Cœlomate Metazoa with bilateral symmetry (plano-symmetry).
2. Metameric segmentation.
3. Nervous system is a brain above œsophagus, a circumoral ring and double ventral nerve-chain with ganglia.
4. A vascular system of vessels or sinuses and perivesceral cœlom is usually present.
5. Paired lateral appendages often present.
6. Muscles are arranged in definite circular and longitudinal layers.
7. Excretory organs are paired nephridia (many).

| Class I.<br>ARCHIANNELIDA<br>*Type—Polygordius.* | Class II.<br>POLYCHÆTA.<br>*Types—Arenicola and Nereis.* | Class III.<br>OLIGOCHÆTA.<br>*Type—Lumbricus.* | Class IV.<br>HIRUDINEA (DISCOPHORA).<br>*Type—Hirudo.* |
|---|---|---|---|
| 1. No setæ on body. | Many setæ on parapodia. | No parapodia and few setæ. | A pair of suckers and no parapodia. |
| 2. Prostomial tentacles, but no branchiæ. | Usually branchiæ, cirri and tentacles. | No branchiæ, cirri or tentacles. | No branchiæ, cirri or tentacles. |
| 3. Diœcious. | Diœcious. | Hermaphrodite. | Hermaphrodite. |
| 4. Larval development. | Indirect larval development (Trochophore). | Direct development. | Cœlom reduced to a dorsal and ventral sinus and other smaller parts, which communicate with the vascular system. Gonads have separate ducts to exterior. |
| 5. Marine. | Marine, free-swimming or sedentary. | Freshwater or terrestrial. | Free freshwater or marine, partially ectoparasitic. |

## SUB-PHYLUM II.—ARTHROPODA.

In the ARTHROPODA the body, as a rule, is enclosed in a thickened cuticular exoskeleton, which may or may not be further strengthened by calcareous particles. The paired appendages undergo a similar modification, producing jointed limbs. These are bent towards the ventral surface and serve to support the body. These appendages show far more adaptive modification into jaws, legs and feelers than in the lower sub-phylum. In many of the higher types of *Arthropoda* the body and its parts become compressed into a compact form, losing the elongated character and disguising the segmentation. The simple annelid eyes are replaced by the compound eyes.

In the mesodermic organs there are important modifications from the annelid type. The simple circular and longitudinal muscles of the body-wall become largely broken up into segmental muscles and limb-muscles. At the same time the perivisceral part of the cœlom is replaced by the enormously developed hæmocœle or blood-space, the actual body-cavity of an arthropod being a venous blood-space communicating directly with the heart. The paired nephridia or excretory organs are replaced gradually within the sub-phylum by excretory organs of another type. The nephridia are still present in *Peripatus*, but the coxal glands of *Arachnida*, and the shell-gland and green-gland of *Crustacea*, are usually supposed to be much modified nephridial organs. Malpighian tubules appear in *Insecta*, *Arachnida* and *Myriapoda*. Lastly, a centrolecithal type of segmentation appears to be characteristic of the *Arthropoda*.

The Arthropoda have five classes — (1) Crustacea, (2) Protracheata, (3) Myriapoda, (4) Insecta, and (5) Arachnida.

## CLASS I.—CRUSTACEA.

The *Crustacea* are typically aquatic and breathe by gills. They have two pairs of antennæ or feelers on the head. The first five segments are aggregated together into one mass, termed the head, and a number of the other segments may form a thorax and abdomen. The appendages are typically biramous and used for swimming, but more or fewer are modified into legs and jaws. The *Crustacea* are typically marine and the lower marine types have a free *nauplius* larva. This larva is pelagic and has a dorsal shield, an unpaired eye and three pairs of swimming appendages round the mouth. The first is uniramous and becomes the antennules; the second and third are biramous and form the *antennæ* and *mandibles*. The nauplius, like the trochophore, grows into the adult by elongation of the hind-end of the body and production of fresh segments. In the higher *Crustacea*, with much yolk in the egg, a stage comparable to the nauplius is passed through in the egg.

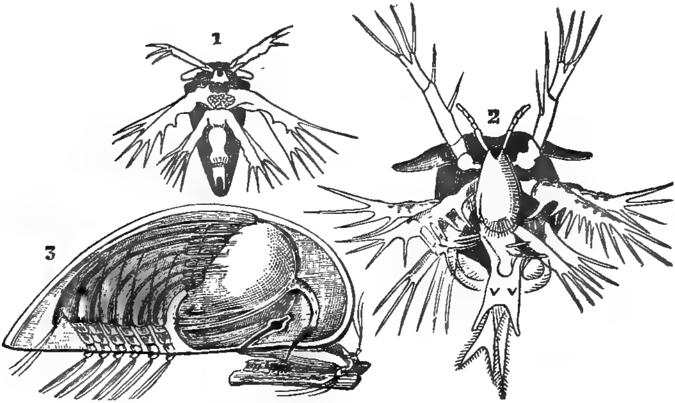
If we trace the class from the lowest to the highest, we can notice a general advance in size and complexity of the body, in reduction and consolidation of the segments, and in the gradual adoption of embryonic development.

There are two sub-classes—(1) Entomostraca and (2) Malacostraca.

### SUB-CLASS I.—ENTOMOSTRACA.

These are nearly all small and simple *Crustacea*. There is great variety in the number of the segments. The excretory organ (shell-gland) is situated on the second maxillæ, and there is never a gastric mill. The *Entomostraca* develop by a free-swimming *nauplius* larva.

Fig. 158.—THE LIFE-HISTORY OF CIRRIPEDIA.



1. Nauplius larva of *Balanus*. Ventral view. Note three pairs of swimming appendages, the last two being biramous and the median simple eye.

2. A rather later larval stage of *Chthamalus*. The posterior region is elongating.

3. *Cypris* larva of *Lepas*. Just fixed by its anterior end (antennæ) to a piece of wood. Note the six pairs of biramous appendages and the enveloping shield.

The *Phyllopoda* have foliaceous or leaf-like appendages. Some are small and are known as water-fleas. *Daphnia* is a very common freshwater type. *Apus* is a large phyllopod with a head-shield covering most of the body. The

*Ostracoda* have the exoskeleton formed into a pair of lateral shells resembling those of bivalve *Mollusca.* They show a very degenerate condition of the body. *Cypris* is a common freshwater type. The *Copepoda* are an immense assemblage of marine and freshwater crustaceans, usually of small size. They play the part in marine life of the insects on land. Great numbers are pelagic and form the staple food of larval fish. *Cyclops* is a common little "water-flea" found in ponds. Many *Copepoda* are parasites and are so modified in form and shape that their crustacean affinities would hardly be recognised except for the early development. Much the same remark applies to the *Cirripedia*, of which the barnacles and acorn-shells are important types.

The barnacle (*Lepas*) has a long stalk which is usually affixed to a floating log, the hull of a ship, &c. The body is enclosed in five calcareous shells, and there are six pairs of legs which are covered with processes. Their perpetual movement serves to supply the animal with microscopic food. The acorn-barnacle has no stalk and is enclosed in a conical outer shell in addition to the movable shells. In each case the young start life as *nauplius* larvæ, and pass through the stage of a free-swimming crustacean which fixes itself to a foreign body and becomes a sessile adult.

Fig. 159.—Lateral View of Lepas (Barnacle). (Natural size.) (*Ad nat.*)

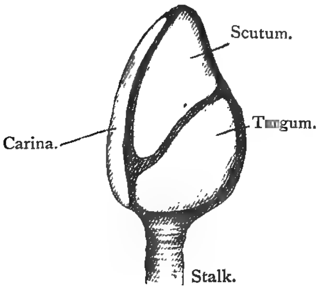
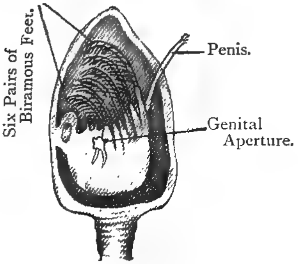


Fig. 160.—Lateral View of Lepas Anatifera. (*Ad nat.*)



With right shell removed showing anima lying in mantle cavity.

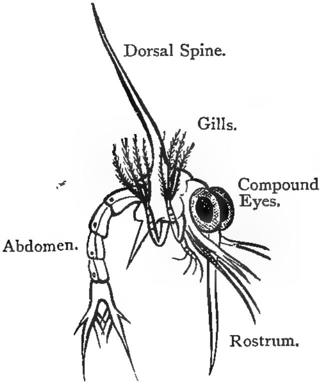
## SUB-CLASS II.—MALACOSTRACA.

The *Malacostraca* include the higher types of *Crustacea.* The body usually consists of twenty segments and the appendages are much modified. The excretory organ, the antennary gland, opens on the second antennæ and there is usually a gastric mill. The nauplius larva is of rare occurrence, the early development being embryonic.

The order *Arthrostraca* comprises *Crustacea* with sessile eyes, and with not more than two thoracic segments fused with the head. The freshwater shrimps, sand-hoppers, and the terrestrial woodlouse (*Oniscus*) are good examples. The *Decapoda* form the most important order of *Malacostraca.* The head and thorax are enveloped in a carapace and there are five pairs of legs (including chelæ). The eyes are stalked. They include the lobsters, shrimps and prawns, the crabs and hermit-crabs.

The crabs have the abdomen reduced and tucked forward on the under side of the thorax. The appendages are closely similar to those of the lobsters, but the nerve-ganglia are more consolidated. The hermit-crabs have a long, soft abdomen, which they protect in a shell. The shell is usually a disused whelk-shell or that of some smaller gastropod. The chelæ are of different sizes, adapted to the spiral of the shell. The appendages on the abdomen are vestigial.

FIG. 161.—A ZŒA LARVA OF A DECAPOD. (Lateral view.)



Note the paired eyes, the spines, abdomen without appendages, and gills with no gill-cover.

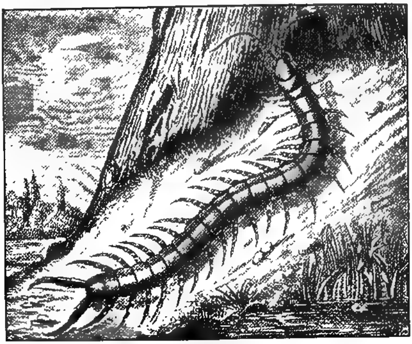
## CLASS II.—PROTRACHEATA.

*Peripatus* constitutes, not only the type, but the sole order of this class.

## CLASS III.—MYRIAPODA.

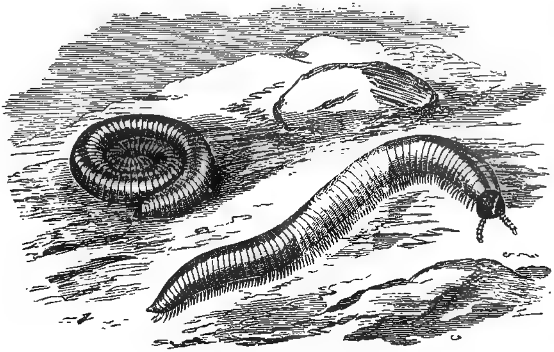
The *Myriapoda* resemble most nearly the *Insecta*. Like them, they breathe by tracheæ, excrete by malpighian tubules and have one pair of antennæ. They differ from them in having no definite thorax nor abdomen; the body

Fig. 162.—SCOLOPENDRA CINGULATA (A CENTIPEDE).



Note head with antennæ, segmented body and a single pair of jointed legs to each segment.

Fig. 163.—JULUS TERRESTRIS (A MILLIPEDE).



Note head with antennæ, the very numerous segments, and two legs to each segment. On the left is seen an individual coiled up.

consists of a series of separate segments, each having one (or two) pair of jointed legs *Scolopendra* is typical of the carnivorous order of *Chilopoda* (*Centipedes*). The other order, *Chilognatha*, is herbivorous and a common example is the millipede (*Julus terrestris*). The millipedes chiefly differ from centipedes by the more cylindrical body, two pairs of legs in each segment and the forward position of the genital aperture.

## CLASS IV.—INSECTA.

In the *Insecta* the body is sharply defined into three parts—the *head*, *thorax* and *abdomen*. The head consists of five segments and carries one pair of *antennæ* and *three pairs of jaws*. The thorax has three segments and bears three pairs of legs. It may also carry two pairs of *wings*. The abdomen is jointed and has about *ten* segments with no appendages. There are no true gills and respiration is effected by tracheæ. Excretion is by *malpighian tubules* and there is usually a metamorphosis.

Insects are mainly terrestrial and ærial. The cockroach is typical in all features except the absence of a metamorphosis.

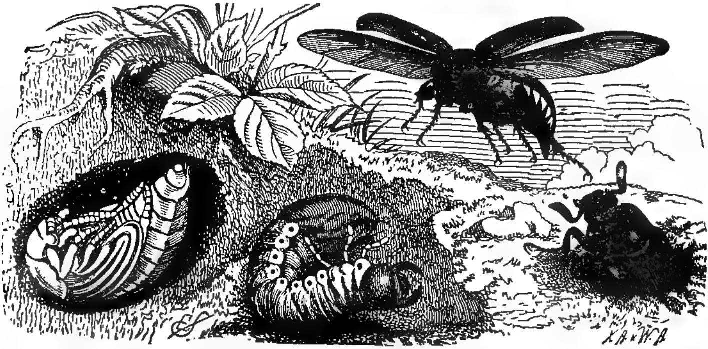
Amidst a multitude of adaptive modifications, the insects conform to a remarkable extent to the general characters of the class. They are divided into orders by (1) the adaptations connected with the mouth-parts or jaws, (2) the condition and structure of the wings, and (3) the degree of metamorphosis.

The largest and economically the most important orders are those with a full metamorphosis. The young one is hatched as a *larva* which is usually more or less worm-like. The larva passes through a quiescent *pupal* stage of varying duration, and is then set free as the *imago* or perfect insect.

### ORDER I.—*Coleoptera* (*Beetles*).

The beetles have a complete metamorphosis, the mouth parts, like those of the cockroach, are of the biting type, and the first pair of wings are modified into hard *elytra* or wing-covers.

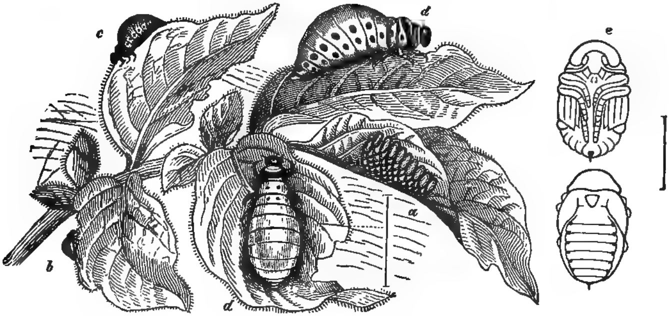
Fig. 164.—THE LIFE-HISTORY OF THE COMMON COCKCHAFER (*Melolontha vulgaris*).



The underground larva is seen in the middle, the pupa to the left, and the male is emerging on the right. The female is flying, showing elytra and wings.

A very typical and common beetle is the cockchafer which works havoc upon vegetable life throughout its career. The eggs are laid in the soil and the larvæ feed upon the roots of grass or almost any herbaceous plant. After about four years of larval and pupal life, the beetle emerges in early summer and commences its depredations upon the leaves of trees. The larva of some click-beetles is called a "wire-worm" and does great harm to crops. The Colorado

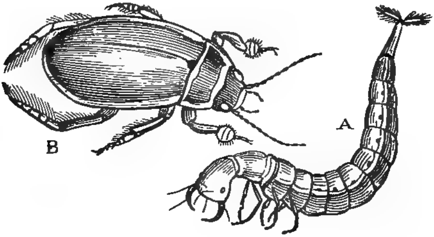
Fig. 165.—COLORADO BEETLES (*Chrysomela decemlineata*).



*a*, Eggs on the under surface of the leaf; *b*, *c*, *d*, various stages in the larva; *e*, pupa—the upper is the ventral view, the lower the dorsal.

or potato-beetle works untold mischief in potato fields, the larva feeding upon the leaves. The whole development is accomplished in four weeks and the fecundity is very high. Other interesting beetles are the burying-beetles which bury the bodies of small animals as food for their larvæ, the useful "lady-birds" which feed on green aphides, and the various water-beetles which have aquatic larvæ.

Fig. 166.—A WATER-BEETLE (*Dytiscus marginalis*).



A, The aquatic larva with soft body.

## ORDER II.—*Hymenoptera*.

The metamorphosis is complete, the mouth parts are modified for biting and licking and there are two pairs of membranous wings. There is no one popular name for the *Hymenoptera*, but they include the Ants, Bees, Wasps and Gall-flies. The "biting and licking" mouth parts are well illustrated by those of the bee. The mandibles are of the biting and crushing type, and the first maxillæ form a pair of semi-cylindrical tubes enveloping the labium. The maxillary palps are vestigial. The labial palps are long and the end of the labium is produced into a long flexible hairy "tongue" or *ligula*. It can be withdrawn inside the basal part of the labium. The maxillæ form a suctorial cylinder and the ligula serves to lick honey and pollen.

The *Hymenoptera* are of special interest from their social habits. Ants, bees and wasps of many species live in communities in which there is structural and physiological division of labour. In the case of the bees there can be distinguished the males or drones, the female or queens,

Fig. 167.—THE HIVE BEE (*Apis mellifica*).

Drone ♂. Queen ♀. Worker or Neuter.

Three sorts of individuals.

and the workers, which are sterilised females. In the ants the workers have no wings.

The gall-fly lays its eggs on plants and the "gall" is produced by the plant around the egg. The insect escapes from the "gall" by a small hole. The ichneumon-flies are of economic value from their habit of laying eggs in caterpillars of certain *Lepidoptera*. The larvæ feed on the substance of the caterpillar and eventually kill it. The saw-flies have larvæ somewhat like caterpillars but with more legs. They are sometimes called "false" caterpillars and

Fig. 168.—THE GALL-FLY (*Cynips quercus-folii*).

The galls are shown on the left, the interior of a gall on the right, and the perfect fly below.

infest turnips. Many of the *Hymenoptera* have a sting at the hind end of the abdomen. This is modified from the ovipositor which in its turn is comparable with the gonapophyses of the cockroach. In the saw-flies the ovipositor is in the form of a pair of saws which are used for perforating holes in twigs, in which the eggs are deposited.

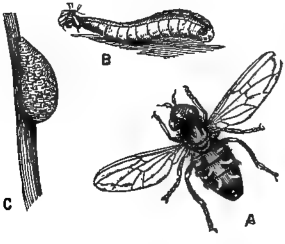
### ORDER III.—*Diptera.*

Fig. 169.—TSETSE FLY (*Glossina morsitans*) × 3.

The deadly African fly.

The *Diptera* have a full metamorphosis, the mouth parts adapted for "piercing and sucking," and there is a single pair of membranous wings. The hind wings are reduced to a pair of small *halteres* or balancers, processes with knobs. They comprise the Flies, Gnats and Fleas.

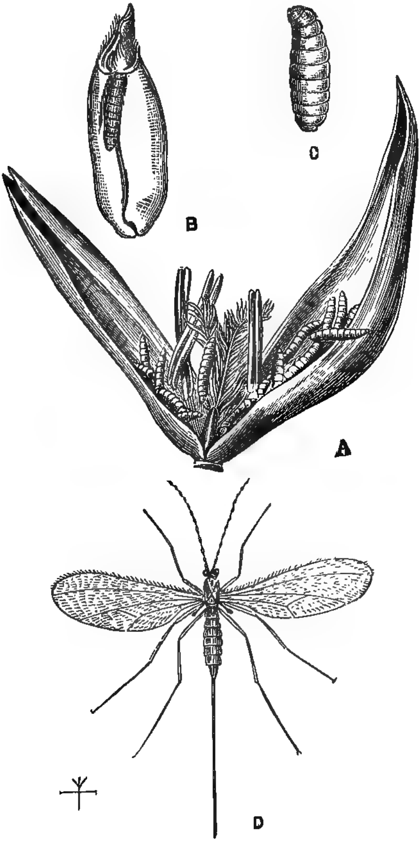
Fig. 170.—SYRPHUS PYRASTRI.



A fly (A) whose larva (B) feeds upon the green aphis; C is the pupa.

The “piercing and sucking” mouth parts are well shown in the gad-fly (*Tabanus*). The upper lip (*labrum*) mandibles and maxillæ are lengthened and produced into sharp stylets, whilst the labium is produced into a long hairy proboscis with two terminal lobes. In gnats the “piercing” stylets are best developed, whilst in flies, such as the house-fly, the ‘sucking” proboscis is large and the stylets are small.

Fig. 171.—WHEAT MIDGE (*Cecidomya tritici*).



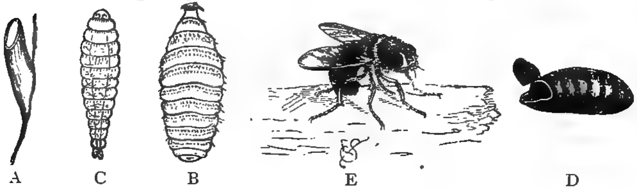
A, Larva in wheat-flower; B, larva in grain; C, larva; D, fly.

The gnats have aquatic larvæ, the eggs being laid on the surface of the water. The Hessian Fly and the Wheat Midge both belong to the same genus, and both are destructive to crops, the larvæ feeding on the leaves or flowers. The common "daddy-long-legs" or crane-fly has a larva which feeds underground on the roots of grass. The bot-flies have a peculiar life-history. The common "horse-bot" lays its small white eggs on the hair of the horse. The larva is found in the stomach of the horse and may give rise to serious inflammation. Other "bots" live in the nasal cavity of the sheep or under the skin of

Fig. 172.—THE DADDY-LONG-LEGS OR CRANE-FLY (*Tipula oleracea*).

Male and also larva on the left, the female and the pupa on the right.

Fig. 173.—THE HORSE-BOT (*Gastrus equi*).



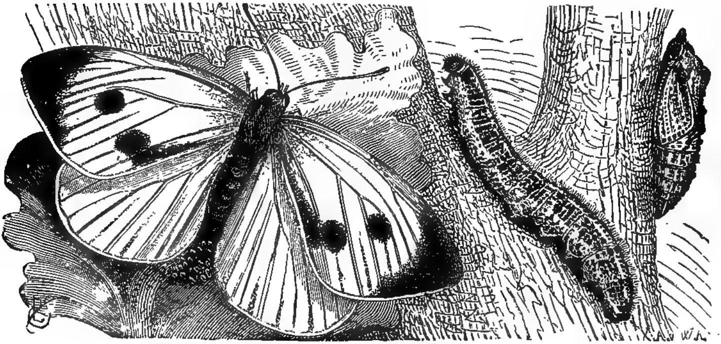
A, Egg on a horse-hair; C and B, larvæ; D, pupa case; and E, the fly.

the ox. The fleas form a modified type of the *Diptera*, with the wings reduced to mere rudiments, a loss of motor organs characteristic of parasites.

## ORDER IV.—*Lepidoptera.*

The metamorphosis is complete. The mouth parts are adapted for "sucking," and there are two pairs of large opaque wings which are covered with minute scales. In this order are included the "butterflies" and "moths." The mouth parts are much modified. The mandibles are mere vestiges, and the maxillæ are produced into a long spirally-coiled "proboscis," composed of two half-cylinders apposed together. The labium is small and bears a pair of fairly large labial palps; the maxillary palps are vestigial. In use the proboscis is uncoiled and thrust into flowers, nectar being sucked up its interior.

Fig. 174.—THE CABBAGE WHITE (*Pieris brassicæ*).



Female depositing eggs, larva (caterpillar), and pupa.

The wings are covered with minute scales of varying shape which are easily rubbed off when the membranous wing is exposed. As a general rule butterflies or moths have bright colours on the upper surface of the wings, and sombre protective colours below (*cf.* Chap. IX.).

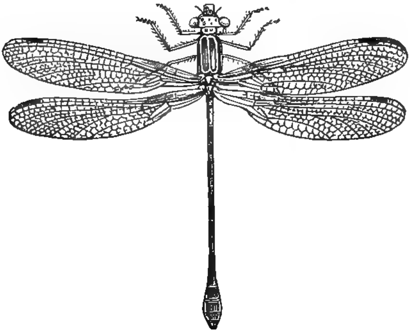
The larva is a "caterpillar" which often executes great destruction amongst plant-life.

The "Cabbage White" lays its eggs on cabbages and turnips which the larvæ devour. A great number of the night-flying moths have underground caterpillars which do damage to crops.

The relationship of *Lepidoptera* to flowers and the correlated structural modifications in each are full of interest. In a general way, the flowers employ *Lepidoptera* to carry pollen, and so fertilise and attract them by a supply of nectar.

### ORDER V.—*Neuroptera.*

Fig. 175.—DEMOISELLE DRAGON FLY (*Agrion puella*).

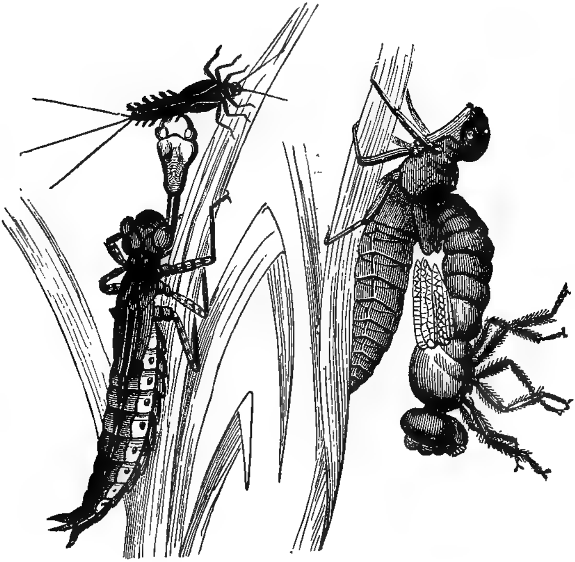


Notice the Nervured Wings.

The *Neuroptera* have biting mouth parts and two pairs of membranous wings, usually of equal size and covered with a network of veins. The metamorphosis is usually incomplete, but in many cases is complete.

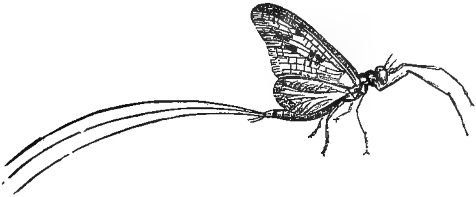
The most important of the *Neuroptera* are the Dragon-flies, with an incomplete metamorphosis and an aquatic larva with a movable labium like a hand; the May-flies, also with aquatic larvæ, the fly only living a few hours; the Caddis-flies, the aquatic larvæ of which protect themselves in cases of twigs or stones and pass through a complete metamorphosis with a pupal stage; lastly, the Ant-lions, the larval stage of which digs traps for ants.

Fig. 176.—THE STAGES OF DRAGON-FLY.



Larva of Dragon-fly catching prey (a larval May-fly) by the labium. On right the perfect insect is emerging.

Fig. 177.—THE MAY-FLY *(Ephemera vulgata)*.



## ORDER VI.—*Orthoptera*.

The mouth parts are of the "biting" type; the first pair of wings are chitinous and form covers for the second pair which are membranous. The metamorphosis is incomplete or absent.

Our type, the cockroach, belongs to this order and with it is a remarkable series of forms, of which we can merely mention the most important. The earwigs have the gonapophysis formed into pincers and live mostly in flowers. The grasshoppers and locusts are large types with powerful hind legs; in tropical countries great devastation is caused by swarms of the migratory locust. The mole-cricket has the habits and many of the structural peculiarities of the mole. The stick- and leaf-insects exhibit remarkable protective resemblance.

Fig. 178.—The Grasshopper (*Locusta viridissima*).

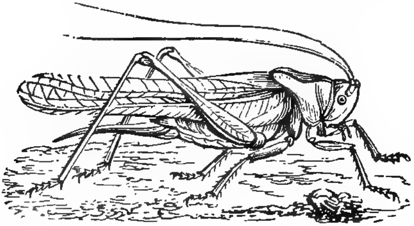
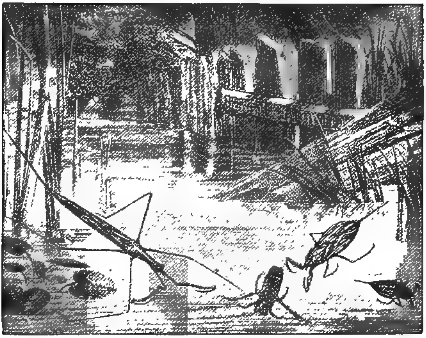


Fig. 179.—A Group of Hemiptera (Water-Bugs) in natural surroundings.

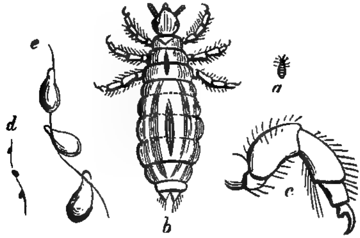


On the left is the long *Ranatra linearis*; on the right are two Water-Scorpions (*Nepa cinerea*); and in the centre is the Water-Boatman (*Notonecta glauca*).

## ORDER VII.—*Hemiptera.*

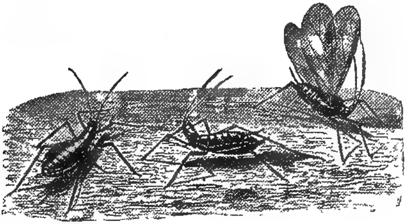
In this order there is great variety in the wings, which are often absent, but the mouth parts are typically "sucking," the labium forming a long sucking "rostrum," and the metamorphosis is incomplete. The *Hemiptera* are mostly either aquatic insects or dwell on plants and suck their juices. Of the aquatic types the "water-scorpion" has the first pair of legs modified into kind of maxillipedes; the water-boatman swims at the surface on its back, the hind legs imitating a pair of oars. Of the terrestrial type the green aphis is peculiar in reproducing parthenogenetically during the summer, and in secreting a juice of which ants are very fond.

Fig. 180.—THE COMMON LOUSE (*Pediculus*).



*a*, Natural size; *b*, magnified; *c*, a leg; *d*, hair with "nits" or eggs; *e*, ditto magnified. A degenerate Hemipterous insect.

Fig. 181.—THE ROSE APHIS.



## ORDER VIII.—*Aptera.*

A few small insects comprise this order, their mouth parts are biting, they have no wings and no metamorphosis.

In addition, the segments of the thorax are free. They are probably the most primitive of insects. The common silver-fish *(Lepisma)* is a good example.

## CLASS V.—ARACHNIDA.

The spider is not so typical of the *Arachnida* as is the cockroach of the *Insecta*. The *Arachnida* are a more primitive class and the various orders are more divergent in structure than those of the *Insecta*.

As a class they are distinguished by the absence of pre-oral appendages or antennæ, by the division of the body into cephalothorax and abdomen, or no division. They resemble the insects in the common presence of tracheæ, in the malpighian excretory organs, and in absence of appendages on the abdomen. The four pairs of walking legs are usual and the presence of coxal glands in several of the orders is important.

Of the many and divergent orders we can here only refer to three.

### ORDER I.—*Scorpionida.*

The scorpions are large arachnids. They have six pairs of appendages on the cephalothorax, as in spiders, but the first two pairs form small and large chelæ (called *chelicerœ* and *pedipalpi*) respectively, the other four being the walking legs. The abdomen is segmented, the first seven segments being much larger than the last five. The sternon of the first segment has a pair of genital apertures. The second bears a pair of *pectines* or combs, probably tactile in function, and the next four have diagonal slits on their ventral surface, the *stigmata*, leading into the lung-books. The seventh segment has no appendages nor apertures. The five last are elongated and form the tail, terminating in a post-anal spine. At the base of the spine is a poison-gland, a duct from which passes up a groove along the sting The scorpion agrees with the spider in the possession of simple eyes, coxal glands and the general structure of its body, but its nervous system is less concentrated.

### ORDER II.—*Araneina.*

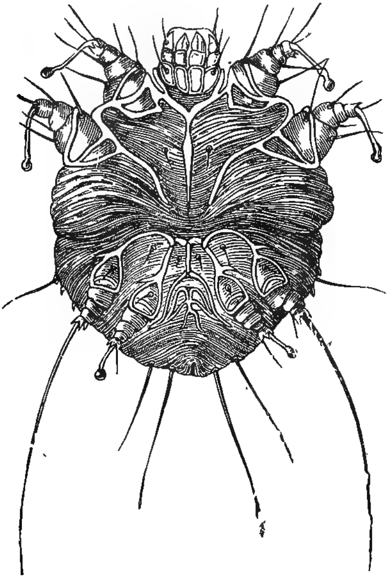
The spiders are a widely distributed and successful order of Arachnida. They prey naturally upon insects which they either hunt or catch by webs. One group, with four pulmonary sacs, contains large hairy hunting spiders. Some build small tunnels with trap-doors. The other group, with only two pulmonary sacs, contains all the common web-spiders. One species (*Argyroneta*) lives under water in a web diving-bell.

Female spiders, as a rule, are larger and more powerful than males.

### ORDER III.—*Acarina.*

The mites are small animals with soft globose body in which there is no distinction of cephalothorax or abdomen, and no trace of segmentation. They have four pairs of legs and the cheliceræ and pedipalpi are used for piercing

Fig. 182.—MITE CAUSING MANGE IN THE PIG (*Sarcoptes scabii*) × 120.



Ventral view. Note the cheliceræ, pedipalpi and four pairs of legs.

and sucking. The best known are skin-parasites (or ecto-parasites) upon various animals. The type shown is a mange-mite which tunnels in the skin of the domestic animals, and gives rise to the painful "itch" or skin mange.

Other *Arachnida* are the little long-legged "harvest-men," the book-scorpions and certain parasites. Lastly, there is an interesting animal, the king-crab (*Limulus*), which lives in mud of shallow seas in the Oriental region. It breathes by gill-books and has a large cephalothoracic shield, six pairs of chelate appendages and a long post-anal spine. It appears to be an aquatic Arachnid of very primitive character.

Fig. 183.—THE HARVESTMAN (*Phalangium cornutum*). Magnified.

[TABLE.

## SUB-PHYLUM ARTHROPODA.

1. Cœlomate metazoa with bilateral symmetry.
2. Metameric segmentation.
3. Nervous system is a brain over the œsophagus, a nerve-ring and a segmented ventral nerve-chain.
4. A well-developed vascular system with dorsal systemic heart.
5. Paired lateral jointed appendages are found on each segment.
6. Body encased in hard ectodermal cuticular exoskeleton to which may be added calcareous matter.
7. Paired compound eyes are usually present.
8. Cœlom is reduced and largely replaced by blood (hæmocœlic) spaces, such as the pericardium and the body-cavity.
9. Development usually with superficial segmentation (centro-lecithal).

| Class I.—PROTRACHEATA.<br>*Type—Peripatus.* | | Class II.—MYRIAPODA.<br>*Type—Scolopendra.* | Class III.—INSECTA.<br>*Type—Blatta.* | Class IV.—ARACHNIDA.<br>*Type—Scorpio.* | Class V.—CRUSTACEA.<br>*Type—Nephrops.* |
|---|---|---|---|---|---|
| 1. Body divided into head and body. | | Head and body. | Head, thorax, and abdomen. | Cephalothorax (prosoma) and abdomen (mesosoma, metasoma). | Head thorax (or cephalothorax) and abdomen. |
| 2. One pair of antennæ. | | One pair of antennæ. | One pair of antennæ. | No antennæ. | Two pairs of antennæ. |
| 3. One pair of jaw appendages (oral papillæ). | | Two pairs of jaw appendages (mandibles and maxillæ). | Three pairs of jaw appendages (mandibles, two pairs maxillæ). | Two pairs of jaw appendages. | Many jaw appendages. |
| 4. Breathe by tracheæ. | | Breathe by tracheæ. | Breathe by tracheæ. | Breathe by tracheæ or pulmonary sacs or gill-books. | Breathe by gills. |
| 5. Many soft legs. | Annelid Characters. | Many jointed legs. | Three pairs of legs on thorax (no appendages on abdomen). | Four to five pairs of legs on cephalothorax (no appendages on abdomen). | Many pairs of legs (usually paired biramous appendages on abdomen). |
| 6. Excrete by nephridia. | | Excrete by malpighian tubules. | Excrete by malpighian tubules. | Excrete by malpighian tubules and coxal glands. | Excrete by shell-gland or antennary gland. |
| 7. Simple eyes. | | | Commonly a metamorphosis. | | Often a free larval nauplius. |
| 8. Crural glands. | | | | | |
| 9. Simple layers of muscles. | | | | | |
| 10. Terrestrial and widely distributed. | | Terrestrial. | Terrestrial. | Terrestrial (*Limulus*, water spiders, &c., aquatic). | Aquatic, freshwater and marine. |

# CHAPTER XVIII.

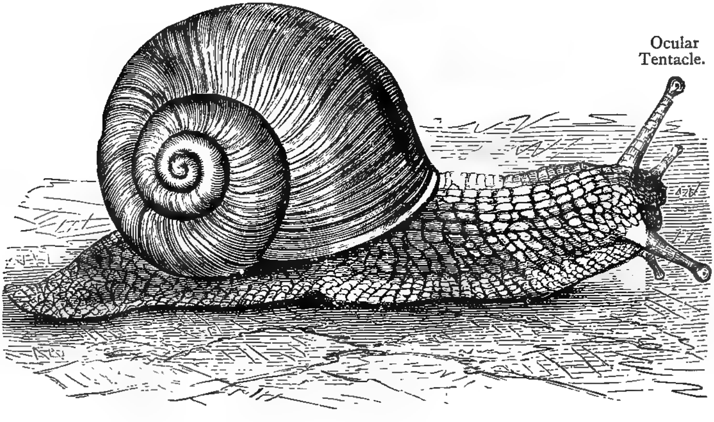
## MOLLUSCA.

HELIX. ANODON. SEPIA.

## I.—HELIX.

| | |
|---|---|
| PHYLUM | MOLLUSCA (p. 282). |
| CLASS | GASTROPODA (p. 283). |

Fig. 184.—LATERAL VIEW OF THE ROMAN SNAIL (*Helix pomatia*). Natural size.



Note the creeping foot, spiral shell and head with tentacles.

**Helix pomatia** (the edible or Roman snail) is slightly larger than *Helix aspersa* (the garden snail) and more convenient for dissection. It does not differ in essential features. The body is of a dark greenish-slate colour, and the shell of a uniform pale drab.

**Colour.**

The snail is a vegetable-eater and mostly nocturnal in its habits. It hibernates in the winter, when it closes up the aperture of the shell by an *epiphragm* of chalky matter and hardened mucus. It is in most features a plano-symmetric animal but its symmetry is in

**Habits.**

part destroyed by the twisting of the portion contained in the shell and consequent loss of some organs and distortion of others.

**External Features.**

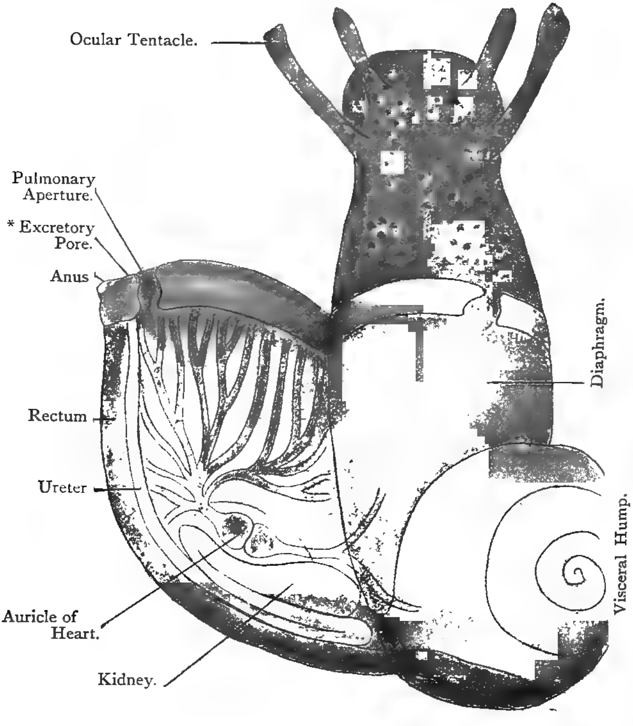
The whole ventral surface is expanded into a flat muscular creeping organ or *foot*, and in the mid-dorsal region is the *shell*, containing a part of the body called the *visceral hump*. The whole body is soft, and has no cuticular exoskeleton as in the *Arthropoda*, nor is there any trace of metameric segmentation.

The shell is a right-handed spiral. Its central axis is called the *columella*, with a hollow cavity, the *umbilicus*, in its centre. The apex of the shell represents its first formed portion or *nucleus*. The shell consists of three layers, the outer *chitinous* and coloured part, the middle white *calcareous* layer, and the inner thin smooth *nacreous* layer. Round its edge may be seen the *collar* or thickened edge of the *mantle* which secretes the shell. The anterior end of the body forms the *head*, which bears two pairs of retractile tentacles, the upper of which carry a terminal *eye*. Just below the head is the mouth, with a chitinous upper jaw and a pair of soft lateral lips. Below the head and above the foot is the wide opening of the *pedal gland* which secretes the slime on which the foot creeps. On the right side of the head is a small opening, the *genital aperture*. Towards the right end of the collar is a large opening, the *pulmonary aperture*, leading into the *pulmonary chamber*, a space below the mantle. Close to this aperture are the *anus* and the *excretory pore*. All the four external apertures last mentioned are therefore asymmetric and on the right side only.

If the shell be broken off carefully the visceral hump is exposed. The lowest inch or so of the coil will be seen to be formed of a soft membranous *mantle* in which there are numerous *pulmonary veins*. Air is taken through the pulmonary aperture into the pulmonary chamber, hence the mantle forms the respiratory organ of the snail. In this respect it differs from the great majority of *Gastropoda*, which are aquatic and breathe by gills under the mantle.

If the thickened edge of the mantle (*collar*) be cut away from its line of fusion with the dorsal wall of the body, and the cut be carried up the inner spiral just below the *rectum* (seen as a white tube running down to the *anus*), the mantle flap can be reflected over to the left and the true dorsal surface of the body or *diaphragm* exposed. The pulmonary chamber is then seen to be triangular in shape, bounded by the collar in front, the vascular mantle above and the diaphragm below. Along its outer edge, emerging at the

Fig. 185.—First Dissection of Snail (*Helix pomatia*). (*Ad nat.*)



The snail is pinned out on its ventral surface, and the mantle is cut free from the body by a cut along the collar and round the spiral. Note the pulmonary veins in the mantle leading to the auricle of the heart, which passes to the ventricle and thence by an aorta to the body.

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* The excretory pore is really within the pulmonary aperture.

posterior angle from the upper coils, is the long tubular *rectum* terminating in the anus.

**Excretory.**

**Blood-Vascular.**

Just inside this is a fine tube, the *ureter*, leading from the excretory pore backwards to the *kidney*. This is a large lobular dark-brown organ lying at the posterior angle of the cavity where the mantle joins the body. On its inner anterior side is an oval space with thin walls, the *pericardium*. The kidney opens by a small aperture into the pericardium, which is a part of the cœlom, the kidney being regarded as a large specialised nephridium. Inside the pericardium lies the *heart*, a two-chambered organ. The thin-walled *auricle* receives blood from the pulmonary veins and pumps it into the *ventricle*. This, on contraction, propels the blood along a main *aorta*, which passes into the body and divides into anterior and posterior arteries. The venous system consists of large lacunæ or spaces around the organs. As in the *Arthropoda*, the body-cavity is a hæmocœle or venous blood-space, the cœlom being only represented by the pericardium and possibly other parts. As in the lobster, the heart is systemic and receives blood from the breathing organs.

Fig. 186.—Diagrammatic Median Sagittal Section through the Head of a Snail.

(In part after Howes.)

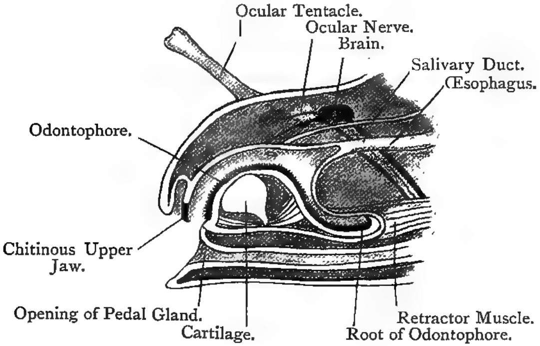
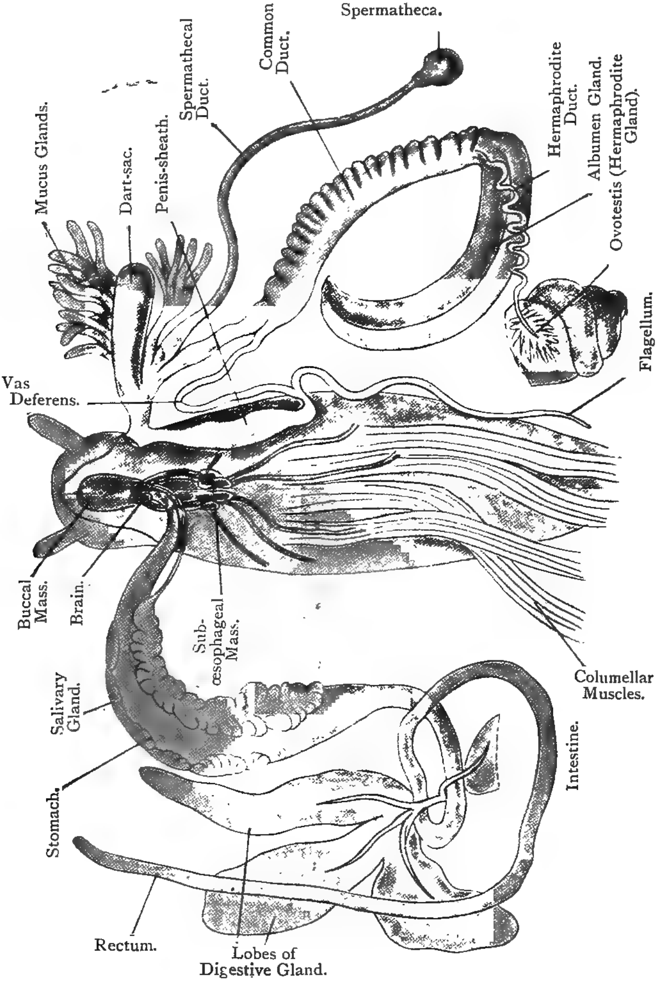


Fig. 187.—Second Dissection of Snail (*Helix pomatia*). (*Ad nat.*)



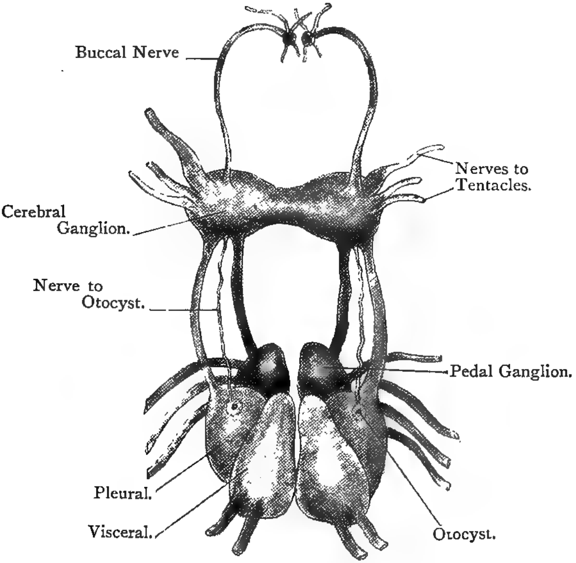
The body wall is cut open along the mid-dorsal line and up the spiral. The spiral lobe of the digestive gland is cut through and thrown over to the right along with all the reproductive organs. The alimentary organs are released and thrown over to the left, the nervous system and columellar muscles remaining in their normal position.

If the dorsal surface of the body be now cut open by a median incision, the alimentary, reproductive and nervous systems are all exposed, and may be easily dissected out. If the alimentary organs be moved over to the left and the reproductive to the right, the appearance of Fig. 187 is produced.

**Alimentary.**

The mouth leads into a large muscular *buccal mass.* It contains the *odontophore* (or radula), an important molluscan organ. The odontophore is a long ribbon bearing innumerable rows of little chitinous teeth. It grows from a root posteriorly as it is worn away anteriorly, and lies over a buccal cartilage moved by muscles. The snail employs it like a rasping tongue. On the dorsal side of the buccal mass, just over the odontophore, open a pair of *salivary ducts* leading from *salivary glands* covering the stomach. The *œsophagus* leads from the posterior end of the buccal

Fig. 188.—The Nervous System of the Snail.
Removed entire, and viewed from the dorsal side. (After Howes.)



mass to the *stomach*—which is a dilatation of the alimentary tube—and is continued onwards as the *intestine*. A little way up the coil the intestine bends on itself and receives the ducts of a four-lobed *digestive gland*. The fourth lobe occupies the top spiral of the shell. After another bend the intestine ends in the *rectum*.

**Nervous.**

The nervous system consists of ganglia and connectives, but the ganglia are to a large extent concentrated. The *brain* (or cerebral ganglia) lies dorsal to the œsophagus* and is joined by two connectives on each side to the *ventral nerve-mass*. This is formed of three pairs of partially-fused ganglia, the *pedal*, *pleural* and *visceral*. The brain supplies the eyes and otocysts and the buccal mass, whilst the ventral nerve-mass sends long nerves to all parts of the body. In the substance of the ventral nerve-mass is a pair of *otocysts*, supplied, as stated, by nerves from the brain.

**Sensory.**

**Reproductive.**

The snail is hermaphrodite and the reproductive organs are complex. The genital organ or *ovotestis* is a small white branching organ situated in the spiral lobe of the digestive gland. From it the *genital duct* passes as a coiled white tube down beside the columella. Here it swells into a wide *common duct*, and receives the opening of the large *albumen gland*. The common duct has its internal lumen gradually divided into male (♂) and female (♀) parts by a septum. Eventually these two diverge as the thin *vas deferens* and the thicker *oviduct*. The vas deferens, after bending on its course, terminates in a large protrusible *penis*. At the base of the penis there is a *retractor* muscle running across to the left side of the body and a long hollow tube or *flagellum*. The oviduct receives the *spermathecal duct*, running backwards beside the common duct to terminate in the round *spermatheca* near the upper end of the latter.† The oviduct leads into the *vagina*. Two branched *mucus glands* then open into this, and it ends at the genital pore beside the male opening. Just at the opening lies a large muscular organ, the *dart-sac*, in the lumen of which there often is found a calcareous dart.

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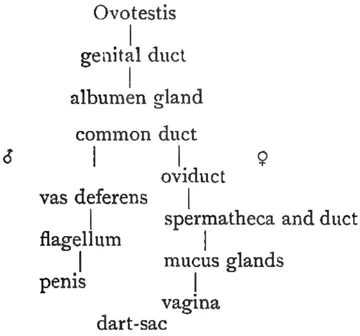
* Occasionally the buccal mass is withdrawn through the nerve-ring and the brain is then found lying in front of the former.

† In *Helix aspersa* the spermathecal duct has a long flagellum.

Hence we have—



The functions of these organs, so far as known, are :—

The snail is a *protandric* hermaphrodite, *i.e.*, the male organs become mature first and the female after. The ovotestis gives rise to spermatozoa, which pass down the genital duct, the common duct and the vas deferens into the flagellum. Here they are aggregated into a rod-like mass, the *spermophore.* During this process darts are secreted in the dart-sac and forcibly ejected from the genital pore into the skin of other snails. This is followed by copulation, when the sperms are introduced by the penis of one snail into the base of the spermathecal duct of another. They pass up into the spermatheca and are there retained.

The ovotestis next produces eggs which pass down the genital duct to the head of the common duct. The sperms then leave the spermatheca, make their way down the spermathecal duct and back again up the oviduct and common duct, at the upper end of which they fertilise the eggs. Albumen is then added to the eggs from the albumen gland, and they pass down to the *vagina.* Here they are covered with mucus from the mucus glands and are discharged to the exterior. In some species they are contained in calcareous shells. The eggs are laid in damp earth and the development is embryonic, the young newly-hatched snail differing little from its parent.

## II.—ANODONTA.

| | |
|---|---|
| PHYLUM | MOLLUSCA (p. 282). |
| CLASS | LAMELLIBRANCHIATA (p. 284). |

**Habits.**

**Anodonta cygnea*** (the freshwater mussel) is a convenient example of the large and important class of *Lamellibranchiata*, or bivalve molluscs. A full-grown individual may be as long as five inches. The

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* This description also applies to *Anodonta anatina.*

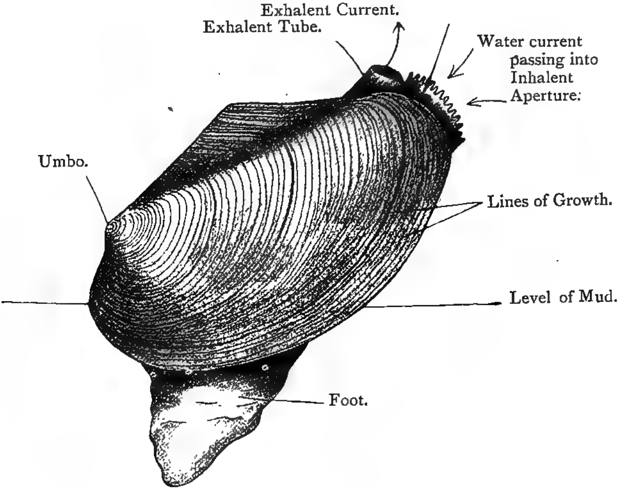
whole body is completely enclosed in a pair of large oval shells which, unlike the shells of *Brachiopoda*, are lateral.

**External Features.**

The animal is found half buried in the mud of ponds and streams. The shells are of a dark brownish-black colour and composed of the same three layers as in the snail. On the dorsal side they move against each other by a *hinge*, and they can be opened by the contraction of an elastic *ligament*, just outside the hinge Just above the hinge is a small first-formed part called the *umbo*. On the inside, the dried shells have several scars caused by the attachment of parts of the body. A little way inside and parallel to the ventral edge of the shell is a line called the *pallial line*, caused by the edge of the mantle, or pallium. At the anterior end of the pallial line is a large oval scar produced by the anterior adductor muscle; and at the posterior end is

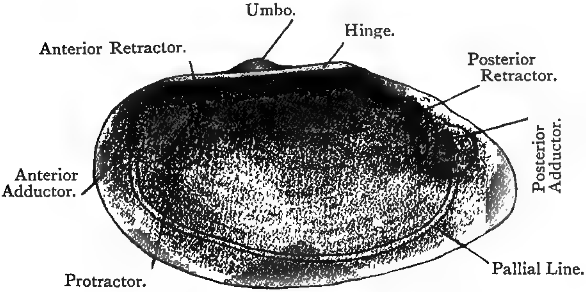
Fig. 189.—LATERAL VIEW (LEFT) OF ANODONTA IN NATURAL POSITION AND FEEDING.

(Mainly after HOWES.)



a similar scar of the posterior adductor. The adductors run across from shell to shell, and their contraction draws the shells together. Inside each adductor scar is a smaller round scar, caused by the anterior and posterior *retractors*, which serve to draw the foot into the shell. Lastly, near the anterior adductor scar is a small *protractor* scar, the muscle serving to draw the foot forward. The attachments of the muscles shift outwards and downwards as the shells grow.

Fig. 190.—Internal View of Right Shell of Anodonta. (*Ad nat.*)



When the shells are forced open they expose a large *mantle-cavity*. This is bounded dorsally by the body of the animal and laterally by the lateral mantle-folds ; ventrally it is widely open to the exterior, except when the shells are shut. The mantle-flaps line the inner surface of the shells, which they secrete. The free edges are pressed together, except at the posterior end, where they diverge to form a large *inhalent opening*, then meet, and again diverge to form the smaller *exhalent opening*.

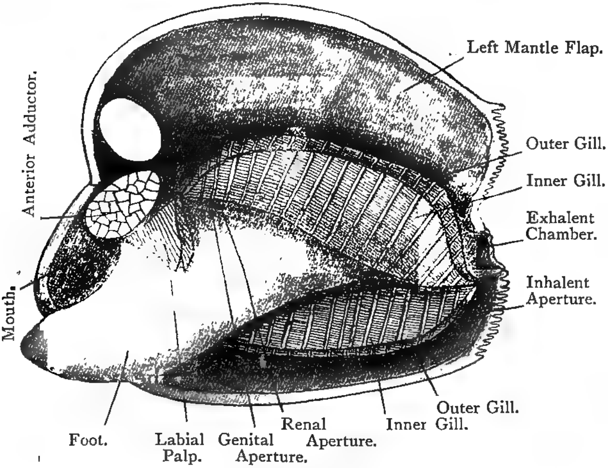
In the centre of the mantle-cavity a large muscular *foot* depends downwards and on occasion it can be protruded outwards between the shells. Embedded in the foot, near the pedal ganglia, are the otocysts, but *Anodonta* has no eyes. There is a pair of *osphradia* or sense-organs of an olfactory nature at the base of the gills, innervated from the visceral ganglia.

**Sensory.**

On either side of the foot there hang the *gill-lamellæ*, or *ctenidia*. These are lamellæ on each side, formed in each case by a *gill-plate* folded on itself, the outer gill-plate outwards and the inner inwards. The gill-plates are themselves composed of a number of *gill-filaments*, which hang perpendicularly in a single row from a horizontal axis which is fused with the body-wall.

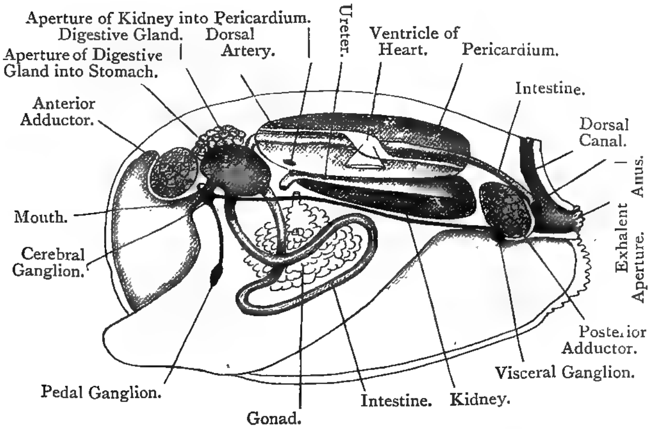
**Respiratory.**

Fig. 191—VIEW OF ANODONTA WITH LEFT MANTLE-FLAP THROWN BACK. (*Ad nat.*)



A ctenidium therefore consists of a medium axis with two rows of gill-filaments, each row forming a gill-plate. In *Anodonta*. but not in all *Lamellibranchiata*, these gill-plates are bent double to form in each case two gill-lamellæ. In addition, the filaments and the gill-lamellæ have fused with their fellows and thus form a network of filaments. The whole are ciliated and cause currents of water and food-particles to pass into the mantle-cavity by the inhalent aperture. The free edges of the upturned gill-plates are fused to the body-wall, and thus shut off outer and inner *supra-branchial chambers* from the mantle-cavity below. Posteriorly these lead into the exhalent chamber. The water appears to pass between the gill-filaments directly into the supra-branchial and exhalent chambers, ærating the blood in the gill-filaments in its course. The food-particles appear to pass forward to the *mouth*, which is situated just under the anterior adductor muscle. They are assisted by a pair of flat triangular *labial palps* in each side. From this it is seen that the ctenidia serve the two purposes of alimentation (food ingestion) and of respiration. They appear to be derived from organs of the same nature as the gills of other molluscs.

Fig. 192.—Dissection of Anodonta from Left Side (Slightly Diagrammatic).



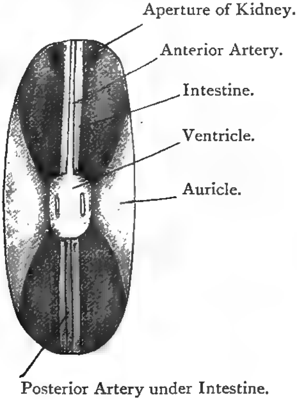
**Alimentary.**

The mouth leads into a short *œsophagus* passing into a globular *stomach*, into which open the ducts of a *digestive gland*. From the stomach the long *intestine* descends into the base of the foot, and after complex coils it again ascends to the dorsal region and passes backwards over the posterior adductor muscle to open by an *anus* into the exhalent aperture. We may note the entire absence of "head," buccal mass and odontophore.

**Motor.** We have already referred to the adductor muscles for closing the shells and the protractors and retractors of the foot. The main substance of the foot is muscular and it is thrust out ventrally at the will of the animal, acting as a burrowing organ.

**Blood-Vascular.** The heart is situated dorsally and is three-chambered. The median *ventricle* envelops the intestine and passes forwards and backwards into main arteries. It is fed by paired lateral *auricles* which open into it by valves. They receive blood from the ctenidia. The heart and this part of the intestine lie in a spacious cavity, the *pericardium*, which is cœlomic in origin. The venous system, as in the snail, is lacunar, and formed of sinuses and cavities in the body. A large median sinus below the pericardium feeds the ctenidia. Hence the blood-vascular system closely resembles that of the snail; the chief difference is the paired condition of the auricles (like that of the shells).

Fig. 193.—Dorsal View of Heart and Pericardium of Anodonta. *(Ad nat.)*



**Nervous.** The brain, situated laterally to the mouth, consists of a pair of *cerebral ganglia* joined forwards by a connective. From the brain there run paired connectives to the *pedal ganglia* in the anterior part of the foot, and to the *visceral ganglia* situated immediately below the posterior adductor muscle. There is here less concentration than in the snail, the pedal and visceral loops being very long and wide.

**Excretory.** Immediately under the pericardium lie the paired *kidneys.* They consist of tubes bent upon themselves. Each has an internal opening into the anterior end of the pericardium, which passes into the lower excretory part or kidney. From the posterior end of each kidney a ureter passes forward between it and the pericardium to open into the inner supra-branchial chamber, and thence to the exterior. These tubes may be regarded as two specialised nephridia. The walls of the pericardium also have excretory cells, which are known as the pericardial glands (organ of Keber).

**Reproductive.** *Anodonta* is diœcious. The *testis* or *ovary* is a diffuse paired organ lying below the kidneys. The paired genital duct *(oviduct* or *vas deferens)* passes up and opens just below the excretory pore on each side.

**Development.** The eggs are shed into the supra-branchial chamber, where they are fertilised and develop into *glochidia,* or small two-shelled larval forms, which differ in many respects from their parents. They leave the parent by the exhalent aperture. A little dorsal to the exhalent aperture, the two mantle-edges again diverge to form a small slit-like aperture. This is connected by a median canal above the intestine with the exhalent chamber, and embryos have been observed escaping by it. The glochidium is said to be parasitic upon certain fish, and undergoes a metamorphosis into the adult.

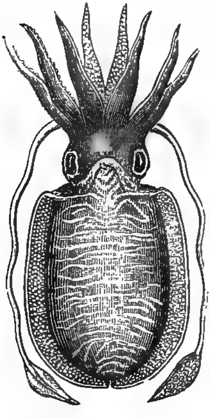
The general likeness of *Anodonta* to the snail will be apparent. The plano-symmetry is, however, more perfect, shown in the paired shells, kidneys, auricles, gills, &c. The absence of buccal mass, odontophore and eyes, and the immense development of the ctenidia (which, present in most *Gastropoda,* are absent in the snail) are the chief points of distinction.

## III.—SEPIA.

| | |
|---|---|
| PHYLUM | MOLLUSCA (p. 282). |
| CLASS | CEPHALOPODA (p. 284). |

**Sepia officinalis** is a large mollusc, often nearly a foot in length. It is found commonly round our coasts, though more abundant in the south. It lives a free, roaming, pelagic life, and is a voracious flesh-eater. Its dried shell is often found cast up on the shore. The animal consists of a *head* and *body*. The body is flattened and shield-shaped, with a lateral expansion or fin along each edge. The head has ten tentacles, of which the fourth pair are as long as the body and bear a pad of suckers at the end. The other eight have four rows of small suckers on their inner surface. A dead "cuttle" appears of a dull white colour with patches of drab, but in life there is a beautiful play of colour and light over the whole surface of the body. This is caused by a number of *chromatophores* or pigment cells which are actively contractile, and hence can alter their extent. The result is an ever-changing colour and iridescence. In a general way, the upper surface of the body is of a dark brown hue. It is horizontally striped with irregular bands of white and the fins are similarly dotted with white. The dorsal surface of the head is also brown. The tentacles and the whole under-surface are pearly white. *Sepia* is plano-symmetric to a marked degree, and there is no trace of torsion as in the snail. The mouth is situated between the tentacles and is armed by a pair of powerful horny jaws or beaks, not unlike those of some parrots in size and appearance. The head is connected to the body by a constricted *neck*, around which hangs the front edge of the *mantle*.

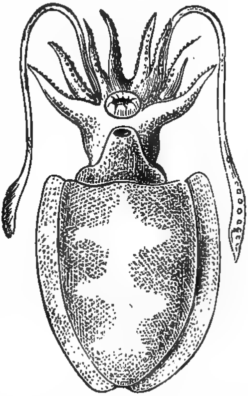
Fig. 194.—DORSAL VIEW OF THE COMMON CUTTLE (*Sepia officinalis*) × $\frac{1}{5}$.



On each side of the head is a large simple eye; although of the simple type the eye is complex in structure. It has all the more important parts of the vertebrate eye, such as *cornea*, *lens*, *iris*, *vitreous humour* and *retina*, and is supplied by large optic nerves from the brain. Just behind each eye is a ciliated *olfactory pit*, and near the brain is a pair of large *otocysts*. As is to be expected from its free active life, large size and complexity of structure, the "cuttle" has sense-organs far in advance of those found in any other *Mollusca*.

**Sensory.**

Fig. 195.—Ventral View of a Cuttle (*Sepia officinalis*) × $\frac{1}{6}$.



Note the ten arms with suckers, the mouth between them and the "siphon" immediately behind it.

**Respiratory.**

The *mantle* fuses on the lower surface to enclose a large *mantle-cavity* which is blind behind but opens widely at the neck. Just in front of this opening lies the *siphon*, a tube which opens by a large funnel behind into the mantle-cavity, and by a small aperture forwards under the head. The hind edges of the siphon are so arranged that water expelled from the mantle-cavity passes through the siphon, but water inhaled passes in between the edges of the siphon and the mantle.

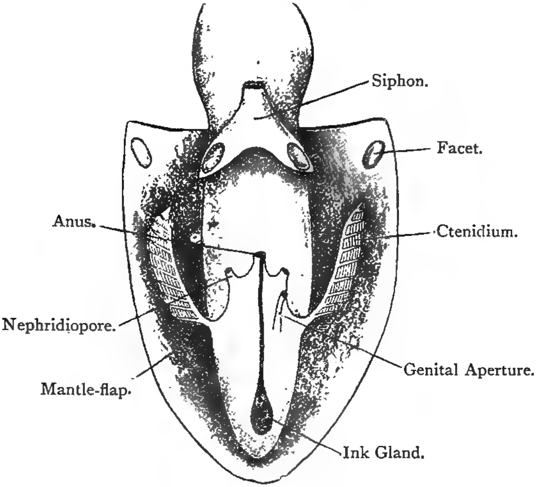
By muscular contraction the animal forcibly ejects water from the mantle-cavity through the siphon, and in this manner drives itself backwards through the water.

If the mantle be cut open along the mid-ventral line and thrown back, the interior of the mantle-cavity is exposed. The two most conspicuous organs are a pair of large feathery *ctenidia*, consisting of a median axis and lateral branches. They are purely respiratory. In the middle line of the body the *rectum* may be seen running forwards and terminating in the *anus*. A little further backwards open the paired *excretory pores* and the unpaired *genital pore* on the left side. As in the mussel and the snail, the mantle-cavity is evidently a part of the external surface of the body.

The mouth leads through the jaws into a buccal chamber which contains a rasping *odontophore* of essentially the same nature as that of the snail. A duct from a pair of *salivary glands* opens into the buccal chamber. The *œsophagus* leads back some way to the *stomach*, a large rounded sac. From close to the junction of stomach and œsophagus the intestine passes forwards and downwards to the anus, and a small saccular *cæcum* opens at the same point. Here also open the paired ducts

**Alimentary.**

Fig. 196.—Ventral View of Sepia Officinalis with Mantle-Cavity Cut Open. (*Ad nat.*)

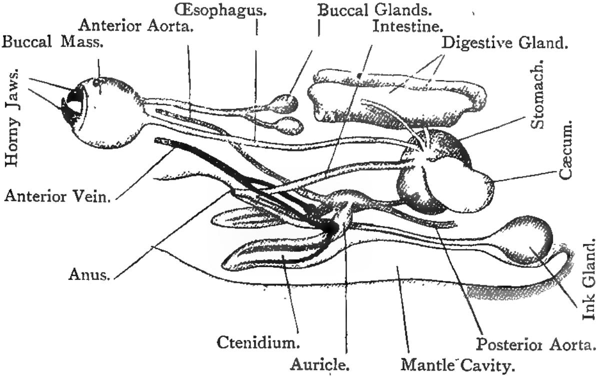


from the two *digestive glands*, large masses lying right and left. The ducts are covered with masses of *pancreatic cæca*. Close to the *anus* the intestine receives the duct from a large *ink-gland*. The ink or *sepia* is ejected with the water from the mantle and forms a dark cloud, behind which the animal can beat a retreat.

The prey is seized by the tentacles with their adhesive suckers and is torn to pieces by the horny jaws and the odontophore. The flesh is passed down the œsophagus into the stomach, in which it is mixed with the digestive juices from the digestive gland and pancreatic cæca.

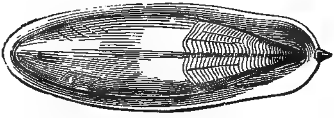
It may be noticed that the anus is not at the hind end of the body, but the intestine is bent forwards along the under surface till the whole alimentary canal is U-shaped, with a ventral flexure.

Fig. 197.—Dissection of Organs of Sepia Officinalis from the Left Side. (Semi-diagrammatic.) (*Ad nat.*)



**Motor.** In its natural position, the cuttle rests suspended in the water near the surface with the body horizontal, the tentacles hanging loosely downwards, the two long ones being coiled up inside the others. A forward swimming motion is caused by undulations of the two lateral fins. A powerful backward jerk is produced by forcible ejection of water through the siphon. There are special muscles for moving the tentacles and the eyes.

Fig. 198.—Ventral View of Shell of Cuttle.



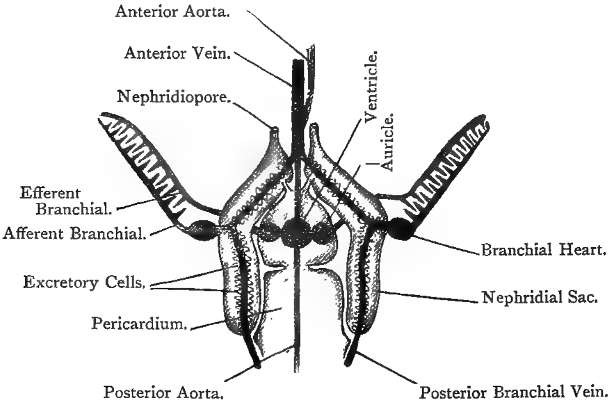
The inner part is calcareous, outer horny.

Along the upper surface the mantle-edges meet and completely enclose the shell, which is therefore invisible externally. If the mantle be slit the shell may be removed. It consists of a long ovate mass of chitin with a calcareous portion on its under surface, thickened posteriorly. Hence only the two outer layers of the typical molluscan shell are represented.

**Skeletal.**

But, in addition, *Sepia* has an important internal skeleton of cartilage. This forms a *cranium* enclosing the brain and the otocysts and bearing a remarkable resemblance to the cranium of a vertebrate. Other cartilages support the fins and the tentacles.

Fig. 199.—SEMI-DIAGRAMMATIC VIEW OF HEART, GILLS AND EXCRETORY ORGANS OF SEPIA OFFICINALIS.



The cœlom is fairly well developed and to a large extent retains its perivisceral or motor function. The anterior portion surrounds the heart and the "branchial" hearts and is usually known as the *pericardium*, and the posterior part contains the ovary. Two small apertures lead from the front end of the cœlom into the paired kidneys, and at the hind end a similar opening leads into the oviduct. (♀).

**Cœlom.**

**Blood-Vascular.** The blood vascular system is highly developed. The *heart* lies below the intestine (if the intestine were bent back into a straight line it would be in the usual dorsal position) and consists of a *ventricle* and two *auricles*. The auricles receive blood from the ctenidia by the efferent branchials and drive it into the ventricle. From the ventricle it passes forwards and backwards by *anterior* and *posterior aortæ*.

The veins are largely sinuses but are rather more definite than in other molluscs. A main vein, the *vena cava*, runs along the mid-ventral line from the head to the level of the anus, where it divides into two *afferent branchials* going out to the ctenidia. At the base of the ctenidia each afferent branchial swells into a *branchial heart* or contractile bulb, which also receives an *abdominal* vein from the hind region and on contraction drives the blood up the ctenidium. The heart of the cuttle, like that of our preceding types, is therefore systemic, but in addition there is a pair of special respiratory or *branchial hearts*.

**Nervous.** The brain is a large mass lying over the œsophagus and protected by the cranial cartilage. It supplies nerves to the eyes and the otocysts. Connections run round the œsophagus to a ventral nerve-mass which, as in the snail, consists of several ganglia. The *pedal* and *pleurovisceral* may be distinguished. Nerves from the pedal supply the ten tentacles and the siphon. For this and other reasons derived from embryology we are led to regard the tentacles and the siphon as together representing the *foot* of the other *Mollusca*. We have seen that the intestine and excretory pores have moved forwards along the mid-ventral line and the foot, divided into tentacles, has moved forwards, like the appendages of the lobster, to surround the mouth. As in the lobster, the ventral surface of the body is bent upwards anteriorly. There are two large *stellate ganglia* on the lateral walls of the mantle-cavity, connected by pallial nerves to the pleurovisceral ganglia.

**Excretory.** There is a pair of large tubular *kidneys* which open internally into the pericardium and externally to the exterior as described. They envelop the afferent branchial and abdominal veins, and their walls consist of thickened excretory cells.

The cuttle is diœcious. The *ovary* is enveloped in an *ovisac* and lies at the extreme hind dorsal end of the body.

**Reproductive.** The single oviduct leads to the exterior on the left side of the mantle-cavity. There are paired *nidamental glands* which secrete a sticky mass for fixing the eggs. The *testis* lies in a similar position to the ovary and is enclosed in a testicular sac continuous with a *vas deferens* which swells into a *seminal vesicle*, receives the ducts of two *prostate glands* and opens along a penis into the mantle-cavity.

**Development.** The eggs are laid on weeds in masses. They are black and like small grapes in appearance. There is much yolk and the development is embryonic, with no larva.

## PHYLUM MOLLUSCA.

The *Mollusca* are the second great division of the *Metazoa*. Their external body-form may be very diverse but they always have a fundamental plano-symmetry. Typically tridermic or triploblastic, the majority have a persistent cœlom, though there may be traced the same general tendency to a reduction of the perivisceral motor part, and a reciprocal expansion of the hæmocœle or venous-spaces. A portion, however, remains as the pericardium. and it typically communicates with the exterior by two specialised nephridia. The gonadial part of the cœlom in some cases still communicates with the pericardial. There is no trace of the metameric segmentation which is so marked a feature of the *Annulata*, though traces of archimeric segmentation persist.

The nervous system consists of dorsal brain, a nerve-ring and at least two other pairs of ganglia below the alimentary canal. Compound eyes are never found, but the simple eye sometimes reaches a high state of perfection. The blood-vascular system is usually well developed, the arteries being nearly always definite vessels. The heart is typically three-chambered, a median ventricle and paired lateral auricles, and is always dorsal and systemic.

The body itself is always soft and has no exoskeleton, but there is usually a dorsal expansion called the mantle which secretes a three-layered shell, either single or double.

Similarly, part of the ventral surface is expanded into a separate muscular organ called the *foot*. This is usually concerned with locomotion, but in the *Cephalopoda* the hind part only assists locomotion, the front part becoming modified into ingestive organs (*cf.* legs of *Arthropoda*).

In all but the *Lamellibranchiata* the buccal cavity contains a peculiar toothed tongue or odontophore. The gills are typically one pair of ctenidia, usually enveloped by the mantle.

The *Mollusca* are sometimes divided into two sub-phyla, the *Lamellibranchiata* being contrasted with the other two classes, but these also are so divergent that it is convenient to keep them apart.

The *Mollusca* do not invade the land with such success as the *Annulata*. Only one class, *Gastropoda*, has terrestrial representatives in the slugs and snails, and these are not completely adapted for terrestrial life, for they revel in wet and can only progress on a wet surface.

The development of the phylum is very divergent. As in the *Annulata*, the lower marine types have larvæ, the pelagic *trochophore* being a specially important type. Again, as in *Annulata*, the terrestrial forms and the highest marine forms (*Cephalopoda*) have eggs with quantities of yolk and an embryonic development.

## CLASS I.—GASTROPODA.

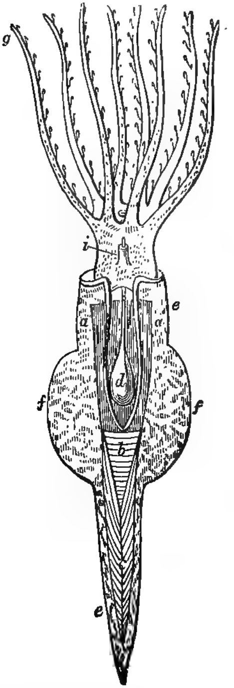
*Gastropoda* are divided into two important sub-classes.

The *Isopleura* are few in number and small, but they are interesting from their worm-like character and the absence of the torsion of other *Gastropoda*. *Chiton* is one of the commonest types. A species about one inch long occurs round our coast. It has several dorsal shells and the gills are also repeated.

The *Anisopleura* comprise all the rest of the *Gastropoda*. They have a trace of more or less dorsal torsion, supposed to be the effect of a spiral shell. In most this also involves the loss or reduction of one gill and one nephridium.

The order of *Pulmonata* stands rather apart owing to the adaptation to ærial respiration and the loss of gills. It comprises the snails and the slugs. The rest are marine or freshwater. Some, the sea-slugs or *Nudibranchs*, lose their shells and have an external approximation to plano-symmetry. Others are adapted for a pelagic life, they are usually transparent, and the shells if present are thin and pellucid. The foot is usually reduced. but may form a swimming organ. The great majority of the sub-class, however, creep on the sea-floor and may be carnivorous scavengers, *e.g.*, whelks, or herbivorous, *e.g.*, periwinkles. The shells of such types as the limpets and earshells (*Haliotis*) are not spirally twisted.

Fig. 200.—A Belemnite Restored. (After Owen.)



*g*, Eight hooked tentacles (the other two longer tentacles are not shown); *f*, fins; *e*, posterior part containing the shell; *b*, phragmacone; *d*, ink-sac; *i*, siphon (or funnel).

## Class II.—Lamellibranchiata.

The bivalve *Mollusca* are usually completely enveloped in the paired shells. The ctenidia have been enormously developed and serve to feed the animal. They are mostly burrowing types, all aquatic, and most are marine. They illustrate degrees in degeneration, the oyster entirely losing its foot. The scallop (*Pecten*) moves actively through the water by snapping its shells together. *Teredo* is a worm-like form with very small shells which bores its way through wood. Cockles and mussels are other common species.

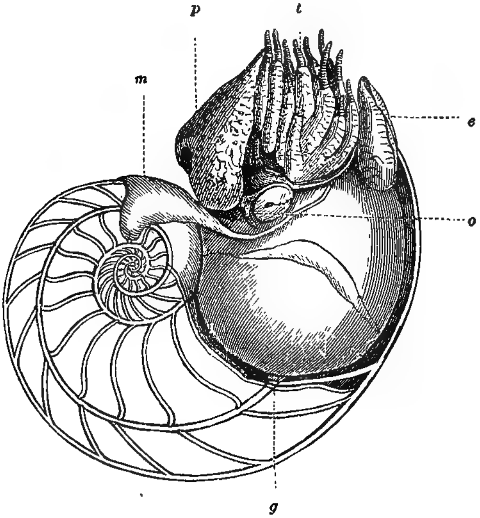
## Class III.—Cephalopoda.

In these the molluscan plan reaches its highest level.

*Sepia* is a very fair type of the class. They are all active free-swimming forms, with the fore part of the foot produced into tentacles, the hind part into a siphon, and the organs are plano-symmetric.

The order *Tetrabranchiata* contains the pearly nautilus (*Nautilus*) and a number of extinct allies. The nephridia and ctenidia are reduplicated, hence there are two pairs. The tentacles have no suckers and there is a large external shell. The shell of the pearly nautilus is chambered. The animal inhabits the last chamber. A median hole through each septum transmits a long process of the body called the *siphuncle*.

Fig. 201.—Lateral View of a Nautilus in its Shell. (After Owen.)



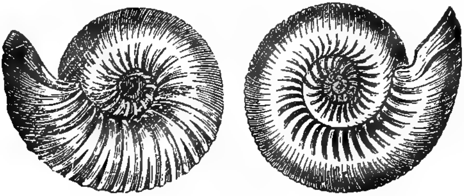
Note the hollow chambered shell and the numerous short tentacles. *o*, eye; *g*, siphuncle; *t*, tentacles; *m*, mantle; *p*, hood; *e*, siphon.

The *Dibranchiata* contains the cuttles, squids and the octopus. In all there are two ctenidia and nephridia and the shell is either internal or absent. *Octopus* has only eight tentacles and no shell. The paper Nautilus (*Argonauta*) also has only eight arms, and the female secretes a thin delicate shell. It is used to carry the eggs and is unchambered.

The ammonites are fossil forms allied to *Nautilus*, whilst the belemnites are fossil *Dibranchiata*. They occur in great numbers in the mesozoic strata. The tentacles in the belemnites had little hooks as well as suckers. The actual term "belemnite" is applied usually to the fossil shell only.

Some of the *Cephalopoda* reach an enormous size, and their whole organisation represents the highest point attained outside the phylum of the *Chordata.*

Fig. 202.—Ammonites or Fossil Nautiloid Cephalopoda.



[Table.

## PHYLUM MOLLUSCA.

1. Cœlomate *Metazoa* with a bilateral symmetry (usually).
2. Unsegmented and soft body without appendages.
3. Dorsal part of body, the mantle secretes one or more shells.
4. Ventral part forms the muscular "foot."
5. One or more pair of gills or ctenidia.
6. Pericardium is a true cœlom leading by paired nephridia to the exterior, and the body-cavity is a venous blood-space.
7. Nervous system consists of brain (cerebral ganglia) over the œsophagus, paired pedal, pleural and visceral ganglia, joined by commissures.
8. A well-developed vascular system with dorsal systemic heart.
9. Development with "veliger" larva and often a "trochophore."

| Class I. | Class II. | Class III. |
|---|---|---|
| GASTROPODA. | CEPHALOPODA. | LAMELLIBRANCHIATA. |
| *Type—Helix* (*Buccinum*). | *Type—Sepia.* | *Type—Anodonta (Mytilus.)* |
| 1. Body elongated antero-posteriorly. | 1. Body elongated dorso-ventrally. | 1. Body enveloped in mantle, and gills enormously developed. |
| 2. Foot simple and forms a creeping organ. | 2. Foot produced forward as series of circumoral tentacles. | 2. Foot, when present, a creeping organ. |
| 3. An odontophore. | 3. An odontophore. | 3. No head and no odontophore. |
| 4. A single shell usually spirally coiled. | 4. A single shell usually symmetrical. | 4. Two shells usually paired left and right. |
| 5. In most the symmetry is destroyed by twisting. | 5. Body remains symmetrical. | 5. Body mostly symmetrical. |
| 6. Marine, freshwater or terrestrial. | 6. Marine free-swimming. | 6. Marine or freshwater, sedentary. |

# CHAPTER XIX.

## CHORDATA.

ASCIDIA. AMPHIOXUS.

## I.—ASCIDIA.

| | |
|---|---|
| PHYLUM | CHORDATA (p. 403). |
| SUB-PHYLUM | ATRIOZOA (p. 404). |
| CLASS | TUNICATA (or UROCHORDA) (p. 405). |

**Colour and Form.**

**Ascidia mentula** is a small sac-like marine animal, of which common examples may be one inch in length. It occurs in great numbers at moderate depths, adhering to shells and other foreign bodies, thus belonging to the sedentary types. The shape is roughly cylindrical and the colour is usually of some dull neutral tint. The aboral end is fixed and the oral end terminates in a round aperture usually termed the *mouth*. A little way down one side there is another opening called the *atriopore*.

**Symmetry.**

The plane passing through the two apertures and dividing the body into equal parts, is the median plane, about which several of the organs are plano-symmetric. Hence, like the *Echinodermata*, the ascidian has an underlying bilateral or plano-symmetry disguised by a more superficial approach to axial symmetry. The surface of the body is smooth and devoid of special features.

If *Ascidia* be watched in the living condition it can be seen that currents of water and food-particles pass into the interior by the mouth, whilst a current of water emerges by the *atriopore*.

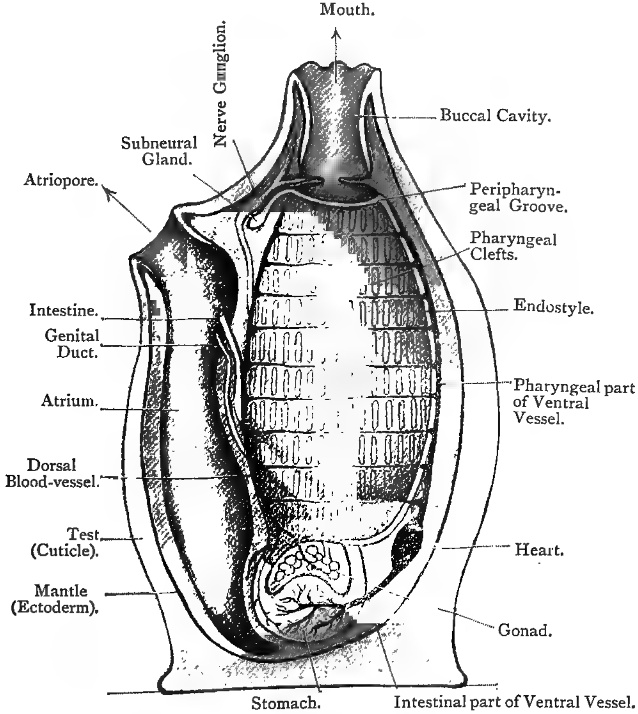
As in the cases of *Sycandra* and *Anodonta*, the exhalent current is devoid of food-particles, which are similarly retained for the use of the animal.

On being disturbed the living animal can contract its body to a considerable extent, and water is then forcibly expelled through the mouth. This habit, occurring in individuals left dry by the tide, has given rise to the popular name of "sea-squirt," applied to ascidians in general.

**Internal Features.**

An incision will reveal at once that the body of the animal is enveloped in a thick *test* (or *tunic*), out of which the animal may be removed entire, like a bean out of its pod. The test is thick and of a semi-transparent, gelatinous appearance. It is produced chiefly by the layer of underlying ectoderm, and consists of a hyaline basis containing *cellulose* (a material mainly confined to the plant-kingdom), through which are scattered a number of cells. Below the

Fig. 203.—DIAGRAMMATIC MEDIAN LONGITUDINAL SECTION THROUGH AN ASCIDIAN.



The right half has been removed.

test is a single-layered *ectoderm*,* covering fairly well-developed *longitudinal and circular layers* of muscles. The test may therefore be regarded as a modified and thickened form of *cuticle* produced from the ectoderm.

**Alimentary.**

On cutting open the body-wall the course of the alimentary canal can be made out. The mouth leads into a *buccal cavity*, which is short, and expands into the enormous *pharynx*. Between the two is a row of small *tentacles*. The pharynx extends nearly throughout the length of the body and forms a large sac, the lateral walls of which are perforated by rows of innumerable small slits, or *stigmata*.

These are evidently clefts in the side-walls of the pharynx, but are not exactly the same as the pharyngeal clefts of the *Chordata*. They are produced from the less numerous true pharyngeal clefts of the larva by secondary division of the latter.

The pharynx is surrounded on all sides except the mid-ventral line by the *atrium*, a large spacious cavity into which open the stigmata. It leads to the exterior by the atriopore.

Along the mid-ventral line of the pharynx is a grooved ridge, the *endostyle*, formed of ciliated and glandular cells. At the oral end of the pharynx it is continuous with the *peripharyngeal grooves*, which pass up each side of the pharynx just behind the tentacles. The two peripharyngeal grooves meet in the mid-dorsal line, and are produced backwards along the mid-dorsal line of the pharynx as the *epibranchial groove*, the edges of which hang down as the *dorsal lamina*. This groove terminates at the dorsal posterior corner of the pharynx, where a small *œsophagus* leads into a sac-like *stomach*. This is continued by a bent *intestine* to the *anus*, opening into the atrium. The greater part of the alimentary canal is ciliated.

The outstanding feature of this system is the pharynx, with its numerous clefts and its system of grooves. The endostyle secretes mucus, which is driven forward by the ciliated cells, up the peripharyngeal grooves and back along the epibranchial groove. The mucus strands appear to form a complex meshwork of glutinous threads hanging across the cavity of the pharynx, the ultimate fate of which is to be carried into the stomach through the œsophagus. The cilia

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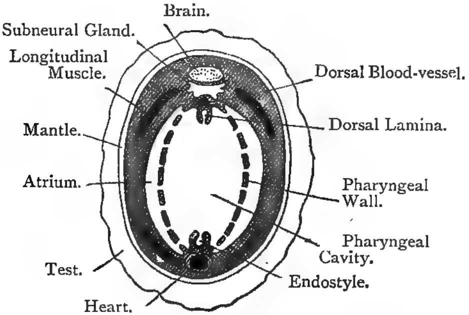
* Often termed the Mantle.

covering the inner surface of the pharynx cause the currents of water already referred to; but, whilst the water itself is carried through the stigmata into the atrium and thence to the exterior, the food-particles become entangled in the mucus and are transferred through the œsophagus into the stomach. The pharyngeal walls between the stigmata carry blood-vessels, and the constant stream of water over them serves to ærate the blood.

**Respiratory.**

Thus the pharynx of the Ascidian, like the ctenidia of *Anodonta*, functions for alimentation as well as respiration, though it should be carefully noted that in the former the alimentation is the original primitive function, the respiration being acquired later; whereas the reverse holds in *Anodonta*, ctenidia being originally respiratory organs.

Fig. 204.—Oblique Section through an Ascidian. (*Ad nat.*)

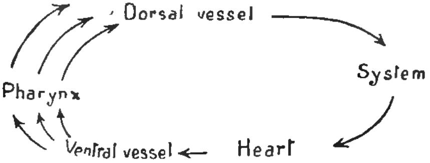


The circular muscles are scattered throughout the body-wall, but mainly concentrated as large *sphincter rings* around the mouth and atriopore. Similarly the longitudinal muscles are best developed in relation to the two external apertures. The circular muscles serve to close the apertures and the longitudinal to contract the whole body.

**Muscular.**

The cœlom is not present as a definite perivisceral space, but the blood-vascular system is not difficult to follow. It consists of a *dorsal* and a *ventral* vessel, connected by vessels and sinuses. The *dorsal vessel* runs above the epibranchial groove, and has paired *branchials* leading down the pharyngeal walls into the *ventral vessel* which lies immediately below the endostyle. The dorsal vessel runs back to the stomach and intestine, over which it breaks up into sinuses. The ventral vessel also runs back to these sinuses; but in its course, just after leaving the pharynx, it is modified into a simple *contractile heart.* The heart has a single chamber and is clearly *ventral* in position. It contracts rhythmically, driving the blood forwards to the pharynx for a certain number of beats, and then, *reversing its action*, drives it backwards to the viscera; hence it is alternately systemic and respiratory. For this reason it is impossible to speak of arteries or veins.

In the accompanying diagram the heart is shown in its respiratory phase, during which the dorsal vessel may be directly compared with the dorsal aorta of *Vertebrata*, the ventral vessel with the ventral aorta and the part of the ventral vessel between the heart and the system with the main subintestinal vein. A reversible heart such as this also occurs in some allies of *Balanoglossus*.



The main nerve-ganglion or brain lies *dorsally* between the mouth and atriopore, just under the ectoderm, and gives off fine branches to the muscles. A main nerve-trunk runs back dorsally to the stomach. Under the brain lies a *subneural gland*, which communicates by a duct with the front part of the pharynx just inside the ring of tentacles. It may possibly be an excretory organ.

**Nervous.**

No special sense-organs are recognisable, though the papillæ around the mouth apparently function for testing the quality of the incurrent water.

Excretory products are said to accumulate in solid masses in parts of the body, and to be extruded only on the death of the individual. No definite excretory organs have been described.

**Excretory.**

**Reproductive.**

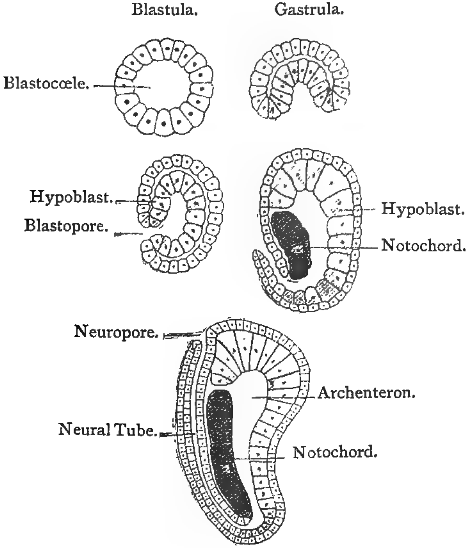
*Ascidia* is hermaphrodite. The *testes* and *ovaries* are simple paired sacs lying over the stomach and leading by separate ducts into the atrium.

**Development.**

The main interest attaching to *Ascidia* is involved in its development. If the anatomical account has been carefully followed, it will have been noticed that *Ascidia* differs from nearly all the preceding types in having the *nervous system confined to the dorsal region* of the body, in possessing *numerous paired slits in the wall of the pharynx*, and in the *presence of a ventral heart*, which is (intermittently) *respiratory*, *involving a backward current in the dorsal vessel* and *a forward in the ventral.* These are all characters in which the *Tunicata* resemble the other members of the important phylum *Chordata.* In addition, in the structure of the pharynx, the method of feeding and the

Fig. 205.—Development of an Ascidian.

(After Kowalevski.)



The various stages are shown in median section.

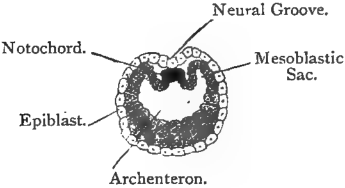
presence of the atrium, *Ascidia* can be directly compared with the other class of the *Atriozoa.*

The conclusions drawn from these characters have, however, an ample corroboration in the development.

The eggs are laid into the atrium, in which they are fertilised and pass their early stages. Later, the larva is free-swimming and pelagic.

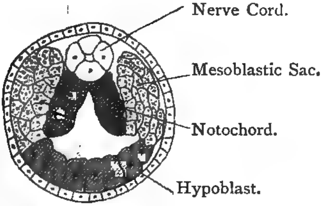
The segmentation is total and nearly equal, producing a *blastula* which is invaginated to form a *gastrula.* The gastrula elongates, and the blastopore comes to lie in a postero-dorsal position in relation to the adult axes. From the blastopore forwards to the anterior end of the gastrula the *median dorsal line* of cells becomes the *dorsal nervous system,* which is at first dermic, but it is transformed into a long dorsal nerve-tube by invagination proceeding from behind forwards. The front end of the tube, called the *neuropore,* is open, and the posterior end, leading through the blastopore into the *archenteron,* is known as the *neurenteric canal.* Meanwhile the hypoblast has been developing. The hypoblastic cells lying in the mid-dorsal line immediately below the neural tube become pinched off from the rest to form a long rod-like body, the *notochord.* Laterally to this organ are paired pouchings of the hypoblast which give rise to the *mesoblast* or third embryonic layer. Their lumen is soon lost, and the mesoblast comes to lie as a pair of lateral masses of cells between epiblast and hypoblast.

Fig. 206.—TRANSVERSE SECTION THROUGH EMBRYO OF AN ASCIDIAN.
(After DELAGE.)



We now have the *typical chordate larva* or *Chordula,* consisting of an elongated body, with a long dorsal nerve-tube, opening anteriorly to the exterior, posteriorly into the archenteron, a median dorsal notochord separated from the

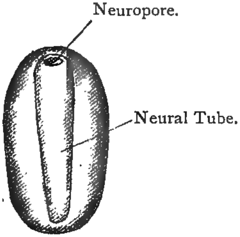
Fig. 207.—TRANSVERSE SECTION OF LARVA OF ASCIDIAN.
(After VAN BENEDEN and JULIN.)



hypoblast, and a pair of lateral mesoblastic masses more or less broken up.

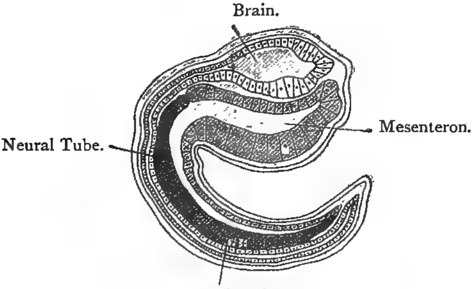
This larva is characteristic of the *Chordata* though only found as a larva in the *Atriozoa*, being represented by an embryonic stage in *Vertebrata*. The further development of the Ascidian diverges from that of the next class. The larva becomes divided into a body and a tail, nearly all the notochord and mesoblast being carried back into the tail (hence *Urochorda*), whilst the tail

Fig. 208.—CHORDULA LARVA OF AN ASCIDIAN.
(After KOWALEVSKI.)



Dorsal view.

Fig. 209.—AN ASCIDIAN TADPOLE.

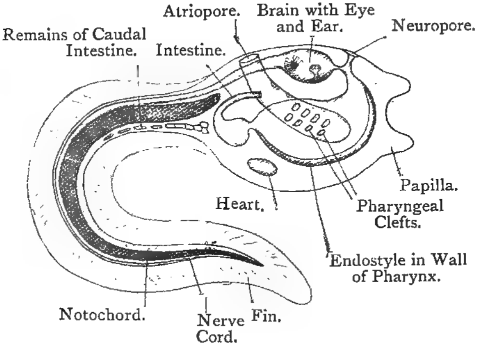


A median section.

part of the enteron remains as a mere cord of cells. In the trunk the enteron becomes modified into pharynx, stomach and intestine and acquires a mouth. The front end of the neural tube becomes a hollow brain in which are formed a median otocyst and eye.

At the front end, below the mouth, are formed *papillæ*, and two lateral pits sink in from the epiblast covering the trunk to form the paired *atrium*. The anus then opens into the left atrium and pharyngeal clefts open into each. Below the enteron the heart is formed from mesoblast. Meanwhile the tail acquires dorsal and ventral median fins, the notochordal cells form a strong elastic median axis, and the notochord, and mesoblast cells form longitudinal muscles.

Fig. 210.—Tailed Larva of an Ascidian seen from the Right Side. (Altered from Seeliger.)



In this manner the tail is converted into an efficient locomotor organ by which the larva can move rapidly through the water. It is often known as the ascidian tadpole, and is evidently a chordate type of comparatively high structure.

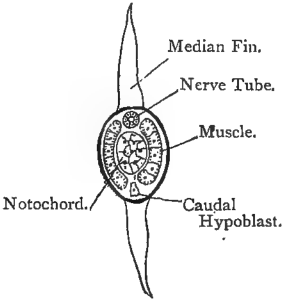
After a period of free life the ascidian tadpole fixes itself by its papillæ to a rock or other object, and is then converted into the adult ascidian by a process of *retrogressive* metamorphosis, *i.e.*, a metamorphosis involving simplification in structure.

The sense-organs atrophy, together with the main part of the brain and nerve-tube, the notochord and tail-muscles break up, the tail is resorbed, and the trunk rotates through nearly 180° upon its papillæ. In this way the active, sensitive, highly-organised "tadpole" is reduced to a quiescent, sedentary, vegetative ascidian.

In Chapter VI. it is explained that ontogeny may in many cases be interpreted as a repetition of phylogeny. This principle applied to the case in hand leads us to the conclusion that the ascidians are descended from active, free-swimming, highly-organised *Chordata* which have degenerated on the adoption of a sedentary habit.

Fig. 211.—Transverse Section through the Tail of an Ascidian Larva.

(After Seeliger.)

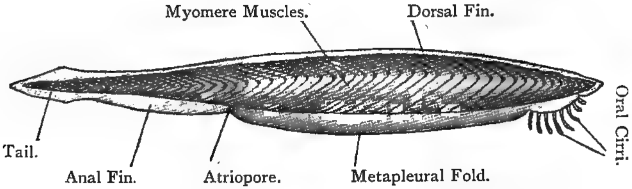


## II.—AMPHIOXUS.

| | |
|---|---|
| Phylum | Chordata (p. 403). |
| Sub-Phylum | Atriozoa (p. 404). |
| Class | Cephalochorda (p. 405). |

Fig. 212.—Lateral View of Amphioxus Lanceolatus × $\frac{3}{2}$.

(*Ad nat.*)



**Amphioxus lanceolatus** (the Lancelet) is a small marine organism about one to one-and-a-half inches in length. It is of elongated, fish-like shape, tapering at each end. It is flattened laterally, and the whole body is planosymmetric. It is of a milky white, semi-transparent appearance, and a number of the organs may be seen through the skin in the living animal.

**Habits.**

*Amphioxus* lives in moderate depths near the sandy bottom. It may swim about actively or may lie on one side upon the sand, or on occasion it may bury all but the anterior part of its body in the sand and there remain in a resting condition.

**External Features.**

There are no definite external divisions of the body, but the anterior part, to about the level of the mouth, is sometimes termed the *head* and the posterior quarter of the body is often referred to as the *tail.*

The anterior end forms a snout or *rostrum,* just below which is the mouth, surrounded by a ring of *oral cirri* or tentacles. Along the mid-dorsal line is a median unpaired *dorsal fin* which is continuous behind with a *caudal fin.* The caudal fin is continued round the tip of the tail and forwards along the ventral surface for about a quarter of the length of the body as an *anal fin.*

The tail of the animal runs symmetrically down the centre of the caudal fin, hence *Amphioxus* is said to have a *protocercal* tail. (See *Pisces.*)

At the anterior termination of the anal fin there is a median ventral aperture, the *atriopore,* and anterior to this, as far forwards as the mouth, there is a pair of ventro-lateral flaps of the body, called the *metapleural folds.* On the left side of the body, at the base of the caudal fin, there opens a minute aperture, the *anus.*

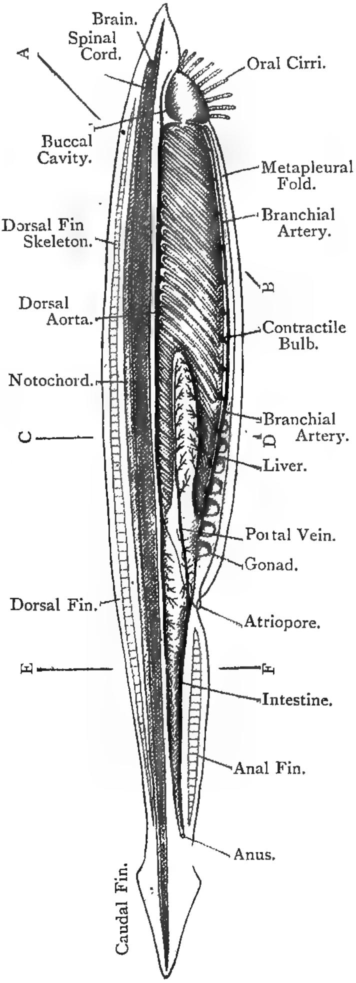
**Integumentary.**

The whole body is enveloped in a thin, transparent skin formed of a single layer of ectodermal cells, which secrete on their outer surface a delicate *cuticle.* Sensory cells are scattered throughout the skin.

**Alimentary.**

The mouth, surrounded by its oral cirri. leads into a *buccal cavity.* The posterior wall of this cavity is formed by the *velum,* a thin septum with a central aperture leading into the *pharynx.* The aperture is surrounded by *velar tentacles* which protrude inwards. The pharynx is a large, spacious chamber extending about $\frac{2}{5}$ of the length of the body. In general structure it

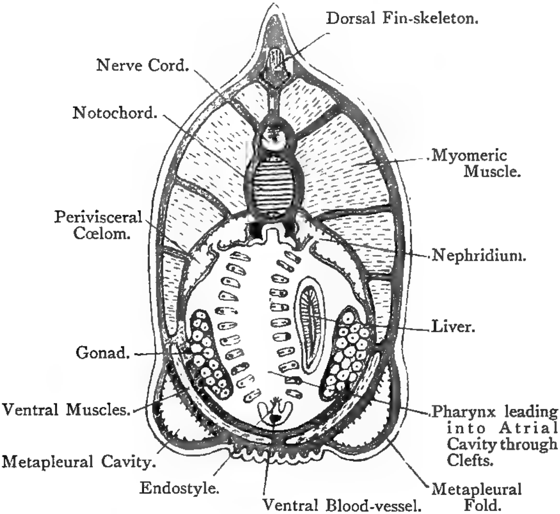
Fig. 213.—View of Amphioxus from the Right Side. (*Ad nat.*)



resembles the pharynx of *Ascidia.* Its internal walls are mostly ciliated. The *endostyle* extends along the median ventral line, joined by *peripharyngeal bands* to a median dorsal *epibranchial groove.* The lateral walls of the pharynx are perforated by a great number of pharyngeal clefts which run diagonally backwards as long slits. These pharyngeal clefts are twice as numerous as those of the larva, each of the latter becoming divided longitudinally into two by a long tongue-bar of the pharyngeal wall growing downwards from above.

The same method of feeding as in *Ascidia* is adopted. The water and food-particles are brought into the pharynx, and the latter are entangled in strands of mucus which are eventually carried into the intestine at the hind end. The water is driven through the pharyngeal clefts into the *atrium*, a spacious cavity which, as in *Ascidia*, surrounds the pharynx. In *Amphioxus*, however, the atrium is not continued round the dorsal line of the pharynx. In *Ascidia* it was the mid-ventral portion which was incomplete. The atrium is continued backwards behind the pharynx and along the intestine until it terminates in the atriopore, through which the water has exit.

Fig. 214.—TRANSVERSE SECTION THROUGH AMPHIOXUS IN THE PHARYNGEAL REGION.
(After LANKESTER, BOVERI and others.)



The dark shading is the connective tissue and the light outside is the simple ectoderm. The myomeres and pharyngeal clefts are cut across as they run diagonally. The section is taken across C D in Fig. 213.

Lying on the right side of the pharynx in the atrium is a long hollow sac, the *liver*, which opens into the alimentary canal at the junction of pharynx and intestine. The *intestine* is produced backwards as a long tube to the anus.

The muscular system is well developed. The longitudinal muscles consist of a dorsal longitudinal system of muscles, called the *myomeric* muscles, extending throughout the length of the body. The muscle-fibres extend between numerous connective-tissue septa which are

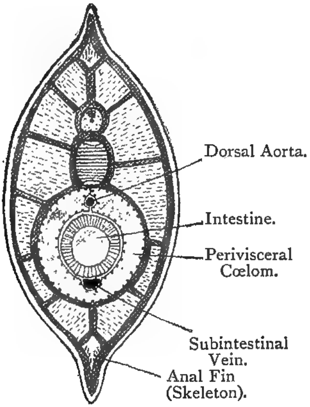
**Motor.**

arranged in V-shaped bars. These characteristic Vs can be seen through the skin in the living animal. Contraction of the myomeric muscles moves the tail from side to side, driving the animal forwards. The *ventral longitudinal* muscles extend from the region of the mouth to the atrium.

**Skeletal.**

The most important skeletal organ is the *notochord*. It extends as a long cylindrical elastic rod from one end of the body to the other. Hence at the anterior end it passes forwards to the tip of the rostrum, in front of the brain. It consists of *chordoid* tissue and is enveloped in a mesoblastic sheath. *Amphioxus* burrows with its rostrum and the notochord apparently gives it the necessary solidity. It also assists the motor muscles by its elasticity.

Fig. 215.—TRANSVERSE SECTION OF AMPHIOXUS BEHIND THE ATRIUM. (*Ad nat.*)



The dark shading is the connective tissue and the light outside is the simple ectoderm. The section is taken across E F in Fig. 211.

Around the notochord and nervous system and between the myomeric muscles is a continuous mass of mesoblastic connective-tissue, which at the bases of the dorsal and anal fins forms a row of *fin-rays*.

The cirri and the side-walls of the pharynx between the pharyngeal clefts are supported by skeletal rods or bars.

**Vascular.**

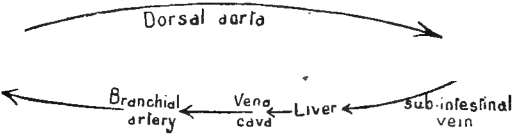
The cœlom is well developed, a perivisceral cavity extending round the intestine and forming a dorsal mesentery behind the atriopore; but forwards its relations are obscured by the presence of the atrium. Its dorsal part lies above the atrium and communicates down the primary pharyngeal bars with the ventral part lying below the endostyle.

**Blood-Vascular.**

The blood system is not unlike that of *Ascidia*. A dorsal aorta or artery extends throughout the body. In the pharyngeal region it is paired and receives numerous *efferent branchials* from the walls of the pharynx. The ventral vessel is a vein and is interrupted at the liver in which it breaks up into small capillaries. The part behind the liver is the *subintestinal vein*. The part running forwards from the liver is the *portal vein*, which runs to the pharynx, on the ventral surface of which it is continued as the *branchial artery*, giving off paired *afferent branchials*. The afferent and efferent branchials really form continuous *aortic arches*. There is no heart but the bases of the afferent branchials are contractile. The arrangement by which the venous blood is supplied direct to the liver instead of passing directly forwards is called the *Hepatic-portal system* and is characteristic of *Vertebrata*.

It should be noted that, as there is no true heart, the terms "artery" and "vein" are not morphologically accurate, but are applied to the vessels which correspond in structure and function with those of the higher *Chordata*.

The course of the blood is as follows :—

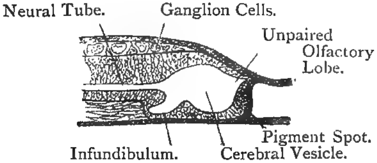


**Nervous.**

The nervous system lies immediately dorsal to the notochord; it consists of a long tube, the front portion of which forms a small *brain* and the rest the *spinal cord*.

The brain has a single ventricle or cavity and two pairs of cranial nerves. The spinal cord gives off paired spinal nerves. The *dorsal* nerves are sensory, the *ventral* are motor, and they do not join.

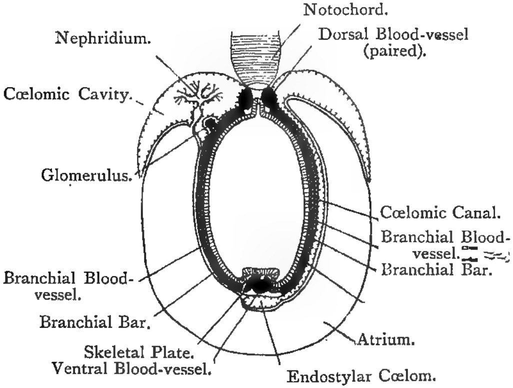
Fig. 216.—MEDIAN SECTION OF BRAIN OF AMPHIOXUS. (After KUPFFER.)



**Sensory.**

The front wall of the brain has a simple unpaired mass of pigment, probably a very simple *eye*. Over the brain there is a pit or depression called the *olfactory pit*.

Fig. 217.—OBLIQUE SECTION OF AMPHIOXUS THROUGH THE PHARYNGEAL REGION.



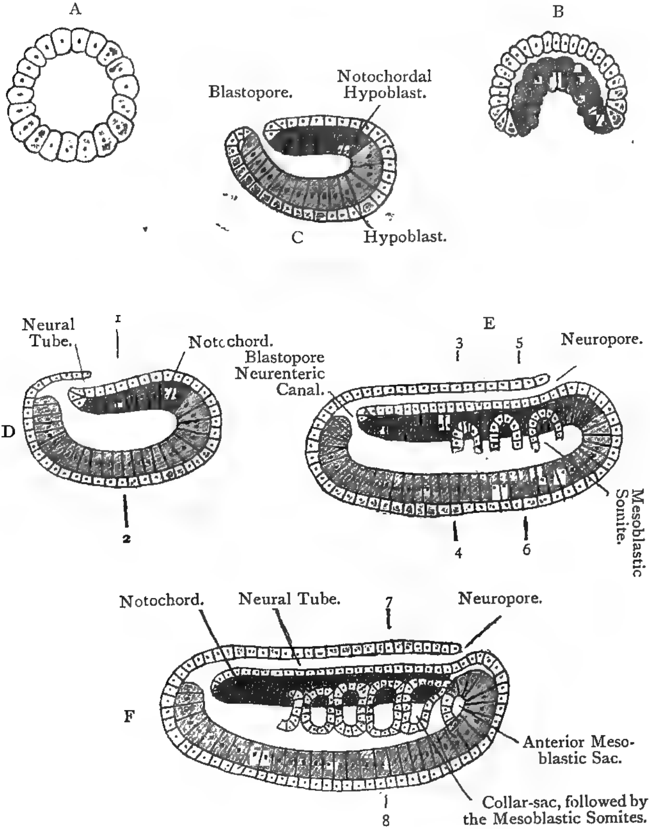
A secondary or tongue-bar is cut through on the left, a primary bar on the right. The section passes along A B in Fig. 213.

**Excretory.**

The cœlom leads to the exterior by numerous *nephridia* which open into the atrium. They are in the pharyngeal region and open over each tongue-bar. There is also a large pair of *atrio-cœlomic funnels* leading from the cœlom into the atrium.

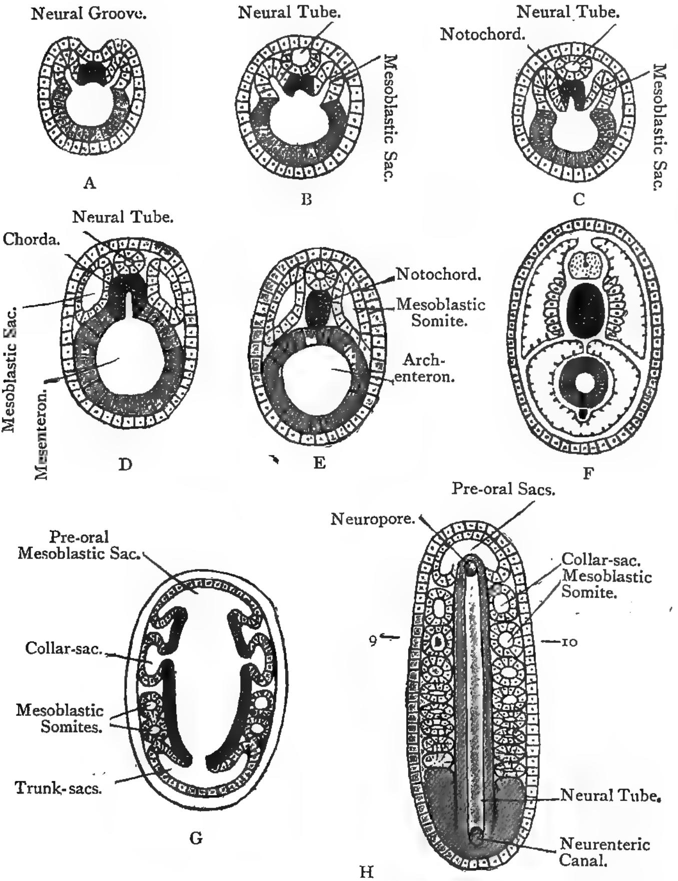
**Reproductive.** *Amphioxus* is diœcious. The gonads lie as a paired lateral row of organs just inside the ventral longitudinal muscles. They are said to have no ducts and to burst into the atrium when ripe.

Fig. 218.—The Development of Amphioxus as seen in Longitudinal Section and Lateral View of Larvæ.



A, Blastula. B, Gastrula. C, Completed Gastrula. D, Commencing Neural Tube. E and F, Lateral view of later chordula stages. (After Hatschek.)

Fig. 219.—The Development of Amphioxus as seen in Sections.



(A Through D 1-2 in Fig. 218; B through E 3-4, and C through E 5-6 in Fig. 218; D through F 7-8 in Fig. 218; E through H 9-10 in Fig. 219; and F through posterior part of Fig. 221.)

A shows the neural groove and developing mesoblastic sacs; B and C show the neural tube; D shows the completed mesoblastic sacs; E shows the notochord completely formed; and F shows the formation of myotome from dorsal part of mesoblast and perivisceral cœlom from ventral. (After HATSCHEK.)

G, Longitudinal horizontal section of an *Amphioxus* larva. (After M'BRIDE.)

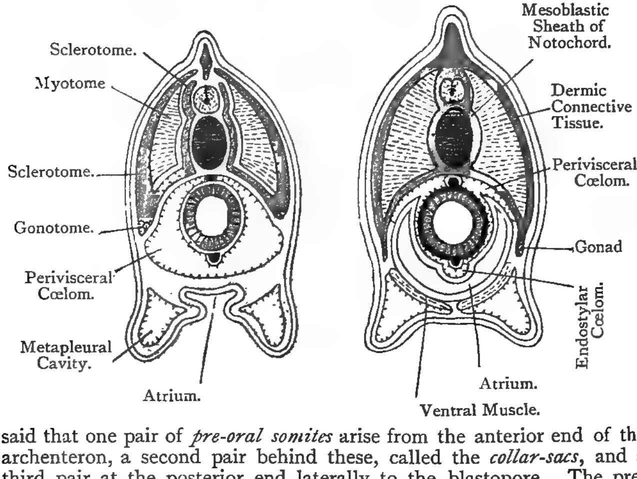
H, Horizontal longitudinal section through advanced chordula larva of *Amphioxus*. (After HATSCHEK.)

**Development.**—The eggs are shed through the atriopore to the exterior, where they are fertilised. Segmentation is total and equal and results in a blastula which in its turn is converted into a gastrula by archiblastic invagination. The gastrula then elongates, the blastopore taking up a postero-dorsal position.

The epiblast then invaginates along the mid-dorsal line to form a nerve-tube and the hypoblast gives rise to a median dorsal notochord and paired lateral mesoblastic sacs. In this manner is produced a *chordula* larva practically similar to that of *Ascidia.* The main distinction lies in the origin of the mesoblast. Instead of a single pair of somites which rapidly become a pair of solid mesoblastic masses, eventually breaking up into scattered cells, there are in *Amphioxus* a great number of somites, each of which has a definite cœlomic cavity. It is said that one pair of *pre-oral somites* arise from the anterior end of the archenteron, a second pair behind these, called the *collar-sacs*, and a third pair at the posterior end laterally to the blastopore. The pre-oral pair form the head-cavity (right) of the larva and the *pre-oral pit* (left). Each of the collar-somites divides into a dorsal portion, which forms the first myomere muscle, and a ventral part forming the metapleural cavity. Lastly, the posterior somites divide up to form a great number of mesoblastic somites: so far as is known, they alone are found in *Ascidia.*

Fig. 220.—Transverse Sections through Young Amphioxus, showing Developing Atrium.

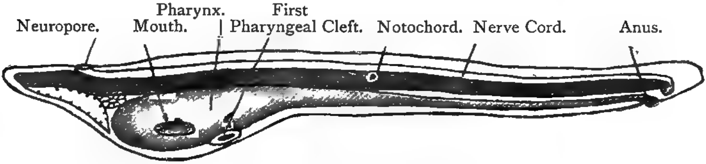
(After Lankester and Willey, Boveri, and others.)



The three pairs evidently correspond to the three archimeric segments of *Balanoglossus* and the other *Archicœlomata*, and the metameric segmentation of the *Chordata* is clearly produced by secondary segmentation of the posterior segment or opisthomere.

The fully-formed chordula larva of *Amphioxus* thus consists of an elongated body with a hollow dorsal nerve-tube opening anteriorly by a neuropore and posteriorly by the neurenteric canal, or persistent blastopore, into the archenteron. Below the nerve-tube is a long dorsal notochord and below this the spacious archenteron. Laterally, between the archenteron and the epiblast lies a row of mesoblastic somites, hollow sacs of mesoblast.

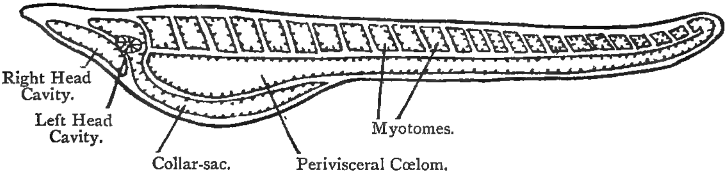
Fig. 221.—Lateral View of Young Pelagic Amphioxus at Commencement of Larval Life × 120. (After Hatschek.)



Note head cavity (with dotted walls) and the thick-walled pre-oral pit in front of pharynx.

A little before this stage the embryonic period comes to an end and the chordula larva is set free from the egg-membrane, swimming in the water by means of the flagella of the epiblast cells. It still, however, subsists upon the diffuse yolk-granules scattered throughout the cells.

Fig. 222.—Diagram of Young Pelagic Amphioxus to Show the Divisions of Mesoblast and Cœlom. (After M'Bride.)



Elongation of the hind end of the body produces a larva much more like *Amphioxus* in shape; at the same time the notochord grows forwards to the extreme front end of the body. The neurenteric canal closes and the mouth and anus open, the former at first on the left side.

The mesoblastic somites have grown downwards round the archenteron and each has divided into a dorsal and a ventral part. The ventral parts unite together to form the continuous cœlom and the dorsal parts divide into three portions, the sclerotome, myotome and gonotome, which give rise to the connective tissue, myomere muscles and the gonads respectively.

The larva lives for about three months in pelagic water and then moves to the sandy bottom. During this period the rows of pharyngeal clefts appear as paired apertures, and the atrium arises as a mid-ventral ingrowth of epiblast which pushes the cœlom before it and comes to lie around the pharynx. It will be noticed that up to the production of the chordula larva the development is closely similar to that of *Ascidia.*

# CHAPTER XX.

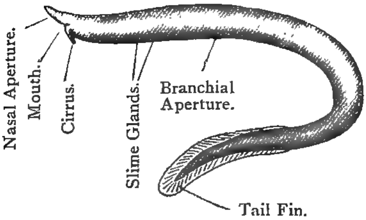
## CHORDATA—(Continued).

MYXINE. RAIA.

## I.—MYXINE.

| | |
|---|---|
| PHYLUM | CHORDATA (p. 403). |
| SUB-PHYLUM | VERTEBRATA* (p. 406). |
| CLASS | CYCLOSTOMATA (p. 433). |

Fig. 223.—LATERAL VIEW OF MYXINE GLUTINOSA × $\frac{1}{4}$. (*Ad nat.*)



**Myxine glutinosa** (the hag-fish) is a small eel-like animal occurring off our coasts. Its body is elongated and cylindrical, about 1 foot long. The hind end or tail is slightly flattened laterally, and is encircled by a simple caudal fin which is part of a continuous median fin running dorsally and ventrally for some distance along the body. The skin is usually of a pale dull-pink hue and is intensely slimy. The slime is secreted by a lateral row of slime-glands which pour out enormous quantities of the adhesive material. The front end tapers to a snout, below

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* The members of this sub-phylum are often called "Vertebrates" in contrast with the rest of the animal kingdom, termed "Invertebrates."

which is the *mouth*, surrounded by four pairs of small *buccal cirri*. Above the mouth is a small median aperture usually termed the *nasal opening*. It leads into a tube, the *pituitary sac*, which also has an internal opening into the pharynx.

The single olfactory sac opens into the pituitary sac near its external aperture. The mouth is situated at the base of a suctorial buccal funnel, on the dorsal wall of which is a large median horny tooth. Other horny teeth are attached to a large *tongue* which is moved by enormous muscles.

**Alimentary.**

*Myxine* is an active carnivorous animal and often devours fish caught on the lines. It is indeed frequently so caught itself. The edges of the buccal funnel are said to form a sucker, and the movements of the tongue serve to rasp the flesh of its victim. The mouth passes into a *pharynx* continued backwards into a *œsophagus*. The pharynx has six pairs of lateral openings which pass outwards into large *branchial sacs* (or gill-pouches) containing the gills. From each of these a canal leads backwards. Those of each side unite to open by a single branchial aperture situated ventro-laterally. Behind the last branchial sac the œsophagus has a duct on the left side (the *œsophageo-cutaneous duct*) leading directly to the left branchial aperture. When the mouth is being employed the respiratory current passes through the pituitary sac to the gills. The œsophagus expands into an intestine which receives a *bile-duct* from a simple *bilobed liver*. There is a small gall-bladder. The intestine terminates ventrally in an *anus*.

**Respiratory.**

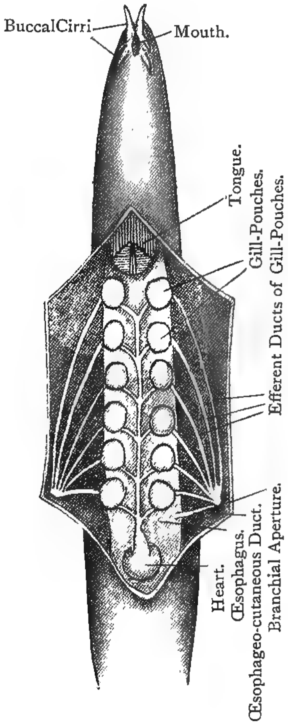
The *notochord* consists of a skeletal chordoid rod running from below the mid-brain to the tip of the tail. It is surrounded by a thick sheath. A membranous sheath also surrounds the nerve-cord. There is no trace of a vertebral column. Cartilage is found in rings supporting the "nasal passage," and the buccal cirri are supported by cartilages. Under the brain there lies a ventral cartilaginous portion of a cranium, completed dorsally by membrane. A trace of visceral arches may be represented by a *subocular bar* and other cartilaginous structures connected with it, united with the cranium.

**Skeletal.**

A small cartilage near the œsophageo-cutaneous duct represents a complex branchial basket found in the lampreys. Lastly, a large *lingual cartilage* supports the tongue.

*Myxine* is unique amongst the *Vertebrata* in having no trace of vertebræ.

Fig. 224. —VENTRAL DISSECTION OF MYXINE GLUTINOSA TO SHOW THE GILL-POUCHES $\times \frac{1}{2}$. (*Ad nat.*)



**Cœlom.**

The cœlom is spacious, and consists of a *pericardium* around the heart and an *abdominal cavity* surrounding the intestine which communicates with the exterior by an abdominal pore.

**Blood-Vascular.**

The *heart* is like that of a fish. It is two-chambered, with one auricle and a ventricle. It lies on the ventral surface of the œsophagus, and drives blood by a *branchial artery* diverging to the six gill-pouches by six afferent branchials. Six efferent branchials unite dorsally to form a dorsal aorta. These branchials pass between the gill-pouches and each supplies blood to the adjacent surfaces of two gill-pouches.

The venous system consists of paired *jugulars* and *cardinals* uniting in a *sinus venosus* and thence to the heart.

**Nervous.**

The *brain* is small and simple. There are *paired cerebral hemispheres*, the *cerebellum* is very small and the optic nerves do not cross. There are *ten cranial nerves*, as in fishes, but there is no sympathetic system.

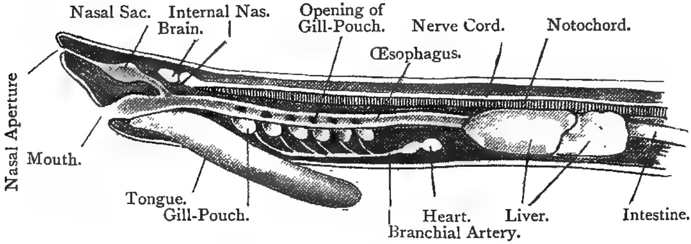
The median olfactory sac has been noted. The paired eyes are present but scarcely functional, whilst the paired *auditory sacs* are small and contain only one *semicircular canal.*

**Sensory.**

The *kidneys* are paired organs lying in the dorsal part of the cœlom. They consist of coiled tubules communicating with the exterior by paired *ureters* beside the anus. The gonad is simple and produces sperms in the young individual and eggs at a later period. Hence *Myxine* is a protandric hermaphrodite. There are no genital ducts.

**Urogenital.**

Fig. 225.—MEDIAN SAGITTAL SECTION THROUGH MYXINE GLUTINOSA × ½. (*Ad nat.*)



The eggs are large, oval, and have much yolk. They are enveloped in capsules which have hooks at each end and are usually found embedded in slime. The development is unknown.

**Development.**

*Myxine* shows a number of very primitive vertebrate features, of which we may specially note the absence of paired fins, vertebral column, pancreas, spleen, sympathetic nerves and genital ducts. The unpaired nasal sac, the peculiar pituitary pouch with its internal aperture, the ear with a single semi-circular canal, and the hermaphrodite condition are also unique characters amongst *Vertebrata.* With the lampreys it constitutes the class *Cyclostomata,* a name emphasising the suctorial condition of the mouth.

## II.—RAIA.

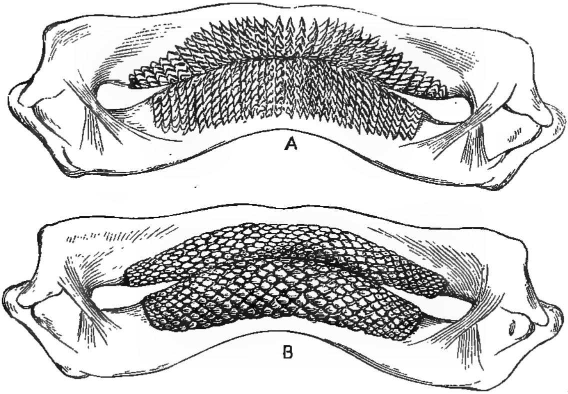
| | |
|---|---|
| PHYLUM | CHORDATA (p. 403). |
| SUB-PHYLUM | VERTEBRATA (p. 406). |
| CLASS | PISCES (p. 435). |

**Raia radiata*** is one of the commonest of the British skates, and is perhaps the most convenient as regards size. The other species only differ in size, colour, general shape of the body and other small structural features.

The skate lives near the bottom at moderate depths, and is carnivorous in diet. In shape its body is rhomboidal, with a long tail depending from one angle. The body is flattened dorso-ventrally, the two large side-flaps being made up of the enormously expanded *pectoral* and fairly large *pelvic* fins. Attached to the pelvic fins in the male is a pair of large *claspers*. These fins represent the front and hind-limbs respectively of the higher *Vertebrata*.

**External Features.**

Fig. 226.—JAWS AND TEETH OF (A) MALE AND (B) FEMALE SKATE.



The pointed anterior end is termed the *rostrum*.

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* The following description will apply for the common British species, *Raia maculata* and *Raia batis.*

On the dorsal or upper surface we can notice the paired *eyes* a little way behind the rostrum, and behind them is a pair of oval apertures called the *spiracles*, for through them passes the water employed in respiration.

The skin is slimy, owing to the secretion of numerous slime-glands, and dotted over its surface are numerous *placoid scales*. Each scale consists of a hard base bearing a sharp spine. Towards the tip of the tail is a pair of small dorsal fins, and the caudal fin surrounds the end of the tail. The upper lobe of the caudal fin is larger than the lower and contains the true end of the tail. Such a shape of tail is called *heterocercal* (see *Pisces*).

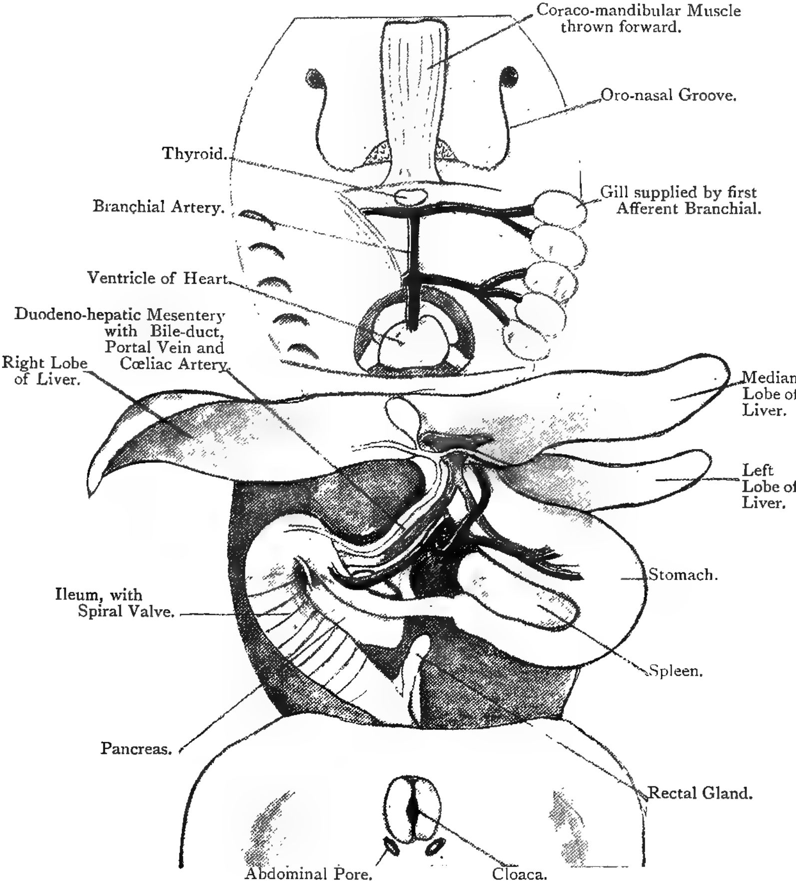
Ventrally we can recognise the median transverse *mouth* with a pair of grooves (*oro-nasal*) passing forwards from each angle to the *olfactory* or *nasal* openings. The jaws bear numerous rows of small placoid scales which act as *teeth*. Posterior to each angle of the mouth, and slightly outwards, there is on each side a row of five diagonal slits leading into the pharynx. These are the *pharyngeal clefts* or *gill-slits*. Behind the last gill-slit and running across the ventral line is the *coracoid bar*, which can be felt through the skin. At the base of the tail is a conspicuous median aperture, the *cloacal aperture*, and close to its posterior border is a pair of minute slits, the *abdominal pores*, which lead indirectly into the abdominal cavity. In front of the cloacal aperture, and crossing the ventral line, may be felt the hard *pubic* bar. Scattered over the skin, especially on the ventral surface, are numerous fine apertures of *sensory tubes*. The tubes are full of a gelatinous material which may be squeezed out of the apertures.

**Alimentary.**

If the mouth be forced open it will be seen to lead into a spacious *pharynx*, into which open dorsally the two spiracles and laterally the five pharyngeal clefts on each side. Posteriorly it can be seen to taper into an *œsophagus*.

If a gill-slit be opened up it will be seen to pass as a short canal into the pharynx. On both anterior and posterior wall of this canal are a great number of branchial filaments constituting the *gills*. In them the blood is only separated from the water by a thin membrane and æration is effected. On the wall of the spiracle may be noticed a *pseudobranch* or vestigial gill. The water passes in by the

Plate I.—FIRST DISSECTION OF THE SKATE. (*Ad nat.*)



The ventral body-wall has been removed completely from the abdominal region, exposing the alimentary system in the abdominal cavity. The lobes of the liver have been spread out and the stomach slightly drawn away to the left. Anteriorly the skin has been removed from the region between mouth and coracoid bar and the afferent branchial system dissected out on the left side only. The heart is lying in its natural position in the pericardium. The veins are blue, arteries red.

spiracle and out over the gills. Breathing is therefore independent of the mouth.

If the skate be laid on its dorsal surface, and the skin and underlying muscle be removed in the area lying between the coracoid and pubic bars, the spacious *abdominal cavity* will be exposed. In it lie freely the other portions of the alimentary system. The *œsophagus* entering the abdomen at the front end leads into the large *stomach*, which is U-shaped and inclined to the left. It is mainly hidden by the spreading trilobed gland, the *liver*, which is attached at the anterior part of the abdomen, but each lobe hangs free posteriorly. From the opposite end of the stomach to the œsophageal opening there arises the *intestine*, a tube of varying calibre passing down to the cloacal aperture. Its first portion, the *duodenum*, is short and leads into the very wide *ileum* containing in its interior a *spiral valve.* The last portion is the *rectum*, narrower than the intestine proper and with no spiral valve. It opens into the *cloaca*.

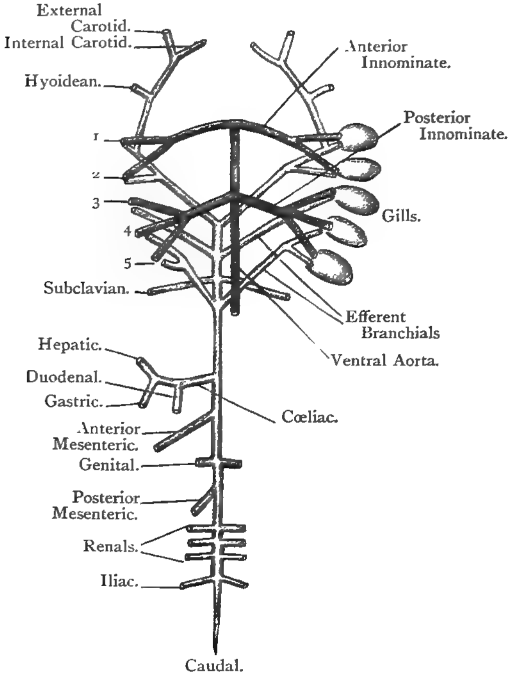
This alimentary canal has three important glands which open into it. The *liver* has already been referred to. Between its median and right lobes is a *gall-bladder*, from which there passes a long *bile-duct* to open into the duodenum. The bile, secreted by the liver, is stored in the gall-bladder and periodically discharged into the duodenum by the bile-duct. Near the duodenum is a bilobed whitish organ of moderate size, called the *pancreas*. It secretes a digestive fluid which is discharged by a short *pancreatic duct* into the commencement of the ileum on its dorsal side. Lastly, near the termination of the rectum is a small oval *rectal gland* opening into the rectum; it may be excretory.

Before leaving the alimentary system, the *spleen*, a dark-red ductless gland near the stomach, should be observed. Note also the *portal vein*, a large vein draining the stomach, intestine, spleen and pancreas, and passing forwards to the liver; and the *cœliac artery* which supplies the stomach, duodenum and liver with arterial blood.

**Vascular.**

If the skin and muscles be removed from the area between the mouth and the coracoid bar, the *pericardial cavity* will be exposed. It communicates with the abdominal cavity by a pair of small canals, and the two cavities compose the perivisceral cœlom. They are lined by a *peritoneum* or thin membrane and contain a colourless cœlomic fluid. The cœlom communicates by the abdominal pores with the exterior. The peritoneum surrounds all the organs in the abdominal cavity, and the œsophagus and rectum are suspended from its dorsal wall by a *mesentery*, formed of two folds of peritoneum apposed; the part of the alimentary canal between these two has no mesentery and lies freely in the cavity. Another fold, the *omentum*, contains the bile-duct and portal vein.

Fig. 227.—DIAGRAM OF ARTERIAL SYSTEM OF A SKATE.
Seen from Ventral Surface.



The afferent branchial system is shaded darker than the rest.

**Blood-Vascular.**

The *heart* lies in the *pericardium*. It has two chambers a thick-walled *ventricle* and a larger thin-walled *auricle* lying dorsal to it. The ventricle leads forwards out of the pericardium as the *conus arteriosus* containing valves, beyond which it is continued as the *branchial artery*.* The auricle receives blood from a thin-walled triangular *sinus venosus* formed from the swollen termination of the main veins.

The branchial artery gives off a pair of *posterior innominates*, which trifurcate into three *afferent branchials* supplying the three posterior pairs of gills. The branchial artery runs forward and terminates just behind the lower jaw, near a small ductless *thyroid gland*. Here it diverges into two *anterior innominates*, each of which bifurcates into two *afferent branchials* supplying the first two pairs of gills : this comprises the afferent branchial system. On contraction of the ventricle of the heart the blood passes forward to the gills, hence the skate's heart is purely *respiratory*. If the coracoid bar be now carefully removed, the sinus venosus will be seen to run downwards and outwards on each side to the *precaval sinus*, which communicates with a spacious *hepatic sinus* in connection with the liver and receives a *jugular* vein from the head, a *lateral* vein (formed of a *pelvic* from the pelvic fin and a *brachial* from the pectoral fin) and a *cardinal* vein from the posterior part of the body and kidneys. A median *caudal* vein from the tail diverges into a pair of *renal portals* to the kidneys, in which the veins break up into capillaries. A skate has therefore a *renal portal system* as well as a hepatic portal.

If the ventral wall of the pharynx and the skin of the roof of the pharynx be removed, the *efferent branchial* system is exposed (Plate II). It consists of five *efferent branchials* leading from the gills towards the middle line and backwards. The two first unite into one, as also do the two last; hence three arteries are produced which then unite to form the dorsal *aorta*. From the first efferent branchial on each side runs forward a carotid, dividing into *internal carotid* to the brain and *external carotid* to the head. The dorsal aorta gives off paired *subclavians* to the pectoral fins, and is continued along the dorsal line under the vertebral

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* Often termed the Ventral Aorta.

column till it terminates in the *caudal*. It gives off a median *cœliac* to the stomach, a *superior mesenteric* to the spleen, pancreas and intestine, paired *renals* to the kidneys and paired *iliacs* to the pelvic fins. These arteries are fully exposed by removal of the coracoid bar and, if necessary, the pubic bar.

We may note some special features of the blood-vascular system of the skate which are also typical of the class. The blood-vascular system can be divided into the arterial and the venous system as in all *Vertebrata*, but the venous system is chiefly composed of wide sinuses (also a common condition of invertebrates). The arterial system has two distinct parts separated by the capillaries of the gills. The *ventral* or afferent branchial system carries venous blood *forwards* to the gills; the dorsal or efferent branchial system carries blood mostly *backwards* to the system. In the venous system the capillaries of the liver and those of the kidney both break up the continuity of the sinuses, forming a hepatic-portal and renal-portal system respectively.

Fig 228.—DIAGRAM OF THE VENOUS SYSTEM OF A SKATE.

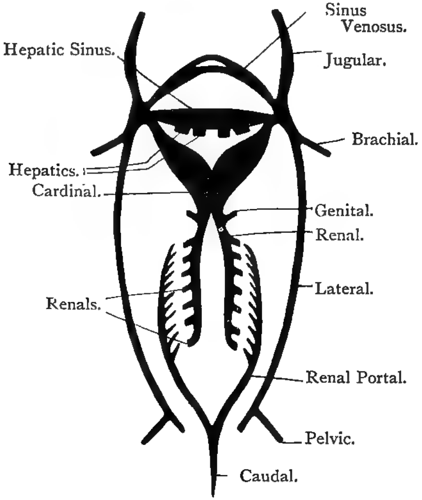
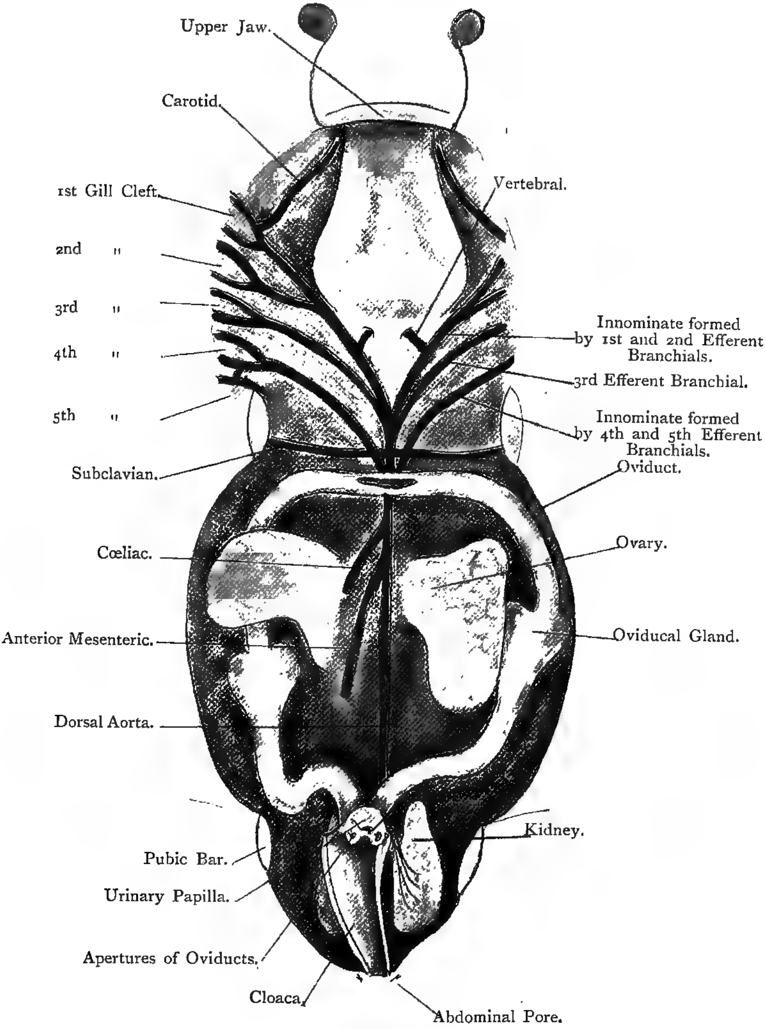


Plate II.—SECOND DISSECTION OF THE SKATE (♀). *(Ad nat.)*



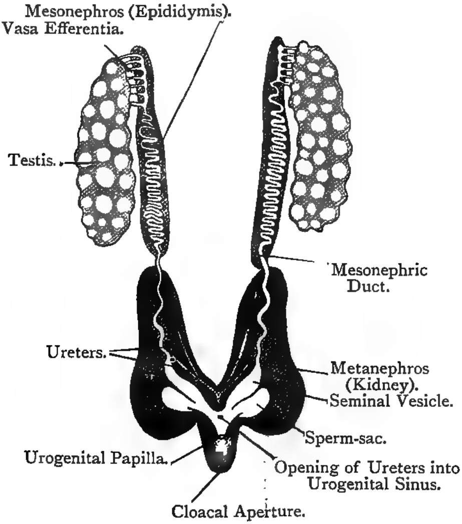
Showing the efferent branchial and main arterial systems and the urogenital systems. The coracoid and pubic bars are cut through, the heart and alimentary canal, together with the floor of the buccal cavity, have been removed.

The chief organs now remaining in the abdominal cavity belong to the urogenital system. The excretory and reproductive organs of vertebrates are so intimately connected that they are usually described in this way as one system.

**Urogenital.**

In the male, the *testes* are two large pale brown organs lying in the abdominal cavity and suspended by a dorsal mesentery towards their front end.

Fig. 229.—Male Urogenital Organs of a Skate. (*Ad nat.*)



Each testis gives off from its anterior end a long coiled tube, the *vas deferens*, which passes along on either side of the dorsal middle line to open posteriorly into the *urogenital sinus*. Connected with its posterior end is the *sperm-sac*. The anterior half of the vas deferens is surrounded by an *epididymis*, which is said to be the persistent mesonephros, and the posterior half is in close contact with the surface of the kidney.

The kidneys are *paired* elongated reddish bodies lying above the abdominal cavity, and they can be dissected by removing the dorsal peritoneum. Each has a fine duct, the *ureter*, leading from its inner lower border posteriorly to open into the *urogenital sinus*. This sinus opens into the cloaca by a small papilla.

As already noted, the male skate has a pair of *claspers*, long firm organs strengthened by cartilages developed in connection with the pelvic fins. They are deeply grooved and have a large clasper-gland which opens into the groove by a duct.

Each testis discharges its sperms into its vas deferens and thence into the sperm-sac in which they are mixed with a secretion; they then pass out of the cloacal aperture and down the clasper-grooves.

In the female, the *ovaries* are paired and occupy the same position as the testes. They often contain large partially ripe ova. The *oviducts* are paired tubes of large size leading the whole length of the abdominal cavity. At the anterior end they open by a common aperture *into the abdominal cavity*, and posteriorly each opens into the cloaca. The anterior part is called the *Fallopian tube* which is thin-walled and of small calibre; the posterior part, sometimes called the *uterine* portion, is thick-walled and wide; at the junction of these two parts is a large *oviducal gland*. (There is a vestige of the epididymis.) The urinary organs do not differ essentially from those of the male.

The eggs on ripening are shed free into the abdominal cavity, and thence pass down the oviducts. They are fertilised in the Fallopian tubes and the oviducal gland then secretes around them the egg-capsule or purse; they are laid singly through the cloacal aperture.

**Nervous and Sensory.**

If the skate be now turned upon its ventral surface, and the skin removed from the head region, as far out as the gills and backwards, the following structures can be recognised (Plate III). In the centre is the *cranium*, the dorsal cartilaginous wall of which may be carefully removed, when it will be seen to possess a large central cavity containing the *brain*, a pair of anterior cavities of the *olfactory capsules* and a pair of posterior cavities, those of the *auditory capsules*. Between these and the olfactory capsules are the eyes. Hence the side of the head in the skate bears three pairs of sense-organs, olfactory sacs, eyes and auditory sacs. The further structure of these organs will be referred to later. Lying farther out on each side opposite the eyes is a large oval *mandibular muscle.* Its front end nearly meets the olfactory capsule and its hind border approaches the auditory capsule. Lastly, the *spiracle* lies slightly in front of the auditory sac.

Returning to the brain, we notice the large *cerebrum* at the anterior end which is produced forward as a pair of long *olfactory* lobes to the olfactory capsules. Behind the cerebrum is the narrow *thalamencephalon* produced dorsally into a small *pineal body* and ventrally into a process called the *infundibulum.* From its ventral surface originate the pair of *optic nerves* to the eyes. The cerebrum and thalamencephalon form the fore-brain with the two first cranial nerves—I, olfactory and II, optic.

The paired *optic lobes* then succeed. They form the mid-brain and give off the third cranial nerves or *oculomotor* (to the eye-muscles) from their ventral surface, and the fourth or *trochlear* (to a single eye-muscle) from their dorsal surface. Behind them is the *hind-brain* formed of a large *cerebellum* which has a large anterior lobe partially covering the optic lobes and a posterior lobe covering the *medulla oblongata.* The medulla oblongata has a thin dorsal wall and is continued backwards into the spinal cord which passes posteriorly to the tail. From its lateral walls there arise the fifth (*trigeminal*), sixth (*abducens*), seventh (*facial*), eighth (*auditory*), ninth (*glossopharyngeal*) and tenth (*vagus*) cranial nerves. They can be seen passing out of the cranial capsule by foramina and their subsequent distribution has now to be followed.

The eye is held in position and moved in the orbit by six eye-muscles which originate in the cartilaginous orbit and are inserted in the *sclerotic* of the eye. At the anterior end are the *obliquus superior* and *inferior* radiating from one point of origin and posteriorly are the four *recti* muscles. These radiate from one point and are easily identified as the *rectus superior*, *inferior*, *internus* and *externus.** Without further dissection we can recognise the

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* The names of the last two have no meaning in an animal like the skate with lateral eyes, but have been passed down from human anatomy.

*obliquus superior* with its *trochlear* nerve, and the *rectus superior*, *externus* and *internus* muscles. The *rectus externus* is supplied by the minute sixth *(abducens)* nerve which is not easily seen. The other four are supplied by the third or oculomotor. (For list of these muscles see page 410.)

Running over the bases of the upper eye-muscles is a long nerve called the *ophthalmicus superficialis.* It enters the orbit posteriorly and leaves it anteriorly to pass forwards to the rostrum. It is a compound nerve formed of the fifth and seventh. Entering the orbit and leaving it by the same foramina as this nerve is another, called the *ophthalmicus profundus.* It, however, lies below the three upper eye-muscles (*i.e.*, rectus superior, obliquus superior, and rectus internus), though well above the other eye-muscles and the optic nerve.

A very little dissection between the auditory capsule and the mandibular muscle will reveal a large nerve, the *hyomandibular*, an important branch of the seventh nerve which can be traced to ampullæ or sensory tubes in the skin and backwards to the front of the auditory capsule. It gives off a large *external mandibular* round the outer folds of the mandibular muscle and other branches which are the *recurrent facial*, *internal mandibular*,* *facial proper* and *hyoidean.*

If the eye be now carefully removed by cutting the eye-muscles and optic stalk and the orbit be cleared, a number of deeper nerves are brought into view. The *outer buccal* (VII.) is a large branch easily found lying between the olfactory capsule and the mandibular muscle. It runs across the floor of the orbit and outwards to ampullæ. Very deep in the orbit, below the ophthalmicus profundus, lies the *inner buccal* (VII.) passing to the roof of the mouth. In the angle formed by the two buccals lie the *maxillary* (V.) to the upper jaw and the *mandibular* (V.) to the lower jaw.

Lastly, in front of the spiracle is a *palatine* (VII.) with a branch, the *prespiracular* (VII.).†

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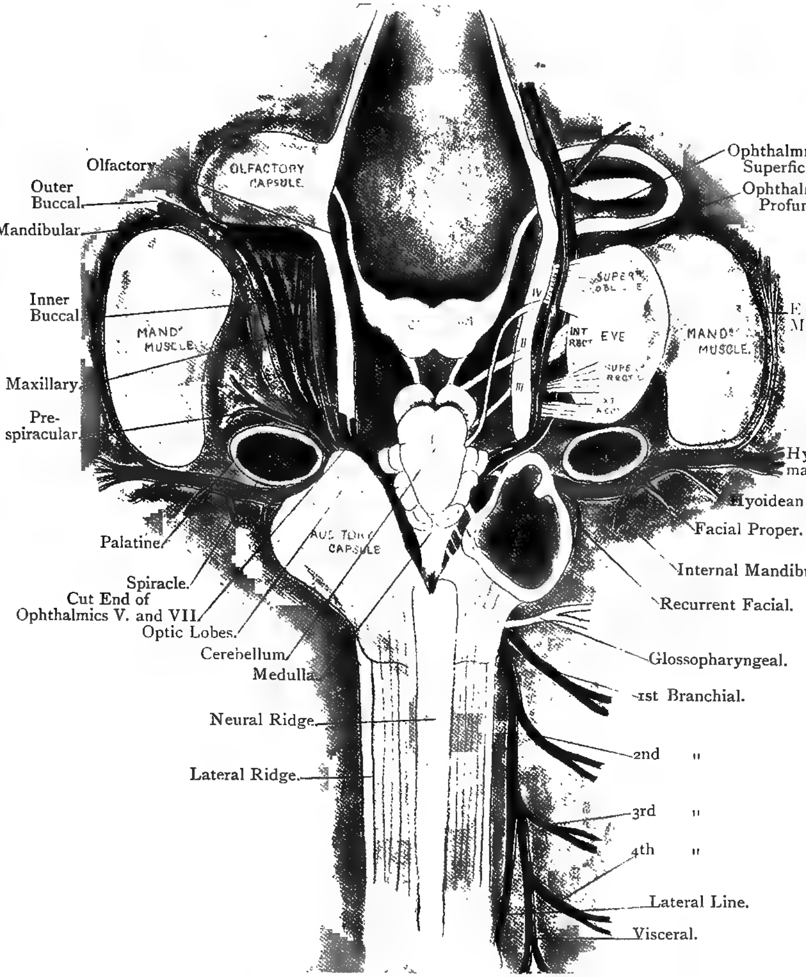
* This nerve is also sometimes termed the *chorda tympani.*

† These lie very deep on the actual roof of the mouth.

Plate III.—The Cranial Nerves of the Skate. *(Ad nat.)*



On the right the eye is seen *in situ* with its muscles: the skin has been removed, exposing the mandibular muscle, and the olfactory capsule has been opened to show the olfactory lobe. The hyo-mandibular has been dissected out with its branches; further back the jugular sinus has been cut open showing the glossopharyngeal and vagus. In the centre the roof of the cranium has been removed to expose the brain. On the left, the eye has been cut away showing the deeper nerves on the floor of the orbit.

The v. or trigeminal nerve is red, the vii. or facial is blue. The x. or vagus is

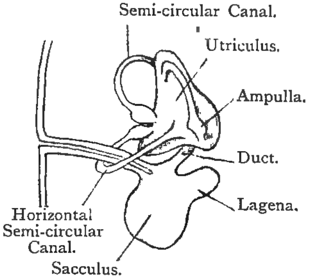
The auditory nerve is simple and short and passes to the auditory capsule.

If the jugular sinus be cut open throughout its length the *glossopharyngeal* (IX.) and *vagus* (X.) nerves will easily be exposed. The IXth is simple and passes from behind the auditory capsule to the first gill-slit.

The *vagus* (X.) has *four branchial* branches to the four last gill-slits, a *lateral line* branch under the skin and a *visceral* branch which passes to the heart and stomach.

The spinal cord gives off paired *spinal nerves*, the first fifteen (or 15 to 18) of which join together to form the *brachial plexus*, passing to the pectoral fin.

Fig. 230.—THE EAR (MEMBRANOUS LABYRINTH) OF THE SKATE (Diagrammatic).



Note that there is no middle or outer ear, and that the inner ear communicates by a duct to the exterior.

We may summarise the cranial nerves as follows :—

| *FORE-BRAIN.* | *MID-BRAIN.* |
|---|---|
| I. Olfactory. | III. Oculomotor. |
| II. Optic. | IV. Trochlear. |

*HIND BRAIN.*

| V. Trigeminal. | VII. Facial. | VIII. Auditory. |
|---|---|---|
| 1. Part of ophthalmicus superficialis. | 1. Part of ophthalmicus superficialis. | IX. Glossopharyngeal. |
| 2. Ophthalmicus profundus. | 2. Hyomandibular. | X. Vagus. |
| 3. Maxillary. | 3. *Outer buccal.** | 1. *Four branchials.* |
| 4. Mandibular. | 4. *Inner buccal.*† | 2. *Lateral line.* |
| VI. Abducens. | 5. Palatine (and prespiracular). | 3. Visceral. |

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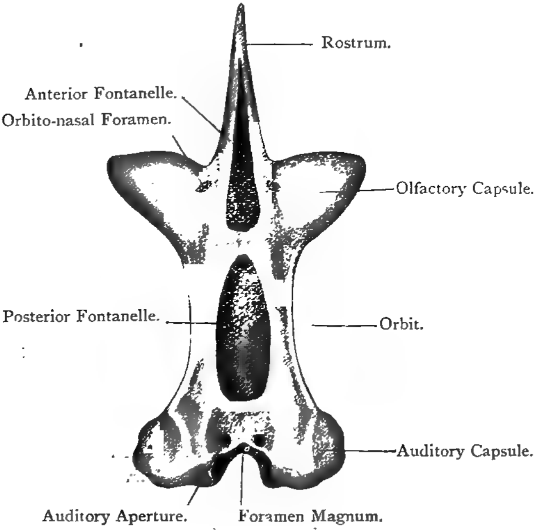
* The branches in *italic* type disappear in *Vertebrata* above the fishes, besides parts of other branches.

† The maxillary anastomoses to some extent with the inner buccal nerve, but whether fibres of V. actually supply the ampullæ at the termination of the inner buccal is doubtful.

We have already referred to the exoskeleton of scales and teeth, but a more extensive *endoskeleton* has to be noticed. This is entirely formed in the mesoblast and consists of connective tissue (or membranous tissue) and cartilage. The connective tissue binds all the organs together and may be directly compared with that of *Amphioxus*. A gentle heat serves to disintegrate this tissue and enables us to easily isolate the firmer and more consolidated cartilage. In certain parts the cartilage is hardened by the deposition of calcareous matter, a foreshadowing of the "bone" of other forms.

**Skeletal.**

Fig. 231.—Dorsal View of Cranium of a Skate. (*Ad nat.*)

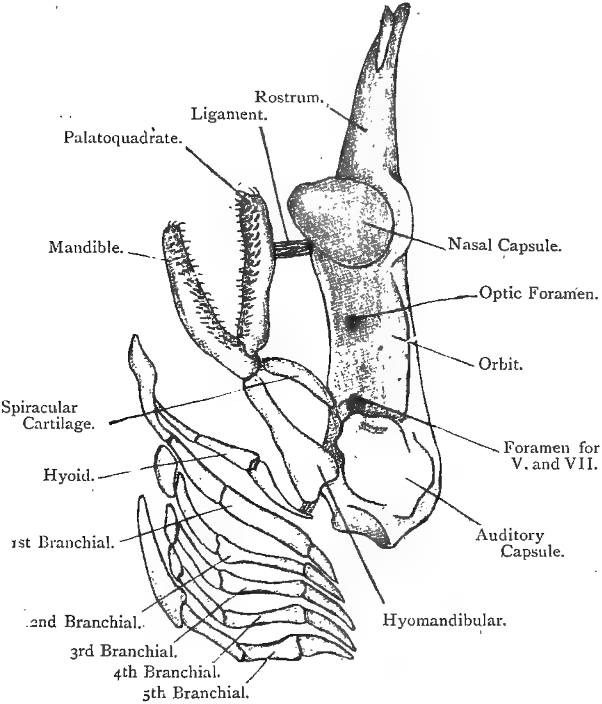


For purposes of description we may divide the cartilaginous skeleton into (1) Axial and (2) Peripheral (appendicular). The Axial is divided into (1) Cranium, (2) Visceral arches and (3) Vertebral column; and the Peripheral into (1) Pectoral and (2) Pelvic elements.

1. Axial.—The Cranium is an elongated hollow case enclosing a spacious cavity in which lies the brain. At the

anterior end it is produced into a pointed *rostrum* and at the posterior end is a large hole, the *foramen magnum*, leading into the cranial cavity. On either side of the foramen magnum is a large *occipital condyle* or facet. At the base of the rostrum on each side is an olfactory capsule opening ventrally and containing the nasal sac. On either side of the posterior region is a large auditory capsule containing the auditory sac. The lateral walls of the cranium bound the orbit and have several foramina for transmission of the cranial nerves.

Fig. 232.—Lateral View of Skull of Skate (Natural Size). (*Ad nat.*)



The cavity of each auditory capsule opens by a small aperture on the dorsal surface. The dorsal wall of the cranium is incomplete and the two large openings are known as the *anterior* and *posterior fontanelles.*

The Visceral Arches form the jaws and the supporting bars of the gill region (*cf.* page 417). The principal parts are (1) The paired *hyomandibular* cartilage, fastened to the auditory region of the cranium; (2) The paired *palatoquadrate* cartilage, bound to the distal end of the hyomandibular. Each has near the hyomandibular a convex condyle to which is articulated the *mandibular cartilage.* The two palatoquadrate cartilages form the upper jaw and the mandibular cartilages form the lower jaw. Each is covered by the placoid scales forming teeth.

Behind the jaws and attached to the hyomandibular is a long jointed *hyoid* cartilage. Behind this are five branchial cartilages on each side, which are joined together ventrally by a median plate of cartilage. They support the gills.

The palatoquadrate and mandibular form the first visceral arch bent upon itself, the hyomandibular and hyoid form the second visceral arch and the branchials are the third to seventh visceral arches.

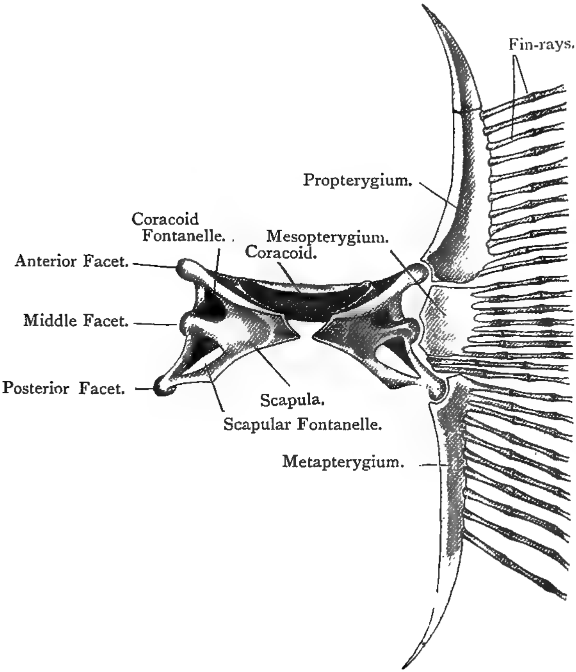
In the skate the first two visceral arches, mandibular and hyoid, are only loosely attached to the cranium, but in the higher types a *skull* is formed by the fusion of the cranium and these two arches, which latter form the *facial* portion of the skull.

The vertebral column consists of a row of axial cartilages from the cranium to the tip of the tail.

The *anterior vertebral plate* is a long cartilage which articulates anteriorly with the two occipital condyles and posteriorly with the free vertebræ. It has a *dorsal* (or *neural*) *ridge* and two *lateral ridges*, and is pierced by the *neural canal* for transmission of the spinal cord. Behind the vertebral plate the vertebral column consists of a series of *centra*, with a hollow facet at each end (amphicœlous). Each has a pair of dorsal *neural* processes and lateral *transverse processes* (bearing small *ribs*). These five cartilages are intimately connected and lie together below the spinal cord. The *neural arch* over the cord is completed by *neural spines* lying directly dorsal to the centrum and lateral *interneural plates.* In the *caudal* (or tail) portion there are added a pair of *hæmal processes* to each centrum and a *hæmal spine.* They may possibly be homologous with the transverse processes and ribs of the trunk-portion, respectively.

2. **Peripheral.**—(1) The anterior or pectoral element consists of a *pectoral girdle* and *pectoral fin*. The girdle is a single piece of cartilage which has a ventral "coracoid bar" across the ventral middle line, and expanded lateral portions. Each of these is pierced by three foramina and bears three *glenoid facets*. Dorsal to these a portion, the *scapular cartilage*, is bent towards the middle line and attached to the vertebral column by ligament. Articulated

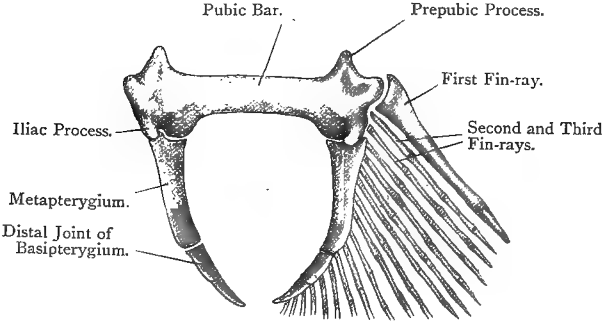
Fig. 233.—Dorsal View of Pectoral Girdle and Fin of the Skate. (*Ad nat.*)



to the facets are the three *basal* elements of the fin, called the *propterygium*, *mesopterygium* and *metapterygium*, the first and last extending forwards and backwards. Each bears on its outer border a row of numerous *fin-rays* which are jointed.

The posterior elements are the *pelvic girdle* and *pelvic fin*. The girdle consists of a ventral *pubic bar* at each end of which is a small dorsal *iliac process*, an anterior *prepubic process* and a pair of *acetabular facets*. To the posterior of these is articulated the *metapterygium*, bearing a number of *fin-rays*. To the anterior facet is attached the thickened first fin-ray.

Fig. 234.—Dorsal View of Pelvic Girdle and Fins of the Skate. (*Ad nat.*)



In its complete adaptation to an aquatic habitat, with gills or gill-slits, its paired fins with fin-rays, its two-chambered respiratory heart, and its sensory ampullæ, the skate is a type of its class *Pisces*.

In its cartilaginous skeleton, its placoid scales, heterocercal tail, spiral intestine and cloaca, the form of its urogenital organs and its embryonic development, it is typical of the order *Elasmobranchii*.

Its dorso-ventrally compressed body and reduced dorsal fin are typical of the *Batoidei*, a group comprising the rays and skates. Minor features determine its family and genus.

**Development.**—The skate lays its eggs in the autumn and the young are hatched in early spring.

The eggs are large yellow spheres which break away from the ovary into the abdominal cavity. Thence they pass into the Fallopian tubes by their internal openings. The male skate is said to thrust the claspers into the cloaca and the base of the oviducts of the female, and to discharge sperms down the grooves of the claspers into the oviduct. The sperms then appear to pass up the oviduct and to fertilise the egg in the Fallopian tube. After fertilisation the egg passes down to the oviducal gland in which is secreted an enveloping egg-case or "purse."

The eggs contained in these purses are deposited two at a time in moderately deep water, usually amongst dark seaweed. The "purse" is of a tough consistency and a dark greenish-black colour. It is flattened and has long processes at the four corners. The "purse" has the edges of its two walls at one end lying loosely against each other, allowing free egress but making ingress impossible. In this purse the egg develops slowly, and the young skate on emergence is practically a diminutive adult. During all this period it is sustained by the maternal "yolk," hence the skate has a purely embryonic development and only a lecithal type of nutrition (see page 427).

**Segmentation.**—The segmentation is meroblastic, *i.e.*, the protoplasm is largely aggregated to one pole of the large egg, and there segments or divides into a multicellular disc or cap called the *blastoderm.* The rest of the protoplasm with few nuclei is scattered throughout the yolk. These nuclei divide and are gradually added to the blastoderm during development. At completion of segmentation the blastoderm has an outer layer or epithelium of cells which represents the *epiblast* and an inner mass which, with the rest of the egg, forms the *hypoblast.*

**Gastrulation.**—One part of the rim of the blastoderm can soon be distinguished by its greater thickness and is called the *embryonic rim.* This represents the future hind end of the embryo, and immediately below it the blastoderm-cells commence to be invaginated, forming an *archenteron.* Hence this rim is comparable to the dorsal edge of the blastopore in *Amphioxus.*

Two separate processes now take place contemporaneously. Firstly, the whole blastoderm commences to envelop the lower yolk-cells by increase of cells at the rim, partly by cells added from the yolk-mass, and partly by division of the blastoderm-cells. This enveloping process does not take place equally all round the edge of the blastoderm or the last point of meeting would be the lower pole, but the embryonic rim does not progress over the yolk; hence the rest of the rim grows over, and the whole rim gradually closes in immediately behind the blastopore.

If it be recollected that the edge of the blastoderm is the line of junction of the epiblast and the hypoblast, it is clear that the growth of the former over the yolk-mass is a modified and retarded form of archiblastic invagination, which is called *epibolic.*

The process is so slow that at the same time the embryo becomes differentiated in the middle line forwards from the *embryonic rim.* The nervous system arises along this region as a median dorsal *medullary groove* which, by the upgrowth and meeting above of its edges or *medullary folds*, becomes converted into a complete tube.

The folds meet in the middle of the embryo and anteriorly, but are open posteriorly till the blastopore is nearly closed; then they meet behind it and so produce a *neurenteric canal.* The anterior end of the nerve tube swells to become the brain and the eyes and parts of the brain arise as described in the general account for vertebrates (see page 406).

Immediately below this nerve tube the hypoblast cells in the middle line become differentiated into a notochord, and laterally the hypoblast also becomes differentiated into a pair of cell-plates which form the mesoblast. The topographical relationships of the neural tube, the notochord and mesoblastic plates are therefore much the same as in *Amphioxus*, but the last two arise as solid masses of cells, not as hollow outgrowths. At the embryonic rim the nerve tube, notochord and mesoblast are all merged into a growing mass of cells.

The embryo then becomes folded off from the rest of the blastoderm until it is only connected therewith by a small stalk called the yolk-sac stalk. The whole developing organism is then clearly defined into the *embryo* and its *yolk-sac*, attached to each other by a short stalk. The wall of the yolk-sac and the embryo are alike produced from the blastoderm, and we may make matters clearer at once by explaining that the yolk-sac is really a huge enlargement of the abdominal wall of the embryo. Over its surface there ramify *vitelline* arteries and veins which serve to absorb nourishment for the embryo.

The mesoblastic plates now grow round ventrally inside the epiblast to enclose the yolk-mass. They divide into a dorsal portion which splits up into a series of *protovertebræ* lying on either side of the notochord and a ventral portion which forms the *lateral plate.* A split occurs between the cells of the lateral plate and forms the cœlom, which is thus schizocœlic. This split extends completely round the yolk-mass, dividing the mesoblast of the lateral plate into an outer *somatic* layer under the epiblast and an inner *splanchnic* layer resting on the hypoblast and yolk-mass.

Thus the extra-embryonic part, which we called the yolk-sac, now consists of an outer layer of epiblast and mesoblast which we may term the *serosa* (or serous membrane) and an inner layer of mesoblast and hypoblast enveloping the yolk and called the *yolk-sac proper.* These two embryonic (or fœtal) membranes are separated by a cavity (the extra-embryonic cœlom) which is continuous through the stalk into the embryonic cœlom.

It is evident that the serosa is merely the much distended body-wall and the yolk-sac proper a similarly distended part of the gut-wall. The protovertebræ give rise to the vertebral column and myomere muscles.

The gill-slits appear at the side of the neck, and from them there soon protrude a number of long, delicate gill-filaments, the external gills which are lost before hatching, their bases alone persisting as the permanent gills.

The organs in general arise much as narrated in the general vertebrate account (see pages 405–430).

In comparing this development with that of *Amphioxus* much assistance will be rendered by study of the frog, which in the amount of yolk and the consequent modification in development is in an intermediate position. The three types will be compared after the frog has been dealt with (see page 358).

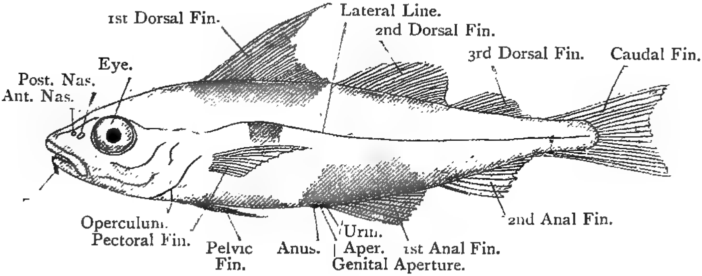
## III.—GADUS.

| | |
|---|---|
| PHYLUM - | CHORDATA (p. 402). |
| SUB-PHYLUM | VERTEBRATA (p. 405). |
| CLASS | PISCES (p. 434). |
| ORDER | TELEOSTOMI (p. 437). |

**Colour and Habits.**

The haddock *(Gadus æglefinus)* is one of the commonest and best known of our British fishes. It is described here as a type of the order *Teleostomi* or bony fishes. The haddock is a smaller fish than the cod but larger than the whiting; all three belong to the large family of *Gadidæ*. It frequents the deeper offshore water and is a ground-feeder upon small *Crustacea*, *Mollusca* and *Annelida*. The freshly-caught haddock is of a beautiful colour. The ventral surface is a pearly-white which gradates up each side into a metallic violet darkest along the dorsal surface. Along each side is a thin black line, the *lateral line*, extending from the head backwards to the tail. Just below the anterior part of this line there is on each side a black spot of pigment. The eyes are silvery and black. The whole body is enclothed in an investing coat of delicate overlapping cycloid scales, developed in the dermis and carrying no spines. The skin is extremely slimy, as in the skate.

Fig. 235.—LATERAL VIEW OF THE HADDOCK (*Gadus æglefinus*) × ⅓. (*Ad nat.*)



**External Features.**

At the anterior end of the head is a large gaping *mouth* armed with upper and lower rows of teeth. Below the chin is a small sensitive papilla called the *barbel*. Above the mouth and quite free from it are two small openings on each side. These are the *nares*, **Respiratory.** each nasal sac having an *anterior* and a *posterior nas* opening directly to the exterior. There is no external opening of the ear. At the hind-end of the head there is on each side a movable plate formed of several bones, called the *operculum*. If this be raised it exposes the four pairs of *gills*, consisting of long rows of gill-filaments, with large clefts between them, leading into the pharynx. In front of the gills on the first cleft is a vestigial gill, the *pseudobranch*. The gills of the haddock appear very different from those of the skate, but they are developed in a similar manner. In the skate the clefts are narrow, the filaments short and the body-wall between the clefts broad. In the haddock the clefts are wide, the filaments long and the intermediate body-wall reduced to a minimum. In addition the gills are covered over by an operculum.

The skate takes water in at the spiracle and passes it out by the gill-clefts, but the haddock normally takes water in at the mouth and passes it out through the gill-clefts, the operculum being opened and shut by special muscles.

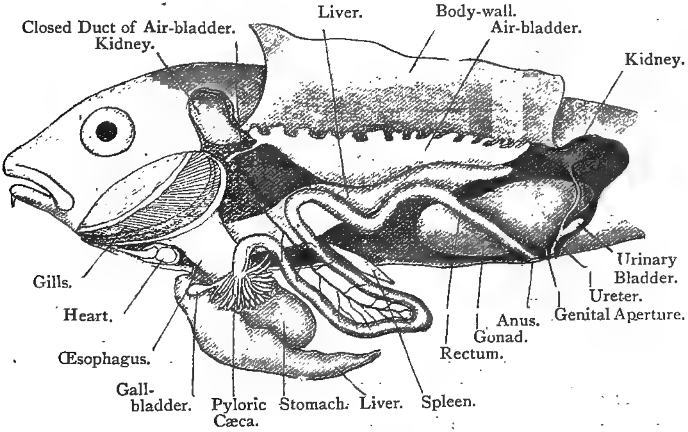
Just behind the operculum and situated laterally are the large *pectoral fins*. Ventrally and slightly forwards are the paired *pelvic* fins. In many *Teleostomi* the pelvic fins are far back, as in the skate, but in the *Gadidæ* they are often *jugular* (on the neck) in position, moving forwards during development. The larval haddock has, in addition to these fins, a continuous median fin stretching along the dorsal surface round the tail and forwards to the *anus* on the ventral side (*cf. Myxine*). In later life this fin breaks up into three *dorsals*, a *caudal* and two *anals*, by differential growth and atrophy of the intermediate parts. The tail-fin is symmetrical, the dorsal and ventral halves being equal, but the end of body bends up into the dorsal half, hence the tail is *homocercal* (see Pisces, p. 435). All the fins have the same structure, consisting of a delicate double fold of membrane supported on a series of elastic skeletal *dermal fin-rays*. Just in front of the first anal fin is a small cloacal depression into which open three apertures. The anterior is the *anus*, the intermediate the *genital aperture* and the posterior the *urinary aperture*. If the skin be carefully dissected off one side there can be noticed fine *superficial nerves* supplying the lateral line and the fins. They arise mainly from the Vth and Xth cranial nerves. Below these the whole lateral wall of the body is formed of diagonal myomere **Muscular.** muscles, separated by connective-tissue *myocommata* (*cf. Amphioxus*). From a little way behind the anus the rest of the body backwards, usually known as the *tail*, is composed almost entirely of these myomere muscles. Their alternate contractions serve to move the "tail" and caudal fin and thus propel the body. This method of locomotion is similar to that of *Amphioxus* and is also found in many *Elasmobranchii*: the skate itself has adopted a different method of progression by the pectoral fins, which in the haddock merely act as balancing, steering and stopping organs.

The *perivisceral* cavity may now be opened up by a median ventral incision from chin to anus. The cavity is completely divided into two parts, the anterior *pericardial cavity* and the posterior *abdominal cavity*.

**Alimentary.** The heart lies in the former and the alimentary canal and other organs in the latter. The somatic layer of peritoneum is deeply pigmented, forming a black wall to the cavity, whilst the splanchnic forms a glistening transparent membrane surrounding the alimentary canal and forming a dorsal mesentery.

The teeth have already been mentioned: they are borne on the premaxilla and dentary and a small inner patch on the vomer (*cf.* Frog). If the jaws be pulled open and the *pharynx* examined, the five lateral gill-clefts can be noticed and in addition a large paired patch of teeth on its dorsal surface, borne on the superior pharyngeal bones or upper bones of the branchial arch. Immediately ventral to these are a pair of patches of teeth on the inferior pharyngeal bones, representing the fifth branchial arches. These teeth, working upon each other, form a remarkable subsidiary pair of jaws for propelling food down the *œsophagus* into the stomach. In all cases the teeth are merely *haplodont*, *i.e.*, they are sharp conical points which sieze prey but are not used for mastication. The *stomach* is large and bent on itself. It is continued into a *duodenum*, at the commencement of which there opens a number of long cæcal tubes called the *pyloric cæca*. They are said to secrete a digestive juice and have been compared tentatively to a pancreas. The *liver* is a large bilobed organ with a gall-bladder from which there passes a single bile-duct to open into the duodenum. The duodenum is continued into the *ileum* which is long and coiled and terminates in the *anus*. Its hind

Fig. 236.—Dissection of Haddock from the Left Side. (*Ad nat.*)



The left abdominal wall has been cut and thrown back dorsally, and the intestine and stomach have been pulled out ventrally.

portion is sometimes distinguished as the *rectum*. The lumen is simple and has no spiral valve.

From the dorsal wall of the œsophagus there is produced a solid cord of connective tissue, which is connected at its distal end with a large and spacious *air-bladder* lying immediately above the abdominal cavity. It is filled with gases and its walls have a dense vascular supply. This air-bladder is used as a hydrostatic apparatus and is not found in demersal fish (those habitually frequenting the bottom). In many, *e.g.*, the herring, the connecting cord is a duct putting its cavity into communication with that of the œsophagus. It always arises in the young as a diverticulum of the alimentary canal.

In the mesentery above the ileum is a small red *spleen*. Dorsally to the abdominal cavity and to the air-bladder lies a pair of elongated *kidneys* of a dark-red colour. They are thin in the region above the air-bladder, but swell out anteriorly immediately behind the head into large bulbous organs, and also posteriorly where they give off an unpaired *ureter* passing down to the *urinary aperture*. It swells into a small *urinary bladder* near the aperture. These kidneys are said to be mesonephric in origin.

**Excretory.**

The heart is smaller in proportion than in the skate. It has two chambers, an *auricle* and a *ventricle*. The former is fed from a thin-walled *sinus venosus*, and the latter leads forwards as the *branchial artery*. There is no valvular conus arteriosus, as in the skate, its vestige being seen in a single pair of valves; there is a swollen base to the branchial artery sometimes distinguished as the *bulbus arteriosus*. The branchial artery gives off four paired *afferent branchials* to the gills which give fine branches to the gill-filaments. The blood after æration is collected by four pairs of *efferent branchials* in the roof of the mouth, which are difficult to follow.

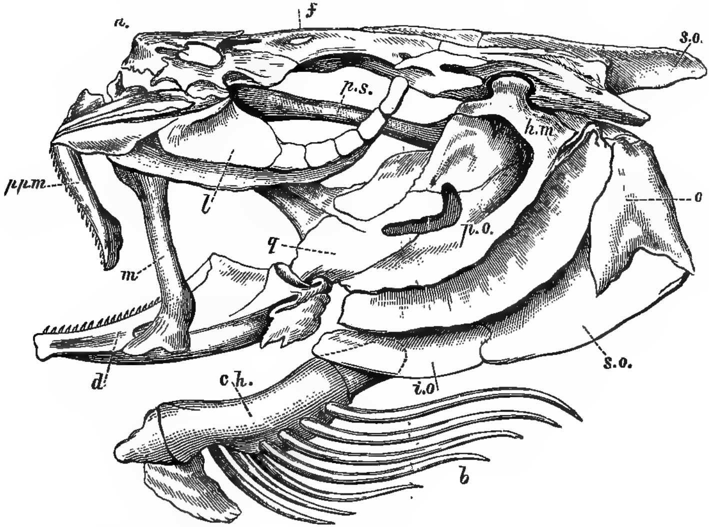
**Blood-Vascular.**

The efferent branchials of each side unite to form a vessel often termed the *epibranchial artery*. Anteriorly each epibranchial is continued forwards to meet its fellow across the base of the skull, completing the so-called *cephalic circle*. Each gives off a *carotid* to the head. Posteriorly each epibranchial converges towards the middle line, and gives off a *subclavian* artery to the *pectoral fin*. They then unite to form the *dorsal aorta*, which runs backwards immediately below the vertebral column. It can be seen between the kidneys on removal of the air-bladder. Posterior to the abdominal cavity it divides into the *caudal artery*, supplying the tail-muscles and the *vesicular* artery to the urinary bladder and anal fin. The dorsal aorta gives off numerous renals to the kidneys throughout its course. From the right epibranchial anterior to the origin of the subclavian there arises a pair of median *visceral arteries*. The anterior of these supplies the *pyloric cæca*, and the posterior, sometimes known as the *cœliaco-mesenteric*, gives branches to the stomach, intestine, air-bladder, spleen and gonads.

The venous system is difficult to follow except in injected specimens. It consists of paired *precavals* leading out from the sinus venosus, which give off *jugulars* forwards and *cardinals* backwards. There are no lateral veins. The cardinals run in the kidneys and receive numerous *renal* veins. The *caudal vein* is large and runs forwards immediately below the caudal artery. At the level of the posterior portion of the kidneys it divides into two *renal portals*, as in the skate; the left renal portal breaks up into capillaries in the left kidney, but the right is usually continuous forwards with the right cardinal vein. A branch from the caudal vein, the *vesicular* vein, runs ventralwards and joins the mesenteric branch of the *portal* vein.

The portal system is well developed and consists of a *mesenteric vein* from the intestine, a splenic from the spleen and a branch from the air-bladder leading to the liver. The blood from the liver is carried by paired *hepatic* veins into the sinus venosus.

Fig. 237.—Lateral View of Cod's Skull.



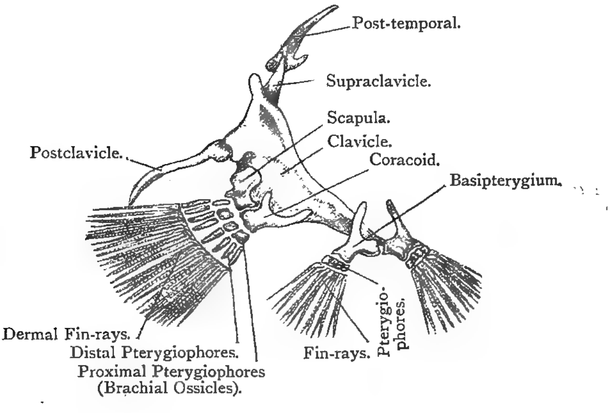
*b.*, Branchiostegal Rays.
*c.h.*, Ceratohyal.
*d*, Dentary.
*f.*, Frontal.
*h.m.*, Hyomandibular.
*i.o.*, Interoperculum.
*l.*, Lacrymal.
*m*, Maxilla.
*n.*, Nasal.
*o*, Operculum.
*p.s.*, Parasphenoid.
*p.m.*, Premaxilla.
*p.o.*, Preoperculum.
*q.*, Quadrate.
*s.o.*, Supraoccipital.
*s.o.*, Suboperculum (lower reference).

The vascular system shows a peculiar asymmetry of both the arterial and venous systems, and a marked tendency to anastomosis of certain outlying vessels, seen also in the bird. Both the veins and arteries are remarkably small compared with the size of the fish, and there is a very small quantity of blood.

**Skeletal.** The skeleton of the cod is in marked contrast to that of the skate in consisting almost entirely of bone.

Axial.—The skull is formed of a cranium, mainly bone, and a series of bony visceral arches. The cranium is formed of (1) an occipital ring posteriorly, consisting of a *supraoccipital*, paired *exoccipitals* and a *basioccipital;* (2) the *otic* bones surrounding the auditory capsule and lying immediately in front of the occipitals. There are five otic bones—*prootic*, *epiotic*, *opisthotic*, *pterotic* and *sphenotic*. On the two last is a large facet for the *hyomandibular* bone. (3) At the front end of the cranium are a series of bones arising in connection with the nasal capsules, the dorsal *nasals*, median *mesethmoid* and lateral *ectethmoids*. (4) Between these and the occipital and auditory region the dorsal surface of the cranium is completed by small *parietals* in front of the supraoccipital and large *frontals* covering the orbits. In front of the otic bones there is a pair of small *alisphenoids* in the orbit. (5) The basal axis of the cranium is formed, anteriorly to the basioccipital, by the long *parasphenoid* and *vomer*, the latter bearing teeth and lying below the mesethmoid. (6) Lastly, in connection with the orbit is a chain of orbital bones, of which the anterior and largest is known as the *lacrymal*.

Fig. 238.—The Right Pectoral Fin and Girdle of the Cod with both Pelvic Fins. (*Ad nat.*)



To this cranium are loosely attached a number of bones belonging to visceral arches. Anteriorly are paired *premaxillæ* bearing teeth, and *maxillæ* without teeth. These are supposed to be connected with the labial cartilages of the skate.

The first or mandibular arch ossifies into the *palatines* attached to the ectethmoids, the *pterygoids* with *meso-* and *metapterygoids*, and the *quadrates* which form the upper half (or palatoquadrate chain) and the *articular*, *angular* and *dentary* forming the lower half or mandible. An articulation is formed between the articular and the quadrate.

The second or hyoid arch consists in its upper half of a *hyomandibular* attached to the otic region, bearing four opercular bones on its posterior border (the *preopercular*, *opercular*, *subopercular* and *interopercular*), and joined to the quadrate by a small *symplectic*. Its lower half forms a chain of *hyoid* bones which carry on their posterior surface seven *branchiostegal* rays.

The four branchial arches consist of *pharyngo-*, *epi-*, *cerato-* and *hypobranchials*, united below by the *basibranchials*. The pharyngobranchials fuse to form the superior pharyngeal bones already noticed, and the *Ceratobranchials* of the fifth arch form the inferior pharyngeal bones.

The vertebral column consists of a large number of *amphicœlous vertebræ*. The anterior are termed *abdominal* and the posterior are *caudal*. All the vertebræ have complete neural arches and neural spines. Most of the abdominal have also transverse processes, which bear a pair of *ribs* and a pair of more dorsally placed so-called *intermuscular bones*. In the caudal vertebræ the transverse processes meet below and form a complete *hæmal arch*. The median fins are supported on dermal fin-rays, which rest on short *pterygiophores* and *interspinous* bones.

Appendicular.—The pectoral girdle is attached to the otic region of the skull by the *supratemporal bone*. There are three clavicular bones, the *supraclavicle*, *clavicle* and *postclavicle*. A small scapula and coracoid complete the girdle; they bear on their posterior border four small *brachial ossicles* (or *pterygiophores*), which in their turn bear the numerous *pectoral fin-rays*. The pelvic girdle is absent, but there is a large *basipterygium* on each side which carries the *pelvic fin-rays*.

**Nervous System.** The brain is small and differs from that of the skate, chiefly in the large *optic lobes* and small *cerebral hemispheres*. On the other hand, the *cerebellum* is equally well developed.

**Reproductive.** The gonads are simple, paired hollow sacs opening by short genital ducts to the exterior. They lie in the abdominal cavity.

**Development.** There is as great a contrast to the skate in the development as in the anatomy. The haddock lays several million eggs which are of small size, perfectly transparent and buoyant. Fertilisation is external and the eggs are pelagic. There is a considerable amount of yolk and segmentation is meroblastic. The young haddock is hatched as a transparent larva, with a large yolk-sac depending from its ventral surface. After a time the young fish absorbs its yolk and feeds on pelagic organisms; still later it takes to a ground-feeding habit.

The haddock is a type of the order *Teleostomi* or bony-fishes, which is usually contained in the class Pisces, with the *Elasmobranchii* and some smaller orders. It is, however, evident that the two types are widely divergent in numerous structural characters.

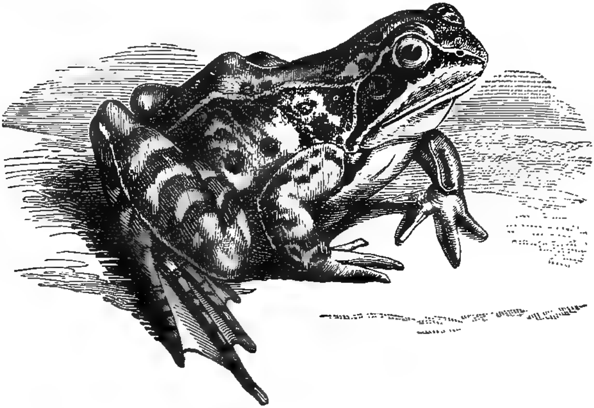
# CHAPTER XXI.

## *CHORDATA—(Continued.)*

## IV.—RANA.

| | |
|---|---|
| PHYLUM | CHORDATA (p. 402). |
| SUB-PHYLUM | VERTEBRATA (p. 405). |
| CLASS | AMPHIBIA (p. 439). |

Fig. 239.—THE COMMON FROG (*Rana temporaria*).
(Natural Size.)

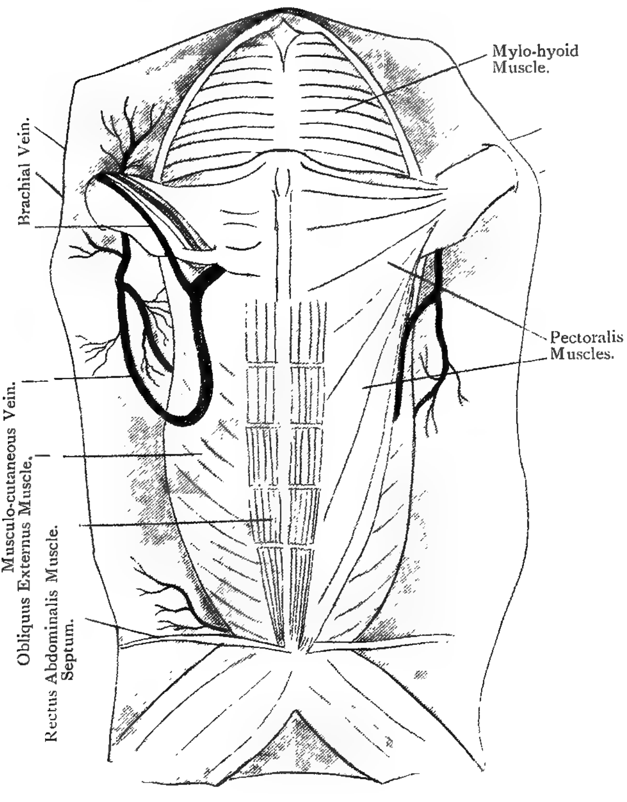


Note the large mouth, and tympanum behind the eye, long hind-limbs with webbed toes and pigmented skin.

**Rana temporaria** is the common British frog of universally familiar appearance. A slightly larger form, *Rana esculenta*, or the Edible Frog, common upon the Continent, is often preferred for dissection, but the description here given will suffice for either species.

The frog is a water-loving terrestrial animal. In locomotion it is equally at home in water or on land. In the early morning and early evening, when dew and damp are frequent, it becomes active in the pursuit of insects, worms

## Plate IV.—FIRST DISSECTION OF FROG. (*Ad nat.*)



The skin is cut by a median ventral incision and pinned back. On the right the *pectoralis* muscle is mostly removed to show the course of the subclavian vein dividing into brachial and musculo cutaneous

and other small animals, but retires through the day into water or rocky holes. In the winter the frog hibernates in pond-mud or in holes.

**External Features.**

The *head* is set upon the *trunk* with no neck and the latter carries two conspicuous pairs of limbs. The *mouth*, when open, is a wide gaping fissure, literally extending "from ear to ear." At the tip of the "nose" is a pair of small *external nares* leading into the olfactory or nasal sacs. Further back are the eyes, and a little behind and below them are the *tympanic membranes* of the ears or auditory organs. These are covered with skin and appear as round surfaces. The *front limbs* have four digits, the thumb being absent. The *hind limbs* have five long toes or digits with a web stretched between them. The male *Rana temporaria* in the breeding season has a thickened callosity on the first digit of each fore-limb. Dorsal to the junction of the hind limbs and the trunk is a single *cloacal aperture.*

**Integumentary.**

The whole body is enclothed in a loose moist skin, with an entire absence of scales, hairs, or other exoskeleton. There are abundant skin-glands which serve to keep the skin moist. Under the skin are numerous blood-vessels which enable the skin to assist in the function of respiration.

The skin has scattered pigment of various colours, and the frog has the power to adapt its general coloration to its surroundings fairly rapidly. If the jaws be widely opened the *buccal cavity* is exposed. The *tongue* is forked, free behind and fastened at the front end; it can be shot out with great rapidity for catching insects.* The lower jaw has no teeth, but a row of delicate teeth lines the upper. In addition there are in the roof of the mouth two patches of small *vomerine* teeth, so-called because they are on the *vomer* bones.

Just behind these teeth are paired *internal nares* leading to the exterior by the nasal sacs and the external nares. They serve for the introduction of air. Further back, near the angles of the jaw, is found on each side a widely-open passage, the *Eustachian tube*, leading almost at once into the

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* The tongue is protruded by the pressure of lymph forced into its interior by the contraction of muscles, such as the mylohyoid.

tympanic cavity. Further back still, on the ventral surface, is a small median longitudinal slit, called the *glottis*, leading into the lungs. Lastly, the wide *œsophagus* leads down to the stomach.

If the skin be cut open along the mid-ventral line from chin to cloaca it will be noticed that its looseness is due to a large *subcutaneous lymph-space* which forms a sort of lymph-jacket between the skin and the body-muscles (see Plate IV.). Emerging from the region of the "armpit" can be seen a large vein, the *subclavian*, dividing into a *brachial* coming down from the fore-limb, and a large *musculo-cutaneous*, which arises by a mass of small veins covering the inner surface of the skin. This vein brings ærated blood back from the skin to the heart.

Extending across from one mandible to the other is a peculiar loose muscle, the *mylohyoid.* Further back the *sternum* may be felt in the mid-ventral line, from the hind end of which to the pelvis there runs a muscular band, the *rectus abdominalis.* In the middle line of this muscle can be seen a dark line caused by the underlying *anterior abdominal vein.*

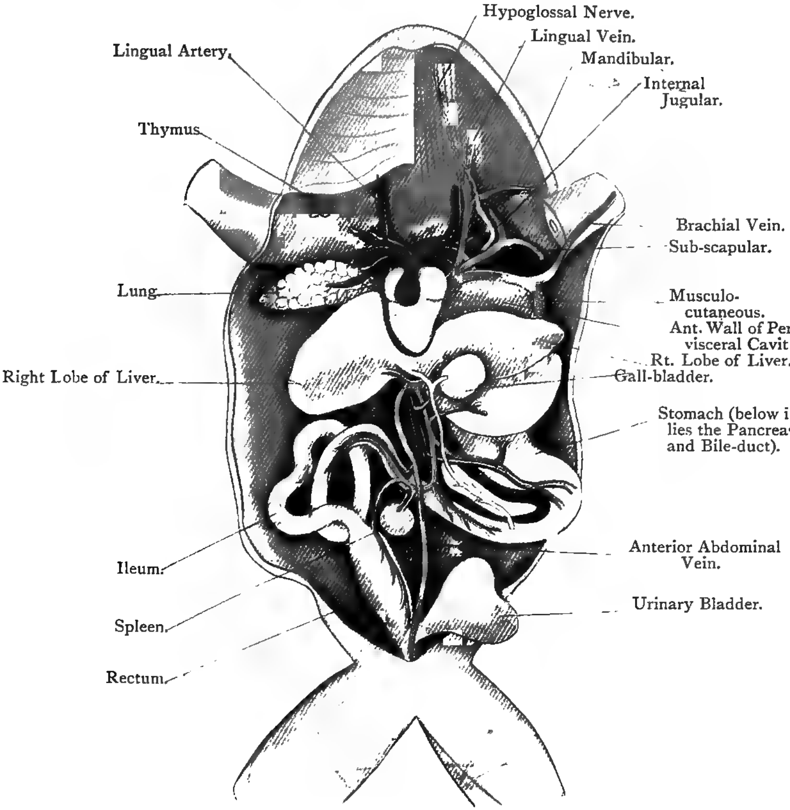
**Cœlom.**

A median incision can now be made from chin to pelvis through the mylohyoid muscle, the sternum and the rectus muscle (to one side of the anterior abdominal vein). The body-cavity thus opened up has much the same relationship as that of the skate (see Plate V.). The *abdominal cavity* extends forwards to the level of the œsophagus and backwards to the pelvis. The much smaller *pericardial cavity* surrounds the heart and is *completely* separated from the abdominal cavity. As in the skate, the organs are suspended in folds of peritoneum which form dorsal mesenteries.

**Alimentary.**

The œsophagus enters the abdominal cavity anteriorly, and soon swells into a *stomach* towards the left side. It is covered by a large two-lobed *liver* with a roundish *gall-bladder*. The stomach leads into a *duodenum* into which there falls a bile-duct leading down from the gall-bladder. Around the bile-duct is a branched whitish gland, the *pancreas*, which opens by ducts into it. The rest of the small intestine, called the *ileum*, is long, of small calibre and coiled. It passes into a wide but short

## Plate V.—SECOND DISSECTION OF THE FROG. (*Ad nat.*)



The ventral body wall is cut open by a median incision from chin to vent through the sternum. The pectoral girdle is completely removed and the body wall pinned out. The mylo-hyoid muscle is removed on the left and the anterior venous system is removed on the right. The branches of the portal vein can be identified by the organs to which they run. The veins are blue, arteries red.

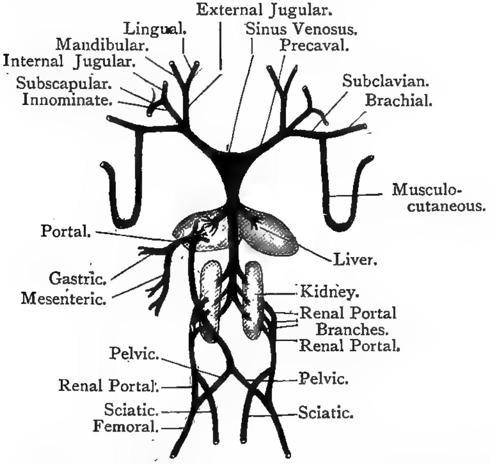
*rectum* which opens into the cloaca. From its ventral wall, close to the cloacal aperture, is a large bilobed *urinary bladder.*

Close to the pancreas, and near the head of the rectum, is a round reddish *spleen*, one of the ductless glands.

**Respiratory.**

At the extreme front end of the abdominal cavity there lies dorsally a pair of *lungs.* Each rests loosely in the cavity, but is attached anteriorly to the œsophagus. If the lungs be inflated by a blowpipe through the glottis they will be seen to consist of hollow sacs of great elasticity. When punctured they return to their former small bulk and soft condition.

Fig. 240.—DIAGRAM OF VENOUS SYSTEM OF A FROG.
(Ventral view.)



The anterior abdominal is unlabelled, but is seen running forwards from the two pelvics to the portal.

The frog fills its buccal cavity with air through the nares, and then pushes upwards the floor of the cavity with its *hyoid cartilage* (or *lingual plate*). This forces the air down to the lungs and effects *inspiration.* The air is expired by the elastic walls of the lungs.* We may notice that the

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* The expiration may be assisted by contraction of the abdominal muscles upon the viscera.

lungs and the urinary bladder belong morphologically but not physiologically to the alimentary system.

**Blood-Vascular. Venous.**

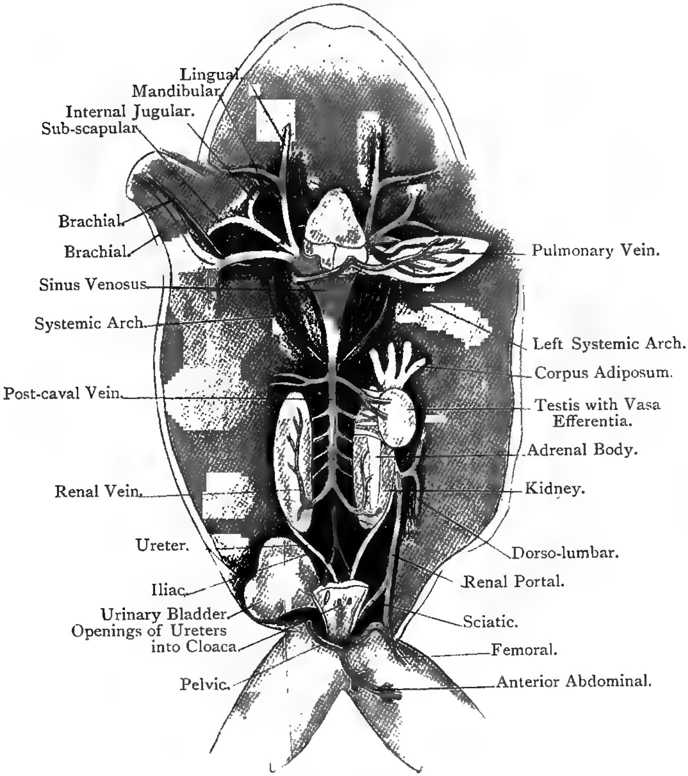
The *heart* lies ventrally to the œsophagus, enveloped in its pericardium. Its structure will be considered later. The veins lie superficially to the arteries and consist of an anterior and a posterior system. The anterior system is paired; the posterior is in great part single.

Anteriorly a small *lingual* vein from the tongue is seen to unite with a *mandibular* from the lower jaw to form the *external jugular*. This runs backwards to join with the large *subclavian* already seen, which runs along the anterior wall of the abdominal cavity. As already noticed, the subclavian is made up of the *brachial* and the *musculo-cutaneous*. The area between external jugular and subclavian is drained by a small but deep vein, the *innominate*, which is formed of the *internal jugular* emerging from the brain and the *subscapular* from the dorsal region. The innominate joins the external jugular and subclavian, the three uniting to form the *precaval* vein, which passes backwards and inwards to fall into the *sinus venosus* dorsal to the heart.

In the posterior system the portal vein can be seen coming from the stomach, spleen, pancreas and duodenum, and falling into the liver; it constitutes the *hepatic-portal* system. Just before it enters the liver it receives the *anterior abdominal vein* already noted.

If the alimentary canal be now carefully removed by cutting through the rectum and through the œsophagus, the *kidneys* are exposed and the rest of the venous system is clearly distinguished (see Plate VI.). The *femoral* veins are large veins leading up from the legs. Before entering the abdominal cavity each *divides* into a *pelvic* and a *renal portal*. The former comes up to meet its fellow and the two form the *anterior abdominal* to the liver. The renal portal proceeds forwards, receives a *sciatic* from the inner side of the leg, and breaks up along the outer border of the kidney; hence the frog has a well-developed renal-portal system as well as a hepatic-portal. The blood from the large hind-limbs must pass either through the kidney by the renal portal, or through the liver by the anterior abdominal before reaching the heart. Between the kidneys is a large *postcaval* which

Plate VI.—THIRD DISSECTION OF FROG.



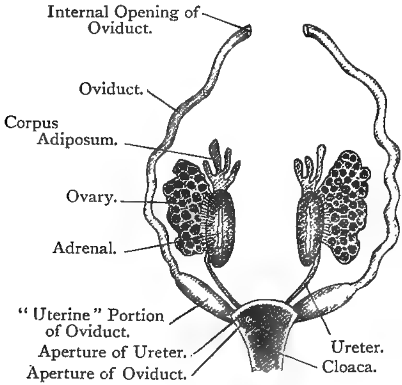
The alimentary canal is cut away together with liver, pancreas and right lung. The heart is thrown forwards and the left lung pulled outwards. The cloaca is slit open. The veins are all coloured blue and the arteries red.

receives blood from the kidneys by *renals* and from the genital organs. It then passes forwards through the liver, which it drains by paired *hepatics*, and discharges itself into the sinus venosus.

The two lungs have separate *pulmonary veins* which fall together into the left auricle of the heart.

In the frog there are no paired cardinal veins* as in the skate, their function being executed by the unpaired postcaval. On the other hand, the presence of a renal-portal system is a feature of both types.

Fig. 241.—Ventral View of the Female Urogenital Organs of a Frog. (*Ad nat.*)



The cloaca is slit open to show openings of ureters and oviducts.

**Urogenital.**

The *kidneys* are long, red bodies lying in the dorsal wall of the abdominal cavity. Each has a thin, yellow, *adrenal* body on its ventral face. A *ureter* leaves the outer posterior border of each kidney to open separately into the cloaca just dorsal to the opening of the urinary bladder already noticed.

In the male the *testes* are oval, light-yellow bodies lying ventral to the anterior part of the kidneys and attached to them by peritoneum. A number of fine tubules, the *vasa efferentia*, pass from the testes into the kidney, through which they eventually communicate with the ureters. These, therefore,

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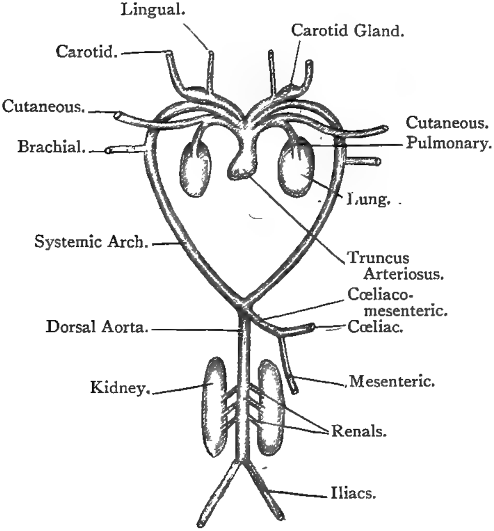
* They are present in the *Urodela*.

function as vasa deferentia and have a small *prostate gland* attached to them.* To the front end of the testes are attached a number of branching *fat-bodies* (or *corpora adiposa*). In the female the *ovaries* are large dark organs, suspended by dorsal mesenteries near the kidneys. The *oviducts* are long, coiled, paired tubes running throughout the length of the abdominal cavity. They open behind into the cloaca, in front into the abdominal cavity by separate funnel-shaped apertures just in front of the lungs. Their lower portions are wide and saccular and are sometimes called the uterine portions of the oviduct. The walls of the upper portion are glandular and secrete albumen. The eggs, when ripe, are discharged into the abdominal cavity and pass

Fig. 242.—Diagram of Arterial System of a Frog.

(Ventral view.)



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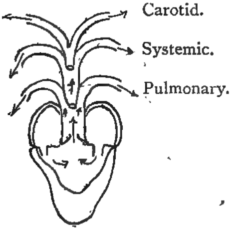
[*] In *Rana esculenta* the prostate gland is absent, but the ureters are swollen for a part of their course.

down the oviducts, where they receive a coat of albumen and accumulate in the uterine part.

**Blood-Vascular. Arterial.** If the urogenital organs and the anterior venous system be now carefully removed the arterial system can be completely exposed.

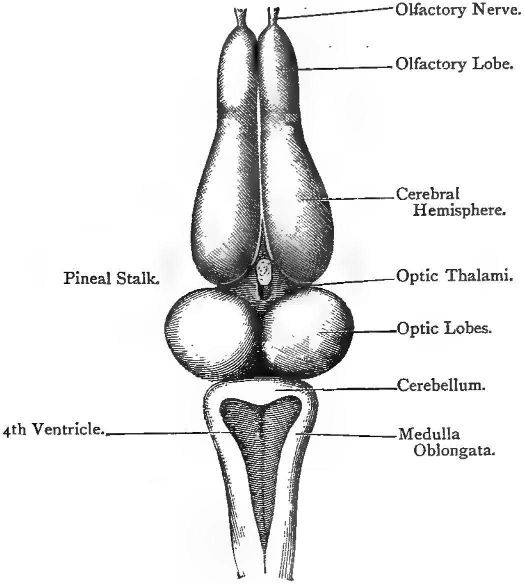
The *heart* is three-chambered, consisting of a ventricle and two auricles. The *right auricle* receives venous blood from the sinus venosus and the *left auricle* receives arterial blood from the pulmonary veins. Both auricles, on contraction, drive their contents through valves into the ventricle. From the ventricle there runs forwards between the auricles a *truncus arteriosus* which first diverges into two, and each of these divides into three, *arterial arches.* The anterior, called the *carotid arch,* passes up to a swollen *carotid gland* and divides into a *lingual* and *carotid artery* to the head. The second or systemic turns backwards, gives off a *brachial artery* to the fore-limb, and meets its fellow dorsally to the liver to form the single *dorsal aorta.* The dorsal aorta gives off a large *cœliaco-mesenteric* to the liver, stomach and other viscera, *renals* to the kidneys, and eventually divides into two *iliacs* to the hind-legs. The third arch, or *pulmocutaneous,* divides into *cutaneous* to the skin and *pulmonary* to the lungs.

Fig. 243.—Diagram of the Truncus Arteriosus of a Frog's Heart.



The *truncus arteriosus* has a long valve running up its lower part which is arranged in such a way that certain portions of the blood pass up certain arches. The auricles discharge venous and arterial blood respectively into the ventricle, and in the ordinary way these would completely mix and every organ would on contraction of the ventricle be supplied with mixed blood. On the other hand, greater efficiency would be attained if the arterial blood could be sent to the tissues generally and venous blood to the lungs, and this is practically the case. The ventricle contracts rapidly after the auricles, before the blood from the latter has had time to mix, and hence the first portion of the blood leaving the ventricle is nearly all venous, because the opening of the truncus inclines to the right. This passes up the wide passage to the pulmonary arches, and only when these are comparatively full does the next portion of mixed blood diverge up the smaller aperture to the top of the truncus arteriosus. Here it passes up the wide openings of the two systemic arches, whilst only the last and most arterial portion reaches the small aperture to the carotids, ensuring a supply of pure blood to the brain.

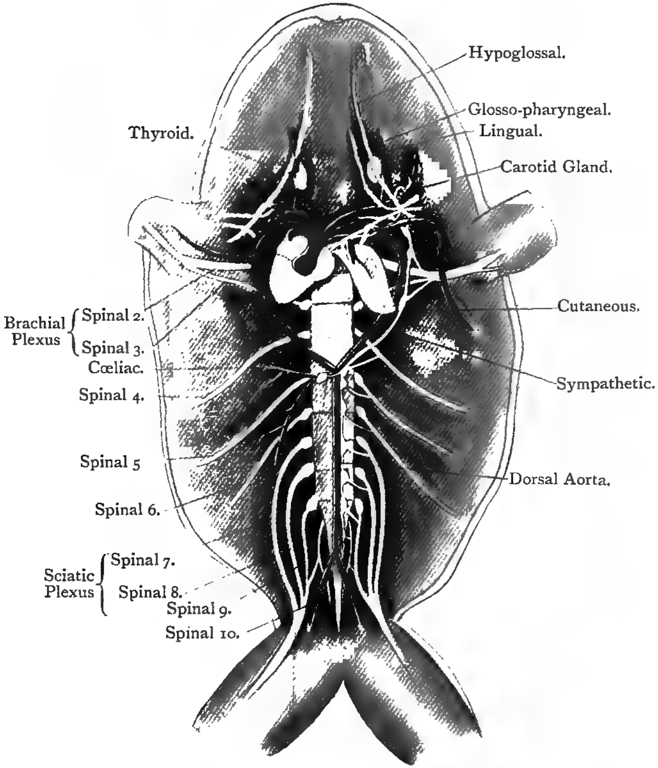
Fig. 244.—DORSAL VIEW OF BRAIN OF FROG.



**Nervous.**

The spinal nerves are clearly seen lying in the dorsal wall of the abdominal cavity. The first spinal, called the *hypoglossal*, lies ventrally to the tongue, and can be seen on removal of the mylohyoid muscle. It joins the spinal cord between the first two vertebræ.

## Plate VII.—FOURTH DISSECTION OF THE FROG. (*Ad nat.*)



Showing IXth and Xth cranial nerves, the spinal nerves, sympathetic nerves, and arterial system. After the third dissection, the kidneys, veins, and liver are carefully removed and the heart is reflected over to the right. The sympathetic and vagus are only shown on the left. The latter is unlabelled but is seen emerging from between the glossopharyngeal and the hypoglossal and passing to the heart and lung, another branch passing behind the lung down the œsophagus.

The second and third unite to form a *brachial plexus* to the fore-limb; the fourth, fifth and sixth pass to the body-muscles; the seventh, eighth and ninth unite to form the *sciatic plexus* continued into the hind-limb. The tenth is a small spinal beside the *urostyle*. On either side of the aorta is a thin pigmented nerve-chain with ganglia, called the *sympathetic* system. From each ganglion a connection passes to each spinal nerve. Forward, the sympathetic chain terminates in the *Gasserian ganglion* of the fifth cranial nerve.

The ten cranial nerves are essentially like those of the skate, though smaller and more difficult to follow, and the fifth, seventh and tenth nerves are much simpler. The fifth has three main branches—the *ophthalmicus*, the *maxillary* and *mandibular*. The seventh has only two main branches—the *palatine* and the *hyomandibular*. The *vagus* has no branchial branches, but supplies the larynx, lungs, heart and stomach.

At the sides of the vertebræ are a number of masses of calcareous matter called *calcareous bodies*. They have a curious developmental connection with the ear.

The brain may be seen by removing the dorsal bones of the cranium. It is small and has a very small *cerebellum*. The various parts are in one horizontal axis and do not overlap each other.

The *spinal cord* passes down the vertebral column, as in the skate, and terminates in the *urostyle*.

The frog has no exoskeleton. The endoskeleton can, as in the skate, be divided into axial and peripheral parts.

**Skeletal.**

The axial is composed of a skull and vertebral column. The skull is composed of the cranium and the first two visceral arches, mostly joined together.

The first important difference from the skull of the skate is the presence of bones in addition to the cartilaginous portion. Some of these bones are formed in dermal membrane and sink on to the cranium; these are called *membrane-bones*. The others are formed in the cartilage, or rather they replace the cartilage which is destroyed as they grow. These are termed *cartilage-bones*. The cartilage may be seen extending between the bones, or the membrane-bones may be removed, in which case the true extent of the cartilaginous cranium can be clearly seen. The actual cranium is small and lies between the two orbits. Its front end is surrounded by a girdle bone, the *sphenethmoid.* Its walls are formed of cartilage, in the roof of which are a large *anterior fontanelle* and a small pair of *posterior fontanelles*, as in the skate. The fontanelles are not seen, as they are covered up by a pair of large membrane-bones, the *frontoparietals.* Lying under the cranium is a long dagger-shaped bone, the *parasphenoid.* At the hind-end of the cranium is a pair of bones, the *exoccipitals*, each of which bears an *occipital condyle.* Anteriorly the cranial cartilage is continuous with the

Fig. 245.—VENTRAL VIEW OF FROG'S SKULL.

Cartilage black, Bones white.

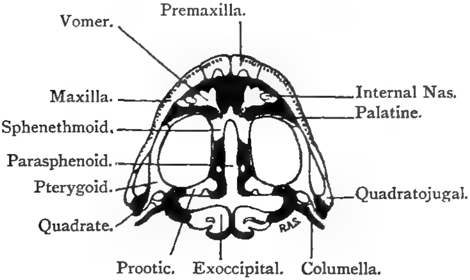
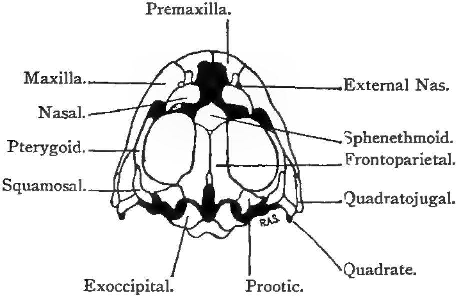


Fig. 246.—DORSAL VIEW OF FROG'S SKULL.

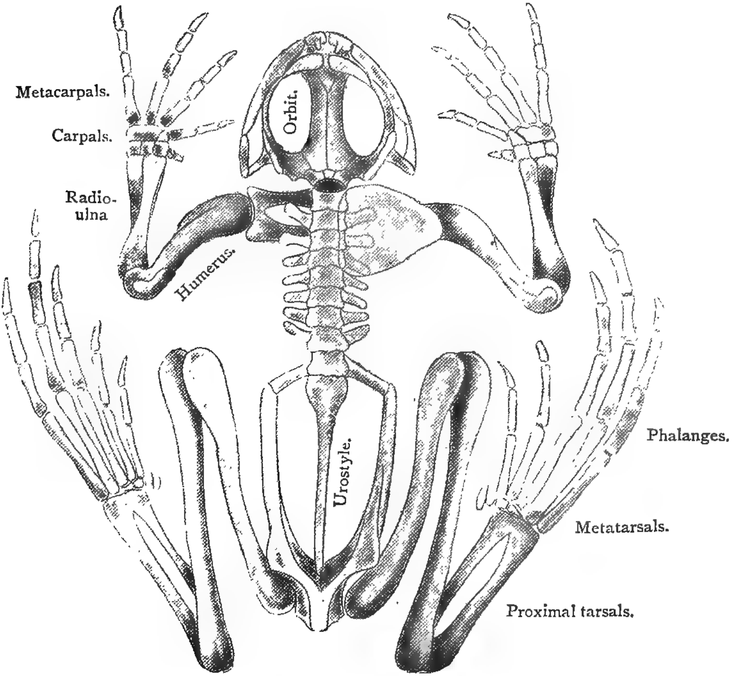
Cartilage black, Bones white.



cartilaginous nasal capsules and posteriorly with the auditory capsules. At the front end of the latter are the *prootic* bones and on the nasal capsules are the *nasals*. On the ventral face of the nasal capsules are the *vomers*.

In the prepared cartilaginous skull, a large cartilaginous bar (the *suborbital* bar) can be seen running backwards from the nasal region outside the eyes to meet a similar bar projecting from the auditory region. Here it protrudes outwards as the *quadrate* cartilage which bears the mandible. The whole represents the palatoquadrate bar of the skate. In the natural condition it is covered up by a number of

Fig. 247.—Dorsal View of Entire Frog's Skeleton.
(Natural Size.) (*Ad nat.*)



bones which thus belong to the visceral arches. In connection with these visceral arches are the *premaxillæ* and *maxillæ* forming the upper jaws and carrying a single row of small teeth. From the hind-end of the maxilla is a small bone (the *quadratojugal*) which unites behind with the quadrate.

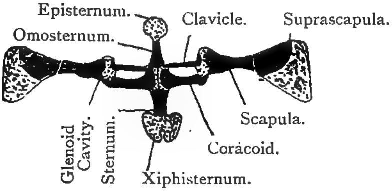
In connection with the suborbital bar are paired *palatines* anteriorly and paired *pterygoids* of a triradiate shape. On the dorsal side a pair of T-shaped *squamosals* overlie the quadrate cartilages. A rod-like cartilage runs from the tympanum to the auditory capsule; it is called the *columella* and probably corresponds to the hyomandibular of the skate. The lower jaw, as in the skate, is formed of the *mandibular cartilage*, but it has also three bones. It bears no teeth.

A large plate of cartilage, the *lingual plate* (or *hyoid cartilage*), rests below the tongue; it has two long *anterior cornua*, which are attached to the auditory capsule, and the *posterior cornua* which are shorter. It is the *hyoid* cartilage, with perhaps a single pair of branchial arches (*posterior cornua*).

At first sight there is little in common between this skull and that of the skate. If, however, we carefully follow the following modifications which have probably taken place, the comparison is easier. Let us suppose that the palatoquadrate cartilages of the skate become fused on to the nasal region anteriorly and to the auditory region posteriorly, and that further these cartilages are bent out laterally so that they lie no longer under the cranium but round the outer border of the eyes. A condition is thus produced closely similar to the cartilaginous cranium of the frog. The cartilage is then replaced by bone in parts, producing the CARTILAGE-BONES, *sphenethmoid*, *prootics* and *exoccipitals*. Lastly, this skull is covered up by a number of MEMBRANE-BONES, paired *fronto-parietals* and *nasals* above, *parasphenoid* and *vomers* below, and a number of others, *palatines*, *pterygoids*, *squamosals*, *quadratojugals*, *premaxillæ* and *maxillæ*, in connection with the visceral arches.

The vertebral column in the frog consists of nine free vertebræ and a *urostyle*. The vertebræ are ossified and form rings. The first or atlas is a simple ring with two facets for articulation with the skull. The second to seventh are procœlous, *i.e.*, they articulate with each other by a concavity in front and a convexity behind. The main portion of the vertebra is called a *centrum* and above this is a *neural arch* covering over the spinal cord. A large lateral process on each side consists of a *transverse process* which bears a small cartilaginous *rib.* The eighth is like the preceding in general structure but is *amphicœlous*, *i.e.*, it has a concave articular surface at each end. The *ninth vertebra* has large transverse processes to which is attached the *pelvis*. Hence this vertebra is called the *sacrum.* It is biconvex, with a convexity at each end of the centrum. The *urostyle* is a long bone formed of at least three fused vertebræ. It is hollow for part of its length and contains the posterior end of the spinal cord.

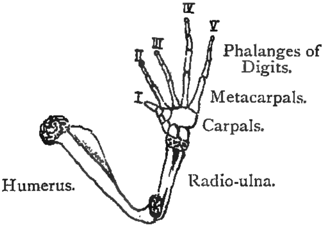
Fig. 248.—Pectoral Girdle of Rana.



View with dorsal parts bent downwards. Bone is black and cartilage dotted.

The presence of this urostyle, the single sacral vertebra and the small number of vertebræ are the important peculiarities of the vertebral column. The vestigial ribs are also to be noted.

Fig. 249.—Fore-limb of Rana.



Note fusion of radius and ulna and absence of pollex, a metacarpal only remaining.

The peripheral (or appendicular) skeleton consists of the two limb-girdles and limbs. These are constructed on the *pentadactyle* type (see page 420). The *shoulder-girdle* (pectoral girdle) consists of paired clavicles and coracoids

Fig. 250.—Pelvic Girdle of Rana.

(Lateral view.)

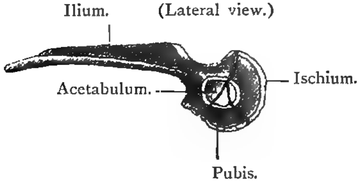
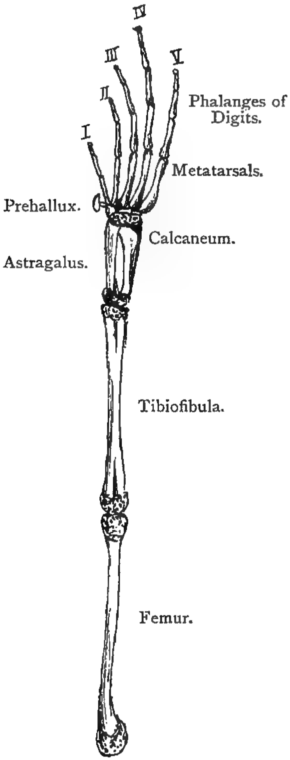


Fig. 251.—Hind-Limb of Rana.



Note elongation of tarsal bones, fusion of tibia and fibula and presence of six digits.

which meet in the mid-ventral line and there bear an *omosternum* in front and a *xiphisternum* behind. They meet laterally with the *scapula* or dorsal element and form the *glenoid cavity* for articulation of the limb. The scapula carries on its dorsal border a *suprascapular cartilage.* The fore-limb has two peculiarities. The *radius* and *ulna* are united into one bone and there is no pre-axial digit or thumb.

The *pelvic girdle* has a very long forwardly-directed *ilium* articulating with the sacral vertebra. The *pubes* and *ischia* are welded into a disc-shaped mass with a concavity on each side, the *acetabulum.* The frog's pelvic girdle is peculiar in the great length of the ilium and the solid nature of the pelvis. The hind-limb is greatly elongated. As in the front-limb, the *tibia* and *fibula* are fused. In addition, the two proximal tarsal bones, the *astragalus* and *calcaneum*, are elongated into long bones. On the inner side of the first digit is a rudimentary sixth digit, the *prehallux.*

**Development.**—The eggs of the frog are small black spheres, about $\frac{1}{15}$-inch in diameter, shed into the abdominal cavity from the ovary. They pass forwards into the oviducts and thence to the exterior. As they pass down the oviduct they are enveloped in a glassy albuminous matter, which, after deposition, swells up by absorption of water into a firm jelly, serving to protect the egg.

The eggs are fertilised outside the body by the sperms of the male shed over them. The early part of the development is embryonic (usually about the first fortnight). During this time the nutrition is lecithal (yolk). The later part is larval and the nutrition is herbivorous. The larvæ are termed tadpoles and show striking resemblances to fish in their general organisation. After about two months of this larval existence a *metamorphosis* occurs. Great changes in most of the organs result in the production of the young frog and the assumption of a terrestrial carnivorous existence.

**The Embryonic Period.**—The egg is telolecithal, *i.e.*, the yolk is aggregated towards one half of the egg, which is lighter in colour, the other half being covered with black pigment. The first two divisions of segmentation are parallel to the axis of symmetry, and hence divide the egg into equal quadrants, but the third divides it into unequal halves, producing four large and four small octants. In further segmentation the cells in the pigmented half are produced more rapidly and are smaller than those in the yolk-half.

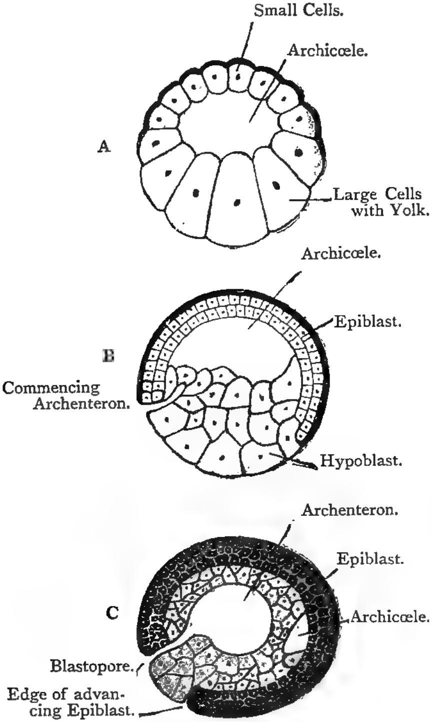
Hence the segmentation is total but unequal, producing a modified *blastula,* in which one half has few large hypoblast cells and the other has many small epiblast cells. Such a blastula is converted into a didermic embryo or modified gastrula, not by archiblastic invagination, but by *epiboly* or gradual extension of the epiblast over the hypoblast.

This overgrowth is not effected all round the edge of the epiblastic portion; but at one spot, the future hind-end of the embryo, there is formed a slight split between the two layers, extending into the hypoblast as the commencing *archenteron.* This spot, the embryonic rim, evidently represents the dorsal edge of the blastopore in *Amphioxus.* Elsewhere, especially at the opposite side, the pigmented epiblast is seen to slowly envelop the hypoblast, till eventually there only remains a small hole just below the embryonic rim which we may recognise as the *blastopore.* The epiblast cells are said not to actually grow over the hypoblast, but to be continually increased in number and extent by actual conversion of the light hypoblast cells into small pigmented epiblast cells. The final result is the same, *i.e.*, that the whole egg becomes *didermic* (or diploblastic), an outer layer of epiblast enveloping an inner of hypoblast. The small blastopore eventually closes into a small longitudinal slit called the *primitive groove.* Meanwhile the archenteric cavity has extended inwards by a splitting of the hypoblast cells, and the blastocœle or segmentation cavity disappears in front of it at the anterior end.

The embryo is now directly comparable to the gastrula of *Amphioxus*, with the reservation that the hypoblast cells containing yolk are heaped up in the floor of the archenteron.

The neural tube is now formed in the mid-dorsal line by the upgrowth and fusion of two neural folds. These extend backwards to envelop the primitive groove, and convert the blastopore into a neurenteric canal, as in *Amphioxus*. Meanwhile the mid-dorsal cells of the hypoblast become cut off as a *solid* rod of cells, forming the notochord, and dorso-laterally two sheets of mesoblast are similarly cut off from the hypoblast, their separation taking place slightly before that of the notochord (as in *Amphioxus*). The differentiation

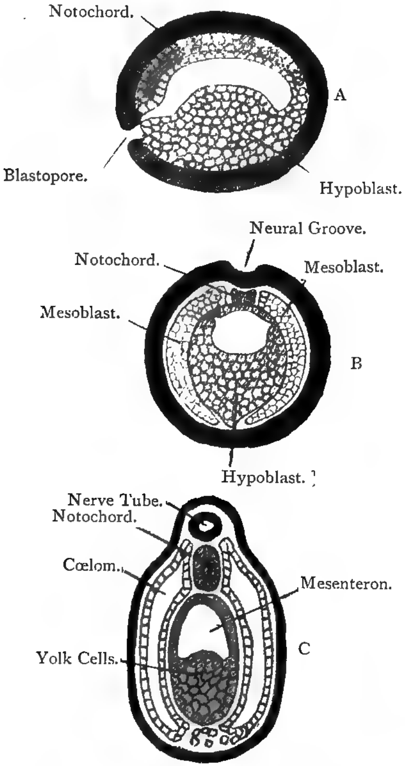
Fig. 252.—THREE STAGES IN DEVELOPMENT OF FROG'S EGG.



A, The Modified Blastula. B, Commencing Gastrulation. C, The Modified Gastrula nearly formed.

takes place from before backwards, hence at the *embryonic rim* the epiblast, mesoblast and hypoblast are all merged into one common mass of cells.

Fig. 253.—SECTIONS OF FROG EMBRYOS.



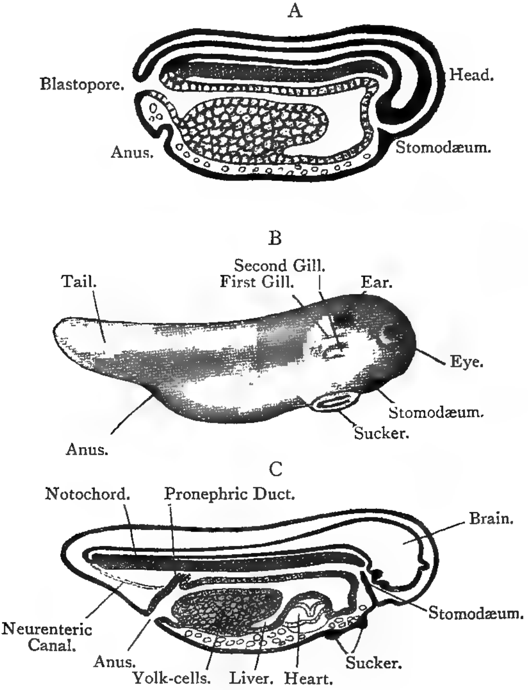
A, Longitudinal Median Section through a Frog's Embryo at a late Gastrula stage. B, Transverse Section through Frog's Embryo (after HERTWIG). C, Transverse Section of Young Tadpole (*ad nat.*).

The mesoblast plates divide into a dorsal *vertebral plate*, segmented into protovertebræ and a ventral *lateral plate*. The lateral plates grow downwards on either side, and a cœlomic cavity arises in each by a splitting between the cells, the mesoblast then forming an outer somatic layer and an inner splanchnic.

The body is now distinctly elongated and compressed slightly from side to side.

This stage may (except for the closure of the neuroproe and precocious formation of the brain) be compared to the chordula larva of the

Fig. 254.—THE STRUCTURE OF FROG'S EMBRYO AND TADPOLE.



A Longitudinal Median Section through an Embryo of Frog × 20 (after MARSHALL). Note the dorsal nerve-tube swollen into a brain anteriorly, the notochord below it, and the mass of yolk-cells on the ventral wall of the archenteron. B, Side (right) View of just-hatched Tadpole of Frog × 6 (*ad nat.*). C, Median Longitudinal Section through a newly-hatched Frog's Tadpole (chiefly after MARSHALL).

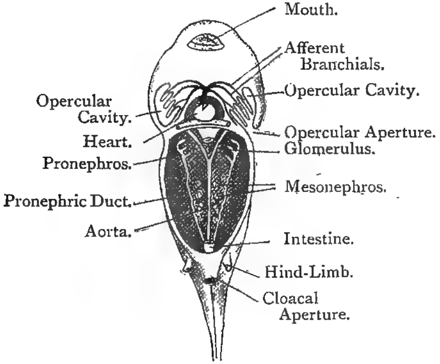
*Atriozoa.* As in the case of the gastrula, the chief difference is in the presence of a large mass of yolk containing hypoblast on the ventral wall of the archenteron.

The step to the newly-hatched tadpole is not great.

The exterior shows the long tail already formed, the developing eyes and ears on the head, the two pair of external gills (soon followed by a third), and, on the ventral surface of the head, a large sucker The openings of the *stomodæum* and *anus* are also seen. The former is blind, but the latter is already an aperture leading into the gut. In longitudinal section we may notice the commencing liver as a ventral diverticulum of the gut, and in front of it the simple tubular heart. The pronephros is present as three ciliated funnels on each side, leading by a paired archinephric duct on each side to the hind-end of the gut.

Fig. 255.—Young Tadpole dissected from the Ventral Side.

(Mainly after Marshall.)



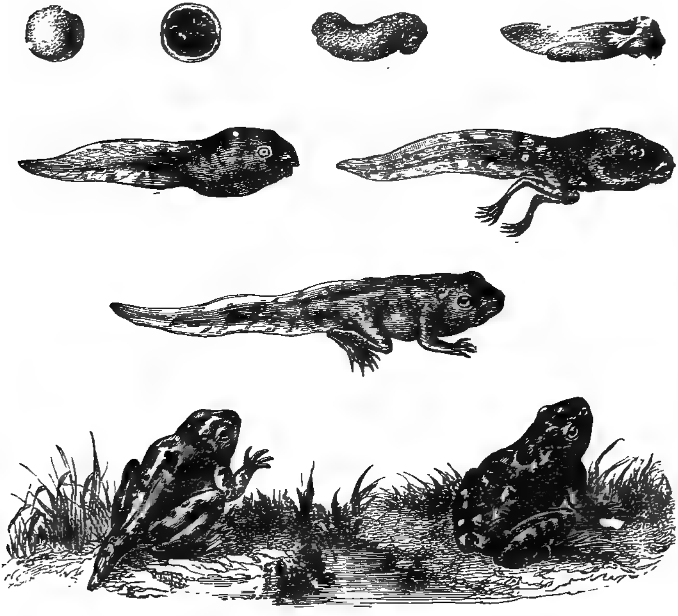
A day or two after hatching the mouth opens, with horny jaws; the yolk has been used up and the tadpole feeds upon small water-plants. At the same time the four gill-clefts open and internal gills are formed on their walls. The external gills then atrophy. The gill-slits become covered over by a fold of skin or *operculum* on each side. A small opercular aperture remains on the left side, but none on the right. The tail is provided with a dorsal and ventral median fin, and the tadpole swims actively by its action. During this stage, which lasts for about six weeks from hatching, the tadpole has an internal organisation like a fish. The two-chambered heart drives blood by afferent branchials to the four gills. The limbs develop as small buds, the fore-limbs in the opercular chamber and the hind-limbs beside the anus. The mesonephros arises as a set of small tubules which join the pronephric duct and gradually replace the pronephros. The lungs then develop and become functional.

The tadpoles frequently come to the surface and take air into the lungs. Thus is instituted a stage comparable to the *Dipnoi*, in which both forms of breathing are functional. At about two months this stage culminates in the metamorphosis. The gills atrophy, the gill-slits close up, the intestine shortens, the aortic arches assume the adult condition and the tail commences to be absorbed. The animal now begins to leave the water by degrees till, when the tail has completely disappeared and the limbs are completed, it becomes a terrestrial frog.

Comparison of Amphioxus, Skate and Frog.—We now have to compare the early stages of the skate, the frog and the *Amphioxus*, The frog passes beyond the fish-stage to the amphibian, but in its early stages, with external fertilisation, short embryonic period and small amount of yolk, it is a nearer approximation to *Amphioxus* than is the skate.

Fig. 256.—The Life History of the Common Frog.

Showing the egg and larval or tadpole stages. (For description see Text.)



**Blastula.**—In *Amphioxus* the segmentation is total and equal and produces a (nearly) centro-symmetric blastula with equal cells. In the frog there is some yolk aggregated in the future hypoblast cells, hence the segmentation is total and unequal, the hypoblast half being retarded. A modified blastula is, however, still produced. In the skate the bulk of yolk is so enormous that only the epiblast cells and a portion of the hypoblast can segment. Hence the segmentation is only partial or meroblastic, producing, not a true blastula, but a cap or blastoderm resting on a mass of unsegmented hypoblast and yolk.

**Gastrula.**—The yolk in the frog is already sufficient to prevent the normal archiblastic invagination, and as the hypoblast is too bulky to be tucked into the epiblast, the epiblast perforce extends round the hypoblast, producing finally a small blastopore in the same position as that of *Amphioxus*, viz., at the postero-dorsal part of the embryo. In the skate this is carried still further, and the rim of the epiblast has to extend so far round and over the enormous mass of yolk that the embryo differentiates during the process. The final result is the same as before, the epiblast eventually meeting round a small blastopore at the posterior end of the embryo.

But in both the frog and the skate it is doubtful how far the archenteron is produced by true invagination. Probably in both cases it arises mostly by a split in the hypoblast. In the frog the archenteron is largely filled by a ventral mass of yolk-cells, but in the skate this is so enormous that it protrudes as a large separate mass of the body.

**Chordula.**—The frog embryo, a day or two before hatching, as has been seen, can be directly compared with the chordula larva, but here again there are modifications. The notochord is not folded off, but arises as a solid mass, and the mesoderm no longer arises as a paired series of pouches with cavities in continuity with that of the gut, but as solid masses, with cavities produced later by splitting.

In the skate much the same as in the frog occurs, if we consider the embryonic portion only. We may note that both the frog and skate appear to have at least the main part of the mesoblast formed from two posterior sheets or plates comparable to the posterior sacs of *Amphioxus* and of *Ascidia.* Again, in *Amphioxus* the whole of these sacs divide into mesoblastic somites, the ventral parts of which fuse later to form the perivisceral cœlom, the dorsal parts remaining segmented. On the other hand, in the skate and frog the ventral part or *lateral plate* is never segmented, but splits at once to form the perivisceral cœlom, only the dorsal part or *vertebral plate* being segmented, as in *Amphioxus.* The result in all three types is the same though brought about in a different manner.

**Fœtal Membranes.**—In the frog the yolk distends the abdomen, but is not sufficient to cause the formation of a complete yolk-sac. In the skate, however, the yolk is so abundant that the embryo cannot possibly be built up to include the yolk, and the latter has to be held in a special sac. The outer wall of this sac is the serous membrane, a continuation of the body-wall, and the inner is the yolk-sac proper, a continuation of the gut-wall. Hence we see that in the skate the abundance of yolk (and lecithal nutrition) has caused the formation of two extra-embryonic *fœtal membranes*, the serous membrane and the yolk-sac membrane. In all the *Amniota* not only are these two present, but two more, the *amnion* and the *allantois*, are superadded.

# CHAPTER XXII.

## *CHORDATA—(Continued.)*

## V.—COLUMBA.

| | |
|---|---|
| PHYLUM | CHORDATA (p. 402). |
| SUB-PHYLUM | VERTEBRATA (p. 405). |
| CLASS - | AVES (p. 447). |

**Columba livia** (the common Pigeon) is a type of convenient size for illustrating the important class of *Aves* or birds. It shares with the next type, the rabbit, the fate of domestication by man. As explained in Chapter X., a careful selection of suitable varieties by man has led to the production of numerous breeds, such as fantails, pouters, jacobins, &c., which, especially in external characters, may differ remarkably from each other. If a number of these breeds be left together and allowed to breed promiscuously, the offspring rapidly reverts to the common wild pigeon from which they have all been derived. Our description will apply to any domestic pigeon.

The *head* is well separated from the *trunk* by a long and flexible *neck* and at the hind-end of the trunk there is a small and stumpy *tail*. The *beak* is formed of horny material covering both jaws. At its base is a small pair of *external nares*, often surrounded by a sensitive swollen patch of skin called the *cere*. The *eyes* are large and have upper and lower eyelids. In addition, there is a thin membranous eyelid which can be drawn from the anterior angle transversely across the eyeball. It is called the *nictating membrane*.

A little way behind and below the eye is a round hole or aperture leading into a tube, the *external auditory meatus*. This passes in for some distance and terminates in the drum or tympanum. Hence the tympanum in the bird is not at the surface, as in the frog, but is sunk to the base of a meatus or canal. The *mouth* opens between the jaws into a buccal cavity, on the floor of which is a pointed *tongue.* Immediately behind the tongue is a median slit, the *glottis.* Dorsally lie the two *internal nares*, and behind them is a *single Eustachian aperture* which soon diverges into the two Eustachian canals to the ears. At the hind-end below the tail is a single median *cloacal aperture.* The fore-limbs are formed into *wings* and the hind-limbs form the *legs.* There are four toes terminating in claws.

**Integumentary.**

The whole body, with the exception of the beak and the lower part of the legs, is completely enveloped in a coat of *feathers.* A feather, structurally as well as popularly, is an organ *sui generis.* Nothing quite like it is found in any group outside the birds. A feather arises from the epidermis and remains attached to the skin by its base. If the feathers be plucked or pulled out of their epidermic pits, it is seen that they are attached only on certain areas of the skin called *pterylæ*, the portions of bare skin between them being called *apteria.*

The skin itself is dry and powdery, and there is an absence of the numerous skin-glands found in the frog, with the exception of the large *preen-gland* at the base of the tail. This involves the "preening" of the feathers by the bird, in which process the greasy secretion from the gland is spread by the bird's beak over each feather.

The largest feathers are found in the wing and tail and form the quill- or *flight-feathers.* The central axis of the feather is hollow in its lower part, called the *quill.* Opening into the hollow cavity is a small aperture at the base, called the *inferior umbilicus;* and at the distal end of the quill region is a smaller *superior umbilicus.** Above the quill the axis is extended as the solid *shaft*, bearing on either side the *vane.* The vane or flattened part is formed of a great number of parallel *barbs* attached basally to the shaft and laterally to each other by small interlocking processes or *barbules.*

The quills on the wing are called *remiges* and those of tail are *rectrices.* A *remex* usually is more tapering, and has the vane very unequal in size in comparison with a *rectrix.*

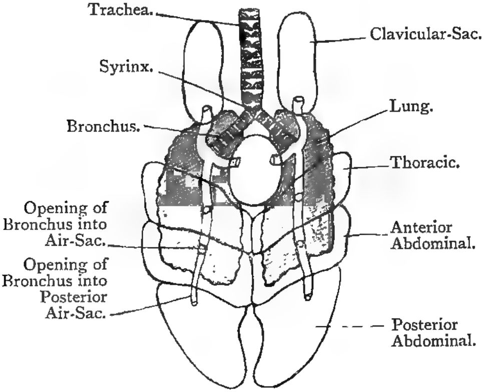
---

* This peculiar structure is explained by the development of the feather from a single tube, of which the part above the superior umbilicus splits longitudinally and spreads out to form the vane and shaft, leaving the quill to open to the exterior by the superior umbilicus.

The smaller feathers are called *coverts* and *contour* feathers, according to their size and structure. The *filoplumes* are still smaller feathers, resembling hairs, with a thin shaft terminating in a very small vane. They can be seen still attached to the skin after plucking. The scales on the legs and claws are epidermic and closely similar to those found in the reptiles.

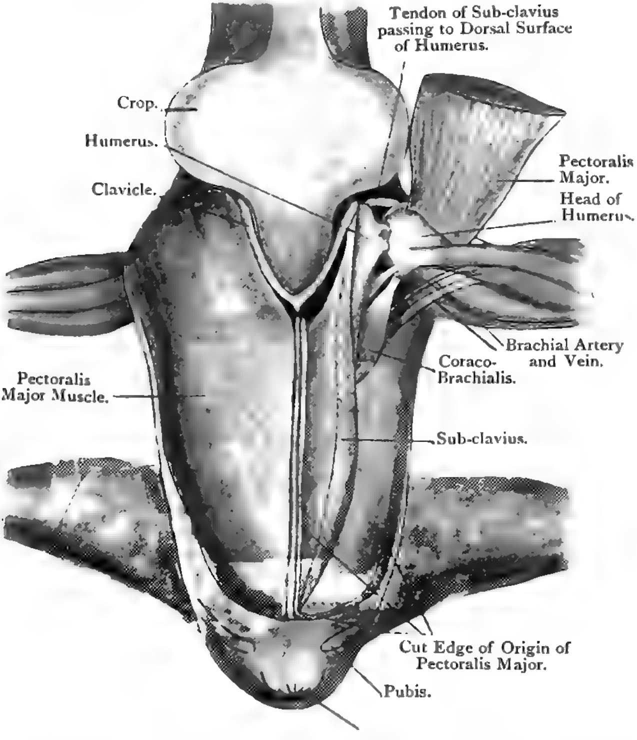
After plucking, the skin may be removed from the ventral surface by a median incision from head to cloacal aperture (see Plate VIII.). The greater part of the body is seen to be occupied by the "breast," a mass of muscles lying on the large sternum. The central *keel* (or *carina*) of the sternum may be seen in the middle line. The *pectoral muscle* can be cut away from its point of origin along the sternum and clavicle, and thence forward. It is inserted into the large *deltoid ridge of the humerus*. It is evident that on contraction this muscle will depress the wing. Under it lies the *subclavian* muscle, originating from the sternum and passing upwards by a tendon which can be followed through a foramen in the shoulder-girdle, called the *foramen triosseum*, on to the upper side of the

Fig. 257.—VIEW OF RESPIRATORY ORGANS OF THE PIGEON. (Slightly Diagrammatic.)



The median sac is the interclavicular.

Plate VIII.—FIRST DISSECTION OF PIGEON. (*Ad nat.*)



The skin and feathers are removed from the whole ventral surface. On the left of the pigeon the *pectoralis major* has been cut away from its origin along the *carina* and posterior border of the sternum and thrown forwards. It is still seen attached.

humerus. By this arrangement a contraction of the subclavian results in raising the wing. The tendon runs along beside the large *coracoid* bone, and on the outer side of this bone originates a small triangular muscle called the *coraco-brachialis*, the tendon of which is inserted in the head of the humerus. It apparently helps in depressing the wing.

The large keel of the sternum is developed in response to the necessity for a large area of attachment for the "flight-muscles." In birds which do not fly the keel is absent.

The sternum may now be removed by cutting round its edge posteriorly and laterally, and the abdominal cavity may be opened by a median ventral incision.

The air-sacs should be noticed, large cavities with thin walls. They are nine in number, and communicate with the lungs (*v.i.*). Some are also produced into the interior of the bones, such as the humerus. Three pairs of them lie behind each other in a row on each side of the viscera, from which they are separated by an *oblique septum.*

**Alimentary.**

Down the neck may be noticed two long tubes, one stiffened with bony rings, the *trachea*, and the other soft, which is the *œsophagus.* The trachea can be traced down to the thorax where it passes dorsal to the heart. The *œsophagus* expands into a large thin-walled sac, the *crop*, from which it passes into the body-cavity dorsal to the heart and terminates in a glandular *stomach.* The stomach opens directly into a large round *gizzard* with very thick muscular walls. The first loop of the small intestine is, as in other types, termed the *duodenum*, and in its loop there rests a whitish *pancreas.* The *liver* is bilobed and lies over the gizzard; it has *two bile-ducts.* The left opens into the proximal loop of the duodenum and the right into the distal; the left is thick and short but the right is longer and more delicate. The pancreas has no less than three ducts which open into the distal loop of the duodenum. The rest of the *small intestine* is coiled and of considerable length. It ends in a short *rectum*, and at the junction below the two is a pair of small pockets, the *rectal cæca.* The rectum opens into the cloaca.

The alimentary system presents some peculiar characters. All modern birds like the pigeon have no teeth, though they are present in certain fossils. The large crop is used for the storage of quantities of grain. The pigeon has many enemies and has to fill its crop when the occasion presents itself. In the crop the food is partially softened, and is passed gradually into the stomach which secretes a digestive fluid. It is then passed into the gizzard in which it is ground and crushed to pieces. There are always present in the gizzard a number of small fragments of stones which, churned together with the food by the muscular walls of the stomach, reduce the grain to small pieces. Thence they pass into the duodenum and ileum in which absorption is effected. It will be seen that there is no gall-bladder in the pigeon, but this is present in closely allied birds.

**Cœlom.**

The cœlom is mainly represented by the large abdominal cavity and the smaller pericardial cavity around the heart. The two cavities are, as in the frog, completely separated from each other.

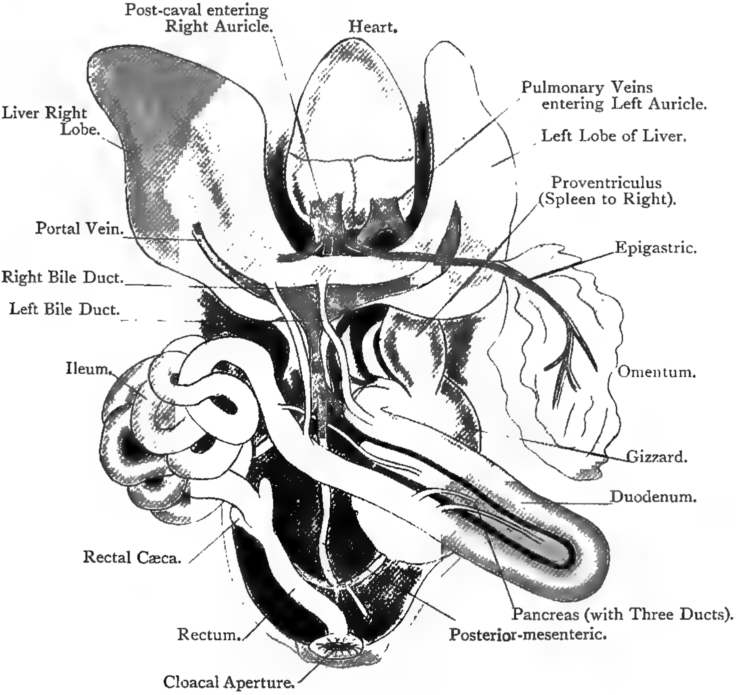
The alimentary canal is suspended by a dorsal mesentery in which run the blood-vessels, as in most vertebrates. A median ventral mesentery attaching the liver to the sternum is termed the *falciform ligament*.

**Blood-Vascular.**

The heart is proportionately very large; it lies immediately in front of the liver, and is four-chambered. The single ventricle of the lower types is here divided into two by a septum. Hence there is a left ventricle communicating with the left auricle and a right ventricle communicating with the right auricle. The supply of blood to the auricles is similar to that of the frog, *i.e.*, venous blood from the system comes back to the right auricle and arterial blood from the lungs comes back to the left auricle. On contraction each auricle empties its blood into the ventricle of the same side through the *auriculo-ventricular valves*. On contraction of the ventricles the left sends its blood to the system and the right to the lungs. Hence the two currents are quite apart throughout their course, and the right side of the heart acts as a *respiratory heart*, the left side performing the part of a *systemic heart*.

If a section be made across the posterior half of the heart, the two ventricles will be seen. The left ventricular cavity is small and has very thick walls; the right is

Plate IX.—SECOND DISSECTION OF THE PIGEON. (*Ad nat.*)

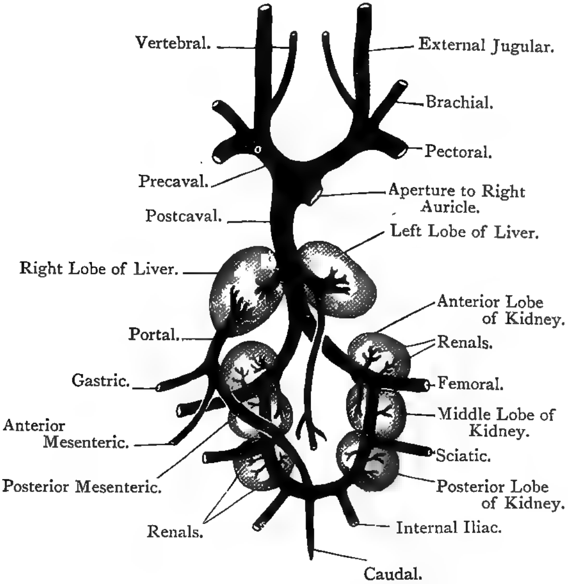


The sternum is removed by lateral cuts through the ribs, the coracoids and clavicles. The liver and heart are both thrown forwards, and the duodenum and omentum are thrown to the left, the ileum to the right. In the mesentery are seen the two bile ducts (white) the portal vein (blue), and the cœliac artery (red).

crescentic and has a thin outer wall, its inner wall being formed of the thick wall of the left ventricle.

The venous system consists of two complete parts—(1) the two *pulmonary veins* which are short and lead directly from the lungs to the *left auricle*, and (2) the systemic system which leads into the *right auricle*. There is no *sinus venosus*, but three large veins converge together to open into the auricle. Two are paired and anterior and are called the *precavals;* the other one is median and posterior, called the *postcaval.*

Fig. 258.—VENTRAL VIEW OF THE VENOUS SYSTEM OF THE PIGEON. (*Ad nat.*)



The lobes of the liver are drained by hepatic veins, and the left hepatic receives a long *epigastric* from the omentum, seen hanging down the centre.

The precavals are formed of three large veins, the *jugular* from the head and neck, the *brachial* from the wing and the *pectoral* from the flight-muscles. The two jugulars anastomose together below the tongue. The postcaval can be traced backwards through the liver where it receives paired *hepatics*. A little way behind the liver it diverges into two *iliac* veins. The *portal* vein may be seen passing to the liver from the stomach and intestine. Its most posterior branch, the *posterior mesenteric*, anastomoses with the systemic system (see below). The portal has the same relationships as in the skate and frog, but there is no anterior abdominal.

The *epigastric* vein is said to represent this vein. It drains the *omentum*, a fatty fold of peritoneum, and runs forward to join the left hepatic vein.

If the rectum be cut through and the intestine carefully removed, the veins and arteries in the abdominal region will be easily seen (see Plate IX.) They are in relation to the two large three-lobed kidneys, lying in a hollow of the pelvis.

From the tail there emerges a small *caudal* vein which bifurcates into two *renal portals* diverging right and left towards the kidneys. Each receives an *internal iliac* and then passes through the kidney. Between the second and third lobe of the kidney, the renal portal receives the *sciatic* and between the first and second it receives a large *femoral*. The femoral and sciatic then form the *iliac* which receives a *renal* from the kidney, and then unites with its fellow to form the *postcaval*. Hence the iliacs and renal portals form a complete "renal cycle" running left and right from caudal to postcaval.

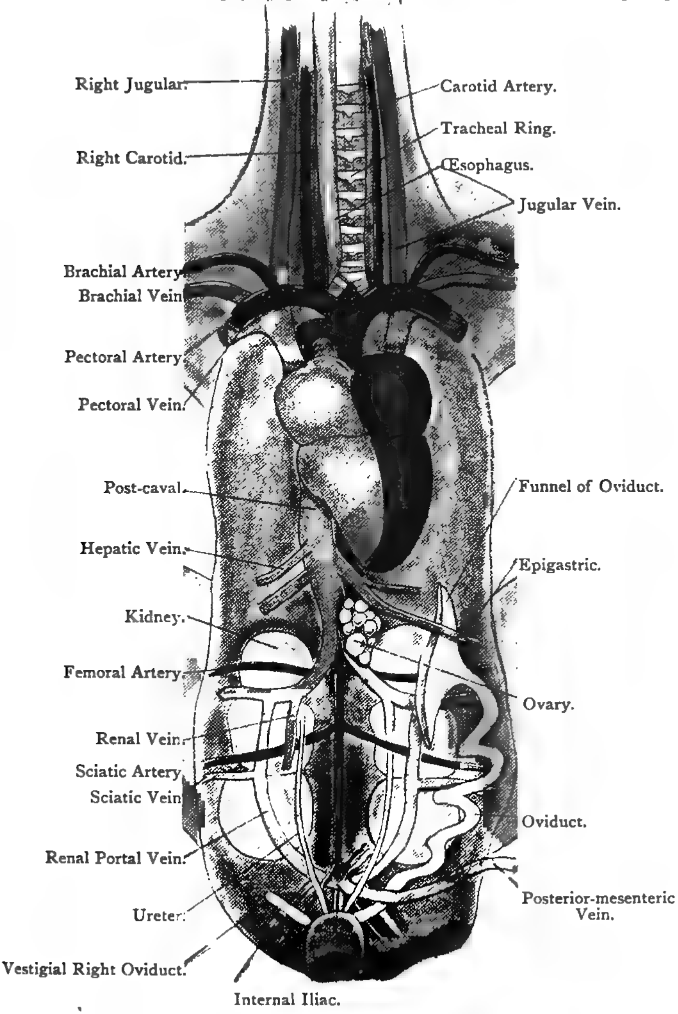
At the point of junction of caudals and renal portals there runs forward beside the rectum a large median vein, the *posterior mesenteric*. It joins the portal anteriorly.

**Respiratory System.**

The arterial system consists, like the venous, of two parts. (1) The right ventricle gives off a trunk which immediately bifurcates into two *pulmonary arteries* going to the lungs. These correspond to the third arterial arches (pulmocutaneous) of the frog. (2) The systemic system—the left ventricle gives off a main trunk which divides into three. Two are paired and anterior; they are called the *innominate* arteries and divide into *carotid* to the head and *subclavian* which itself divides into *brachial* and *pectoral*. The third bends over to the right and passes dorsal to the

Plate X.—THIRD DISSECTION OF PIGEON (♀) TO SHOW THE BLOOD-VASCULAR AND UROGENITAL SYSTEMS.

The colours of the heart are physiological, those of the arteries and veins are morphological).

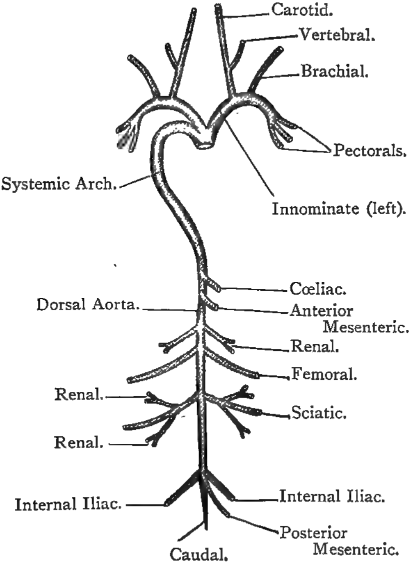


The œsophagus and cloaca have been cut through and the alimentary canal and appended organs have been removed. Note specially the tri-lobed kidneys with ureters, the single left ovary and oviduct, the four-chambered heart, the right systemic arch, the "renal cycle," and the posterior-mesenteric vein.

(N.B.—The left ureter should lie under the posterior-mesenteric, and the [illegible] below the renal portal.)

heart. Here it bends into the middle line and proceeds to the hind-end of the body as the *dorsal aörta.* Its main branches are *cœliac*, *anterior mesenteric*, paired *renals*, *femorals*, *sciatics* and *internal iliacs*, and it terminates in the tail as the *caudal* artery.

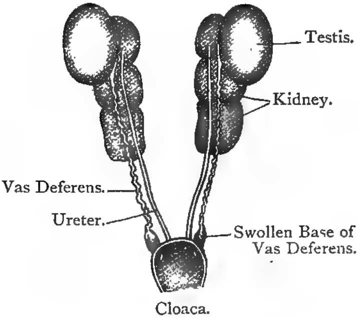
Fig. 259.—VENTRAL VIEW OF THE ARTERIAL SYSTEM OF THE PIGEON. (*Ad nat.*)



The anterior arterial system is peculiar in lying superficially to the venous system. Apart from the four-chambered heart, which is shared by mammals, the blood-vascular system of the pigeon is chiefly remarkable for the very high temperature of the blood, the systemic arch persisting only on the right, and the large size of the pectoral arteries and veins.

If the heart be now removed, the trachea can be traced throughout its length till it bifurcates into the two *bronchi.* At its front-end is a *larynx* which, however, is not an organ for producing sounds in the bird. The trachea is distended by small bony rings; those of the bronchi, except the first, are of cartilage. At the junction of the trachea and bronchi is the *syrinx*, the true organ of voice in the birds. The bronchus passes into the lung and there branches. Its branches emerge from the lung to open into the air-sacs already noticed. The lungs themselves are dense, rather small, and closely pressed against the ribs. They lie dorsal to the cœlom and their ventral face only is covered by peritoneum. The air taken into the lungs can pass freely into the air-sacs. The bird respires in a different manner to the frog. The air is drawn through the lungs into the air-sacs and is expelled forcibly again by the movements of the body-muscles. The lungs themselves have only a small respiratory surface, correlated with the free current of air through them.

Fig. 260.—VENTRAL VIEW OF MALE UROGENITAL ORGANS OF THE PIGEON. (*Ad nat.*)



**Urogenital.**

The general form and position of the *kidneys* have been already described. A small *ureter* passes from the ventral face of each kidney backwards into the cloaca. There is no urinary bladder.

In the male the *testes* are paired and situated just in front of, and between, the kidneys. They are oval, white bodies, and each gives off a fine, twisted tube, the *vas deferens*, passing backwards into the cloaca.

In the female the single left ovary lies between the anterior lobes of the kidneys. It is fastened by a dorsal mesentery and usually contains eggs of various sizes. The *left oviduct* is a large, coiled tube with an internal funnel near the ovary. It opens posteriorly into the cloaca. There is a vestige of the *right oviduct*.

The brain is easily exposed by scraping off the dorsal surface of the skull. The usual parts are all present and the special points to notice are as follows:—(1) The cerebral hemispheres are large and reach the cerebellum posteriorly, hence the *optic lobes* are *lateral* in position. (2) The whole of the brain lies behind a line drawn through the eyes. (3) The olfactory lobes are very small and poorly developed.

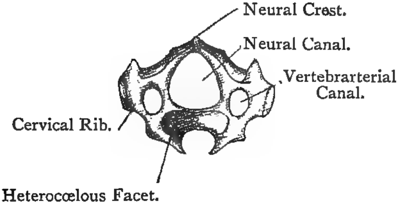
**Nervous.**

**Skeletal.**

The skeleton of the pigeon is as remarkably modified as is the rest of its anatomy.

In the skull we may note the complete fusion of the cranial and some of the facial bones, leaving no sutures. The upper beak is supported chiefly by the *premaxillæ* and by the *maxillæ*, the thin *jugal* joining the maxillæ with the quadrate posteriorly. Further, towards the middle ventral line the two *palatines* pass back from the maxillæ to meet the *pterygoids* which pass outwards and backwards to join the *quadrates.* Each quadrate has a condyle for articulation with the mandible bearing the lower beak; they are freely movable upon the skull. All the other bones are fused.

Fig. 261.—A Cervical Vertebra of the Pigeon. (*Ad nat.*)



The orbits are very large and are separated by a thin septum only partially ossified, the *interorbital septum.* Its ventral edge, under the palatopterygoid junction, is thickened and forms the *rostrum.*

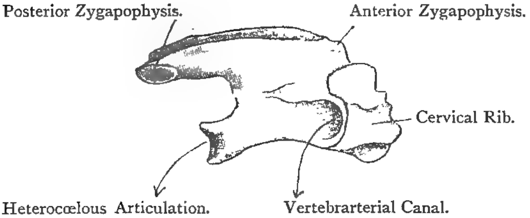
The septum is said to be formed of the mesethmoid and presphenoid of the rabbit, whilst the rostrum is supposed to be homologous with the anterior part of the frog's parasphenoid, the posterior part of which is represented by the paired *basitemporals* ventral to the *basisphenoid.*

There are three ear-bones but the *pro-otic* alone remains free, the others fusing with the occipital bones.

There is a *single occipital condyle* on the *basisphenoid* and the mandible is ossified into five bones.

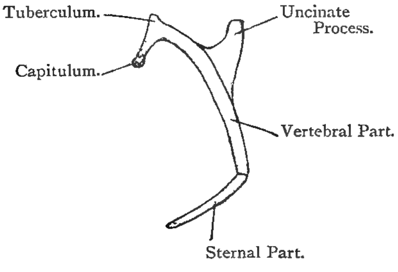
The vertebral column consists of a great number of vertebræ which are known as *cervical*, or neck-vertebræ, *thoracic*, *lumbar*, *sacral* and *caudal*. Of these the cervical are numerous, forming a very flexible neck; the thoracic are largely fused together and rigid, while a great number of the caudal are also fused.

Fig. 262.—LATERAL VIEW OF CERVICAL VERTEBRA OF THE PIGEON. (*Ad nat.*)



The *fourteen cervicals* have (except the first two) cervical ribs fused on to them, and as the ribs have two heads their fusion with the vertebra forms a canal on each side, called the *vertebrarterial* canal because it transmits the vertebral artery. The vertebræ are called *heterocœlous* to describe their peculiar articulations with each other, which are convex in one direction and concave the other, like a saddle. The

Fig. 263.—A RIB OF THE PIGEON. (*Ad nat.*) (Slightly magnified).



five thoracic vertebræ bear ribs which articulate distally with the sternum. Each rib has a longer vertebral part and a shorter external part, and the former has two heads articulating with its vertebra. The first four have short *uncinate processes.* The *capitulum* of the rib articulates with the centrum of the vertebra and the *tuberculum* with the transverse process. The first three thoracic vertebræ are fused, the fourth is free, while the fifth is involved in the sacrum.

In the young bird there are five free *lumbar vertebræ* and then *two sacral* to which the ilium is attached, but as development proceeds the ilium grows forwards and becomes attached to all the lumbar and to the fifth thoracic. Similarly there are in the young bird fifteen free caudal vertebræ, and the ilium gradually grows backwards and fuses with five of these. Of the other ten the last four fuse together to form the *pygostyle.*

This means that the young bird presents us with a reptilian-like condition of the vertebral column in which all the vertebræ are free. They consist of—

| | |
|---|---|
| Cervical | 14 |
| Thoracic | 5 |
| Lumbar | 5 |
| Sacral | 2 |
| Caudal | 15 |

The modifications then take place as age advances.

1. The first three thoracic become ankylosed or fused. 2. The last four caudal become ankylosed to form the pygostyle. 3. The ilium grows forwards and fuses with all the lumbar and the last thoracic, and backwards to include five caudals.

Cervical. Thoracic. Lumbar. Sacral. Caudal.

$$14 \quad \boxed{3} + 1 + \underbrace{1 + 5 + 2 + 5} + 6 + \boxed{4}$$

These fusions are supposed to be a recapitulation of similar modifications which have taken place gradually in the descent of birds from reptiles and in adaptation to the gradual adoption of flight and bipedal progression. It will be remembered that a similar fusion of vertebræ into an anterior vertebral plate is found in the skate, in which the front-limb is greatly developed, and in the caudal vertebræ of the frog (urostyle), in which the hind-limbs are enlarged.

Fig. 264.—VENTRAL VIEW OF STERNUM OF THE PIGEON. (*Ad nat.*)

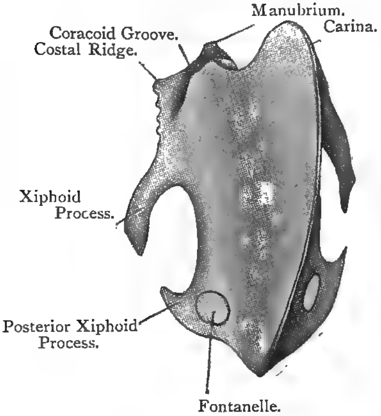
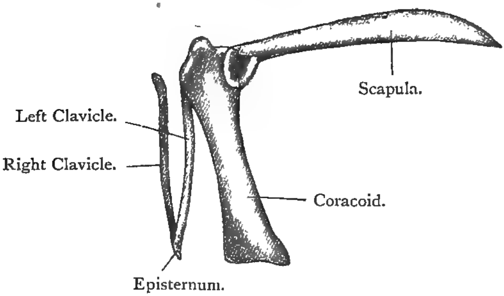


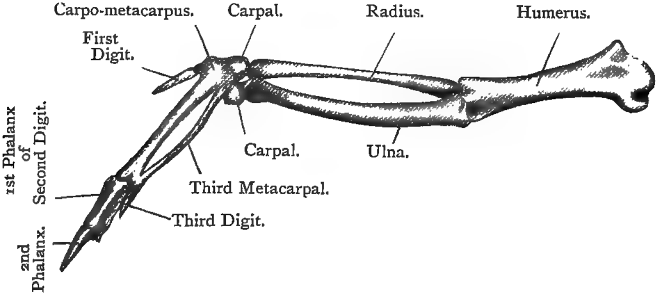
Fig. 265.—THE PECTORAL GIRDLE OF THE PIGEON. (*Ad nat.*)



The shoulder-girdle is formed of three elements, the *clavicle*, *coracoid* and *scapula*. Of these the clavicle is slender and joined to its fellow by fusion with an *episternum*. The compound bone so produced is called the *furcula*; the coracoid is very large and powerful and the scapula is long and flat. The coracoid and scapula form the *glenoid cavity* between them, and on the inner side the three bones border the *foramen triosseum.* The coracoids rest upon the front end of the enormous *sternum*, their ends being fastened in its *coracoid* grooves. Projecting ventrally is the large keel or *carina* and laterally there is a *costal process*, followed by an indented *costal ridge*, to which the distal ends of the ribs are attached.

The fore-limb has a short and powerful *humerus*, a thick *ulna* and a rather more slight *radius*, followed by a pair of proximal *carpal* bones. These are succeeded by a single compound bone, the development of which shows it to be composed of the distal carpals and three metacarpals fused together. It is hence termed the *carpo-metacarpus.* It bears a first digit with a single phalanx, a second digit with two large phalanges and a third with one small one. Hence the two peculiarities of the bird's forearm are the fusion of distal carpals and metacarpals into one bone and the loss of the two last digits.

Fig. 266.—THE SKELETON OF A BIRD'S WING. (*Ad nat.*)



To the first digit is attached the *ala spuria*, a miniature wing. To the hind-border of the second and third digits and the carpo-metacarpus are attached the twelve *primary* quill-feathers, and to the ulna are attached the twelve *secondary* quill-feathers.

Fig. 267.—Left Leg of the Pigeon. (*Ad nat.*)

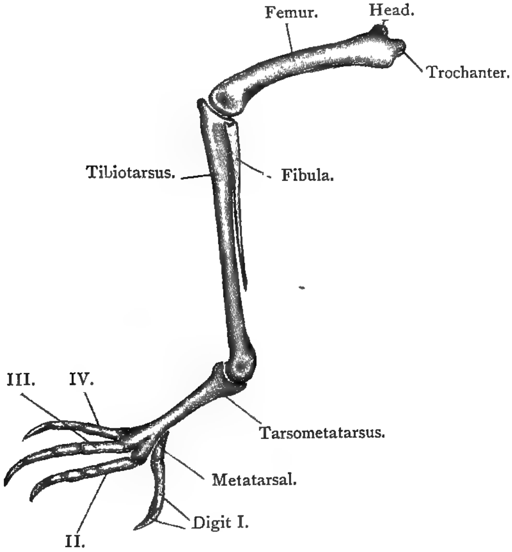
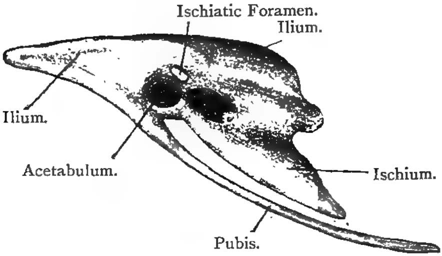


Fig. 268.—Lateral View of Pelvis of the Pigeon. (*Ad nat.*)
(Slightly magnified.)

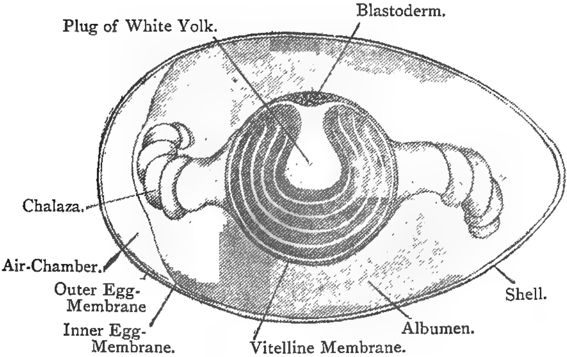


The pelvis has a long *ilium* which, as already seen, is attached to a large number of vertebræ. The round acetabular cavity, which is incompletely ossified, is about half-way along its ventral border. Posterior to it is a triangular *ischium* with a large oval foramen (the *ischiatic foramen*). From its anterior border there runs backwards beside the edge of the ischium a long *pubis*. There is no symphysis. Just above and posterior to the acetabulum is a small facet, the *antitrochanter*, which articulates with the trochanter of the femur.

The hind-limb has a short *femur*, a small and vestigial *fibula*, but a large *tibia* to which are fused the proximal tarsal bones, hence it is known as the *tibiotarsus*. This is followed by another compound bone, consisting of the distal tarsals and three metatarsals, which is known as the *tarsometatarsus*. It forks into three processes at its distal end, each of which bears a digit. A small bone on its inner side is the first metatarsal, which bears the first digit. The number of phalanges increases outwards from two to five. The pigeon has therefore no fifth or outer toe, and the first is opposable to the other three.

Fig. 269.—Diagram of a Fowl's Egg at Laying.

(After Allen Thomson.)



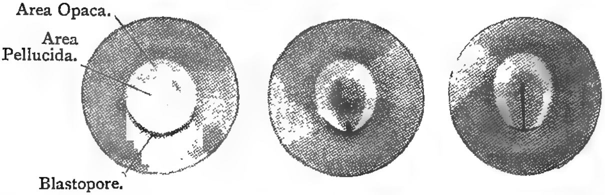
In the hind-limb there can be recognised the same two features as in the front-limb, *i.e.*, the reduction in the number of digits and the fusion of tarsals and metatarsals. In the hind-limb there is, however, a further fusion of the proximal tarsals to the tibia. The foot moves in the birds upon an *intertarsal* joint, the movement being between the two rows of tarsals.

**Development** (*Gallus*).—The true ovum of the fowl is a large yellow sphere enclosed in a delicate vitelline membrane. It is usually termed the "yolk" of an "egg." It is fertilised at the top of the Fallopian tube and passes slowly down the oviduct, developing as it goes, so that a laid "egg" has already developed for about eighteen hours. As it passes down the oviduct albumen is added to it from glands of the oviduct, and this is twisted by rotation of the ovum into two cords at the ends of the ovum (chalazæ). Further down a double egg-membrane and a shell are added and the egg is then laid.

Segmentation is, as in the skate, meroblastic and produces a small blastoderm resting on the yolk. On laying, the reduction of temperature causes development to cease, and in the natural condition it is not resumed till the full complement of eggs has been produced and the hen commences to "sit."

Fig. 270.—Three Consecutive Stages of the Blastoderm of a Chick in early Stages of Incubation.

(After Koller.)

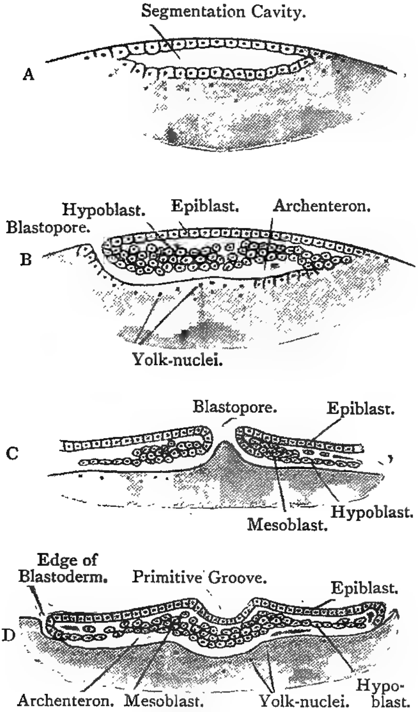


The blastopore is seen in the first to be crescentic, and is gradually converted by differential growth into a longitudinal groove which closes to form the primitive groove.

If sections of the blastoderm be made it will be found, as in the skate, to consist of two layers, epiblast and hypoblast, and a segmentation cavity between them. At the future hind-end, as in the skate, is a thickened rim, immediately behind which a crescentic hole passes into a cavity, the subgerminal (or, possibly, the archenteric cavity). As in the skate, the epiblastic edge of the blastoderm extends gradually round and envelops the yolk by epiboly, but in this case the extension is on all sides, and hence the final closure is effected at the distal pole (opposite to the embryo). In the future posterior region of the embryo the epiblast and hypoblast remain in continuity; hence the epiblast does not actually extend backwards at this point, but it sweeps round each side, converts the crescentic groove into a longitudinal one and completes an even edge beyond it. By the third day the edge of the epiblast has reached the equator and eventually completes the enclosure by the sixteenth or seventeenth day.

Fig. 271.—Section through a Chick's Egg at Various Stages.

(After Duval.)



In each case only the blastodermic pole is shown, the large mass of yolk being cut off below. A, Section through the egg at blastula stage. B, Longitudinal median section of the unincubated egg at the gastrula stage. C, Cross-section through the blastopore of same stage. D, The same further forward.

The crescentic groove, we already showed, was comparable to the blastopore, and, after conversion into a longitudinal groove, it is known as the *primitive groove.* The cells on either side of it are thickened because, as in the lip of the blastopore (*cf.* Amphioxus and Frog), the three layers are there continuous. This thickening gives rise to an opacity called the *primitive streak.*

Fig. 272.—VIEW OF THE AREA PELLUCIDA OF A CHICK'S BLASTODERM OF ABOUT 18 HOURS.

(After BALFOUR.)

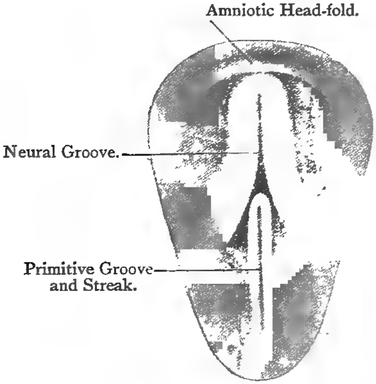
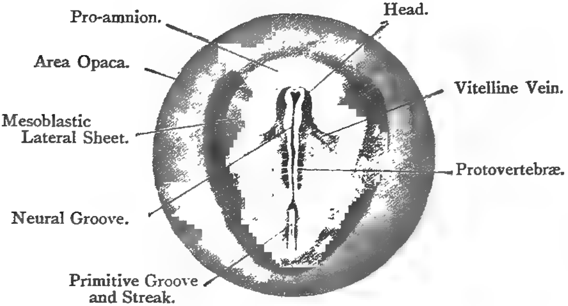


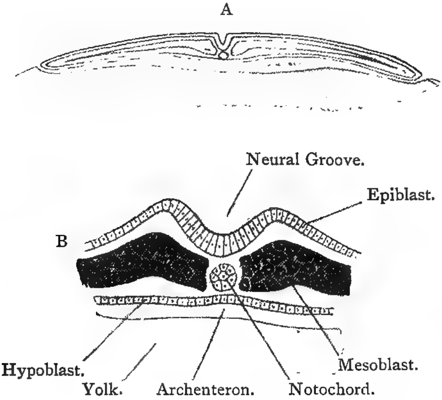
Fig. 273.—VIEW OF CHICK'S BLASTODERM ABOUT 24 HOURS.

(After DUVAL.)



In a similar manner the whole rim of the blastoderm has a thicker layer of cells than the middle and gives rise to an opacity. Hence the rim is called the *area opaca* and the centre the area *pellucida.* These are optical distinctions and there is no real morphological distinction between the two areas.

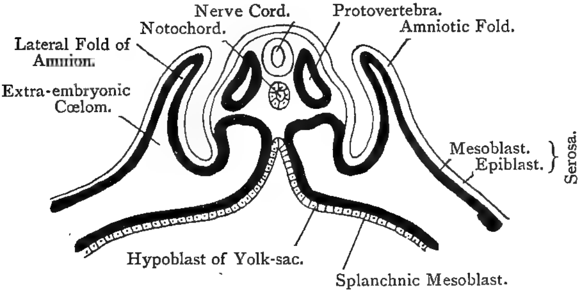
Fig. 274.—CROSS-SECTION THROUGH A BLASTODERM OF ABOUT 24 HOURS.



A shows the whole blastoderm lying on the yolk. B shows the median part only more highly magnified.

Fig. 275.—TRANSVERSE SECTION OF AN EMBRYO CHICK OF THE SECOND DAY. (*Ad nat.*)

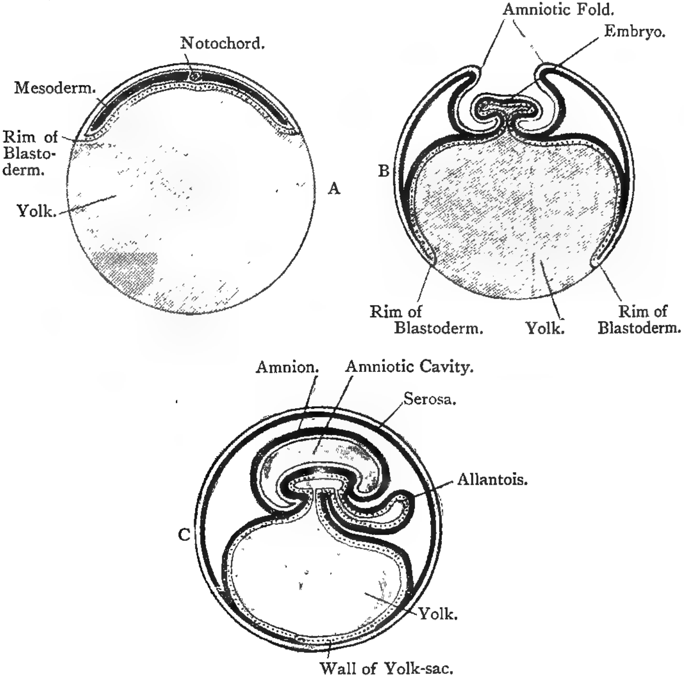
(Slightly diagrammatic.)



The first appearance of the embryo is the neural tube which arises immediately in front of the primitive streak. Paired neural folds grow up to form a neural tube and eventually enclose the primitive streak.

The mesoblast is differentiated from the hypoblast as paired sheets of cells which grow from the primitive streak forwards in two wings. They give rise dorsally to *protovertebræ* along the sides of the neural tube, and ventrally they slowly follow in the track of the epiblastic rim round the yolk. In the median dorsal line a rod of hypoblast cells forms the notochord.

Fig. 276.—Diagram of Developing Chick.



A, The blastoderm is about 2-5ths round the yolk. B, It is about 3-4ths round. C, The blastoderm has nearly enveloped the yolk. For later stage see E on page 428.

At the end of the first day the embryo has about half-a-dozen protovertebræ, an open neural tube, a blastoderm extending about $\frac{3}{8}$-inch in diameter and mesoblast growing out under the epiblast. In front of the anterior end the mesoblast sheets do not meet till late, hence here the blastoderm is only two-layered. This area is sometimes called the *pro-amnion*. On the second day there arises a fold of the blastoderm in front of the embryo, called the head-fold of the *amnion*. Similar lateral folds and a tail-fold all meet above and fuse together. The inner portions of the fold form the *amnion*, completely enveloping the embryo in a sac, and the outer portions are part of the *serous membrane*. The amnion by its formation is clearly lined with epiblast and covered with mesoblast. It contains a fluid *liquor amnii* and envelops the embryo till hatching. The mesoblast has already split into somatic and splanchnic layers before the formation of the amnion. As this split is continued downwards round the yolk-sac, it divides the wall of the yolk-sac into serous membrane and inner yolk-sac membrane. The amnion is completely formed on the fourth day, but the serous and yolk-sac membranes are not completely separated till about the seventeenth day. The embryo becomes pinched off from its yolk-sac in much the same way as in the skate, and the general origin of the organs is much as described in the general account of the *Vertebrata*.

The last fœtal membrane to appear is the *allantois*. Traces of it occur on the second day, but it grows out from the embryo on the fourth and fifth days. It is a median ventral diverticulum of the hind-gut and hence is lined with hypoblast covered with mesoblast. It spreads between the amnion and the dorsal wall of the serous membrane. Its walls are covered with branches of an allantoic artery and vein and it acts as a breathing organ, its cavity serving as a urinary bladder. It has been compared with the urinary bladder of the frog. The yolk-sac membrane also has vitelline arteries and veins which serve to absorb the yolk. In the later stages, the yolk-sac also absorbs the albumen, apparently through the serous membrane. On the twenty-first day the yolk-sac is absorbed, the chick breaks its way first into the air-chamber and inflates its lungs, and then breaks its shell. It ruptures the amnion and the remains of the allantois adhere to the inner surface of the shell.

We may note that the development of the chick, like that of the skate, is purely embryonic, with a lecithal and albuminal nutrition. In contrast with the skate and frog, we note the incubation by the mother and the presence of amnion and allantois.

# CHAPTER XXIII.

## *CHORDATA—(Continued.)*

## VI.—LEPUS.

| | |
|---|---|
| PHYLUM | CHORDATA (p. 402). |
| SUB-PHYLUM | VERTEBRATA (p. 405). |
| CLASS | MAMMALIA (p. 453). |

**Lepus cuniculus** (the Common Rabbit) is a type of the more highly organised and commoner mammals. Its general appearance and habits are too well known to necessitate much description. Of a habit partially terrestrial and partially fossorial or burrowing, the rabbit is little specialised though one of the most successful and dominant of mammals. In nature it is gregarious and of high fecundity. In these respects, and in the burrowing habits, it differs from its close ally the hare (*Lepus timidus*). Except when running it is *plantigrade*, *i.e.*, places the whole foot upon the ground.

**External Features.**

We can readily recognise a *head*, *neck*, *body* and *tail.* The whole body is coloured a dull greenish-brown which harmonises closely with its usual surroundings, but the under-surface of the tail is *white*, the under-surface of the body having a tendency to assume the same colour. It has been suggested that the white tail, so conspicuous when the rabbit runs or disappears down its burrow, is useful as a "danger signal" to the other members of the community that it is time to be moving.

The *mouth* is at the anterior end of the head, and is bounded by soft lips which cover a single row of teeth. The paired *external nares* open above the mouth, and laterally to them are long sensitive bristles or *vibrissæ.* Further back are the large paired *eyes*, facing laterally, which are guarded, as in the pigeon, by three eye-lids

Behind the eyes are the large so-called "ears," or more properly *pinnæ*. At the base of the pinna is the opening of the *external auditory meatus* which leads, as in the pigeon, a short way into the tympanum. The pinna is movable and serves to collect and concentrate the sound.

The limbs closely resemble each other; but the fore-limb has five claws, the hind-limb four. At the base of the tail is the *anus*, and in front of this opening is the *urogenital aperture*, either in the female a simple opening, the *vulva*, or in the male an opening situated at the end of a *penis*, at the base of which are the *testes* situated in *scrotal sacs*. In neither sex is there a cloaca.

**Integumentary.**

The whole body is clothed in "fur," which consists of a dense mass of hair. A hair is an epidermic structure peculiar to mammals; it grows from a follicle and is provided with glands (*sebaceous glands*) at its base (see page 455). The secretion of the glands keeps the hair flexible and moist. The fur forms a remarkable protection, for a warm-blooded animal like the rabbit, against changes of temperature. Like the frog, the rabbit has a great number of glands in its skin. These are known as the *sudorific* glands and excrete water and salts in the form of "sweat." Large *perinæal glands* are also found near the anus secreting an offensive liquid.

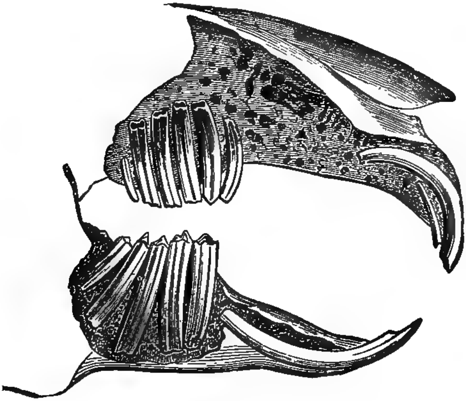
But the most remarkable skin-glands of the rabbit are the *mammary glands*. These are modified from sebaceous glands and secrete "milk." They open by ducts to the exterior upon *mammæ* or *teats* and are intermittently active for the nourishment of the young. In the rabbit the teats are in two ventral rows upon the hinder portion of the body or abdomen.

The skin may now be removed by a median ventral incision from chin to anus, the mammary glands—at the right season—being observed as yellowish glandular patches on the inside of the skin.

A median ventral incision of the muscular wall of the body, as far forwards as the hind-border of the sternum, exposes the large *abdominal cavity*. The anterior end of this cavity is formed of a large *septum* or *diaphragm*, partly muscular and partly membranous: through it emerge the œsophagus and main blood-vessels: in front of it lies another cavity (the thoracic cavity) containing, as will be seen, the heart and lungs.

**Alimentary.** The buccal cavity can be exposed by cutting one mandible. The *tongue* is large and mobile, and behind its base is the *glottis* covered by a flap, the *epiglottis.* The *internal nares* open very far back, almost over the glottis. This is due to the formation of a palate or secondary roof to the buccal cavity which shuts off a complete nasal chamber, at the hind-end of which open the two *Eustachian apertures.*

Fig. 277.—Permanent Dentition of the Hare (*Lepus timidus*).



Note the long incisors, four above and two below, and the cheek-teeth $\frac{3.3.}{2.3.}$

Into the mouth there open the ducts of four pairs of *salivary glands*—the *parotid*, below the ear; the *infra-orbital*, below the eye; the *submaxillary*, between the mandibles; and the *sublingual gland*, under the tongue. These secrete saliva which is mixed with the food by mastication and has a digestive action on certain foods.

At the anterior end of the jaws is a pair (upper and lower) of large sharp-edged *incisor teeth.* These have hard enamel mainly on the outer surface and are kept sharp by wearing upon each other. They grow throughout life as fast as they are worn away by use. Just behind the upper incisors is a pair of little peg-like second incisors. Behind the incisors is a part of the jaws with no teeth, forming a space or *diastema*, and further back is a row of six flat teeth on each side of each jaw. These are the *molar* teeth with flattened ridges which serve to crush and masticate the food (various vegetables). The cheeks can be pushed together across the diastema; and in this way the incisors may be used on occasion for gnawing without the products passing into the œsophagus.

This peculiar type of dentition is characteristic of the order *Rodentia* to which the rabbit belongs.

The *œsophagus* (see Plate XI.) passes down the neck as a soft tube and emerges through the diaphragm, opening into the large *stomach* towards the left side. The *duodenum* forms the usual loop, in which is a diffuse *pancreas* with a single *pancreatic duct* passing into the distal limb of the duodenum. The liver is very large and has five lobes. Partially embedded in it is the *gall-bladder*, from which there passes a *bile-duct* opening into the proximal limb of the duodenum. After the duodenum, the *ileum* forms an enormously long (8 feet) and coiled tube of small calibre. It terminates in the *sacculus rotundus*, a swollen sac which opens distally into the *cæcum*. The *cæcum* is a blind tube of large calibre which terminates in a small process, the *vermiform appendix*. It is continued, in the opposite direction, into the *colon* with sacculated walls and is about 18 inches long. It gradually loses its sacculation and passes into the *rectum*, a thin-walled tube about two feet long terminating in the anus.

The large size of the cæcum (about two feet long) and great length of the intestine are usually correlated with a herbivorous diet.

The duodenum and ileum are the two portions of the small intestine, the colon and rectum forming the "large intestine." The *spleen* is, as in other types, a dark-red body lying near the pancreas and beside the stomach.

The *portal vein*, as in preceding types, should be noticed before removal of the alimentary canal. It is formed of a *lienogastric* from the stomach and spleen, a *duodenal* and *anterior* and *posterior mesenterics*. The organs drained by the portal are supplied with arterial blood by the *cœliac*, *anterior mesenteric* and *posterior mesenteric* arteries, which should be identified (see page 388)

The œsophagus may then be cut through near the diaphragm and the rectum near the anus, and if the mesentery be carefully cut through the whole alimentary system may be removed and unravelled. The thoracic cavity should now be opened by cutting through the ribs on either side and between the diaphragm and the sternum. The cavity is almost entirely filled by the two lungs and the heart. The *trachea* can be traced down the neck (see Plate XIII.). Just where it emerges from the buccal cavity there is a cartilaginous *larynx* which forms the organ of voice. It is formed of thyroid and cricoid cartilages modified from branchial arches in the embryo (see page 417). The trachea throughout its course is distended by cartilaginous rings. It passes into the thoracic cavity anteriorly and divides into two *bronchi* which lead to the lungs in which they branch. (These are best seen on removal of the blood-vessels.)

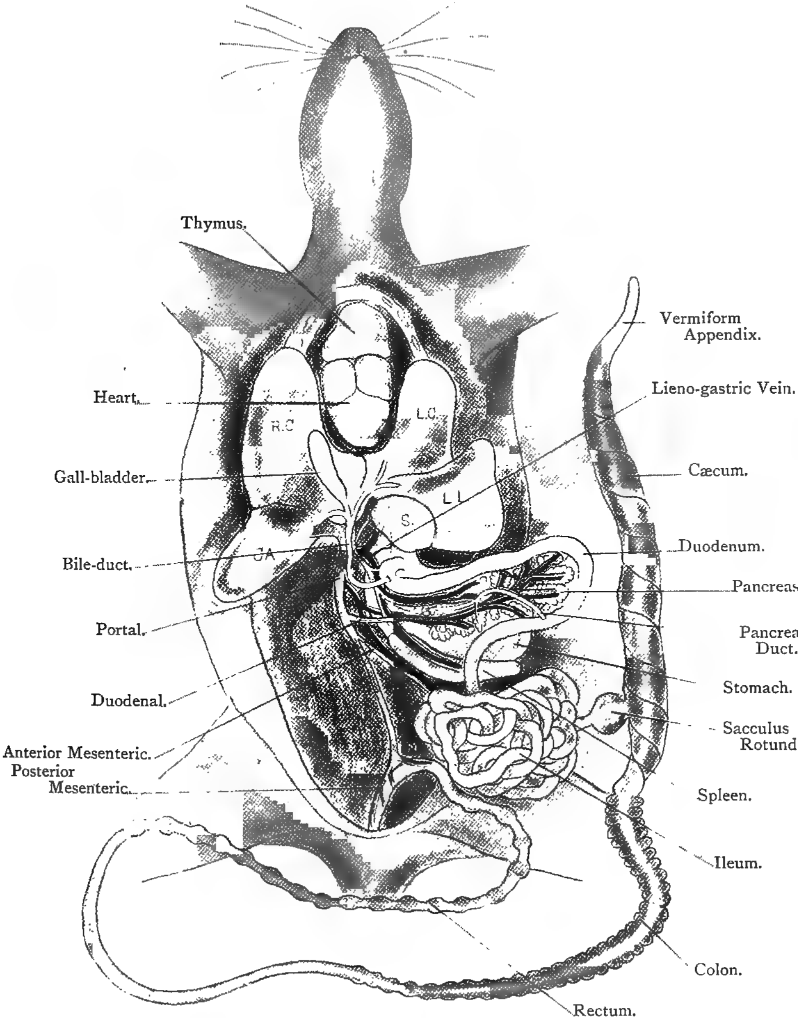
**Respiratory.**

The *lungs* are of a bright-red colour, spongy, and lying quite free in the cavity around them. The left lung has two lobes, the right has four. Each lung is enveloped by a layer of peritoneum called the *pleura*, which has the same relationship to the lung as has the pericardium to the heart. The outer layer of the pleura is pushed against the ribs and the inner adheres to the lung. Between the two is the *pleural cavity*, which is practically squeezed out of existence in the living animal by the expansion of the lungs. Between the two pleura is a space, the *mediastinal space*, nearly filled by the heart and pericardium.

**Cœlom.**

Hence the perivisceral cœlom in the rabbit is divided into no less than four separate parts—the pericardial cavity, two pleural cavities and the abdominal cavity. Between the last and the other three is the *diaphragm*. The diaphragm is innervated by a pair of *phrenic* nerves arising from the fourth spinal nerve in the neck. They may be easily seen passing down between heart and lungs. The capacity of the thorax is increased by raising of the ribs, caused by contraction of the intercostal muscles and by the lowering of the diaphragm. Air is in this way inspired or drawn into the lungs. Expiration

Plate XI.—FIRST DISSECTION OF RABBIT. (*Ad nat.*)



The skin is reflected from chin to anus; the abdominal wall is cut open and reflected; the ventral wall of the thorax is cut away; the intestine is partially freed from its mesentery and thrown over to the right; and the lobes of the liver are thrown forwards. (The lobes of the liver are R.C., Right Central; C.A., Caudate; L.C., Left Central; L.L., Left Lateral; and S., Spigelian. The red arteries are branches of the dorsal aorta lying deep, the more anterior is the cœliac forking into hepatic and gastric, the other is the anterior mesenteric; the blue veins are all branches of the portal.)

is more passive. The elastic lungs contract, the ribs fall and the diaphragm rises.

Anterior to the heart and lying over the great blood-vessels is the *thymus*, a ductless gland which must be removed to expose the blood-vessels.

**Blood-Vascular.**

The *heart* is four-chambered, as in the pigeon, and is but slightly larger. It differs but little from that of the latter. The three auriculo-ventricular valves on the right side are called *tricuspid valves* and the two on the left side are called the *mitral valves.*

The venous system, as in the two last types, has definite vessels or veins and consists of three parts. We have already noticed the *hepatic-portal system.* The *pulmonary system* consists of two pulmonary veins leading from the lungs and opening directly into the left auricle. The *systemic system* consists of three main veins opening into the *right auricle.* Two are paired and anterior, and are known as the *precavals*, and the third is posterior and median, known as the *postcaval.*

The venous blood from the superficial part of the head is removed by the *anterior* and *posterior facial* veins which unite behind the mandible to form the *external jugular vein.* This passes down the neck, at the base of which it receives a small *internal jugular* coming from the brain and a *vertebral.* It then unites with the *subclavian*, a large vein mainly formed of a continuation of the *brachial vein* (of the fore-limb), and the two form the *precaval* which passes into the thoracic cavity in front of the ribs.* The *right precaval only* has an *azygos vein* passing backwards beside the vertebral column and said to be a vestige of the right cardinal vein of lower types.†

The postcaval can be traced backwards through the diaphragm. It commences in the pelvic region by the union of two *internal iliacs*, and then receives two *femorals* from the legs, two *ilio-lumbars* from the back, *genitals*, *renals*, *dorso-lumbars*, *hepatics* and *phrenics* from the genital organs, kidneys, dorsal muscles, liver and diaphragm respectively.

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* The skin has two cutaneous veins not unlike those of the frog in position. The anterior arises from the subclavian and the posterior from the femoral. Both are enormously distended in the female when the mammary glands are active.

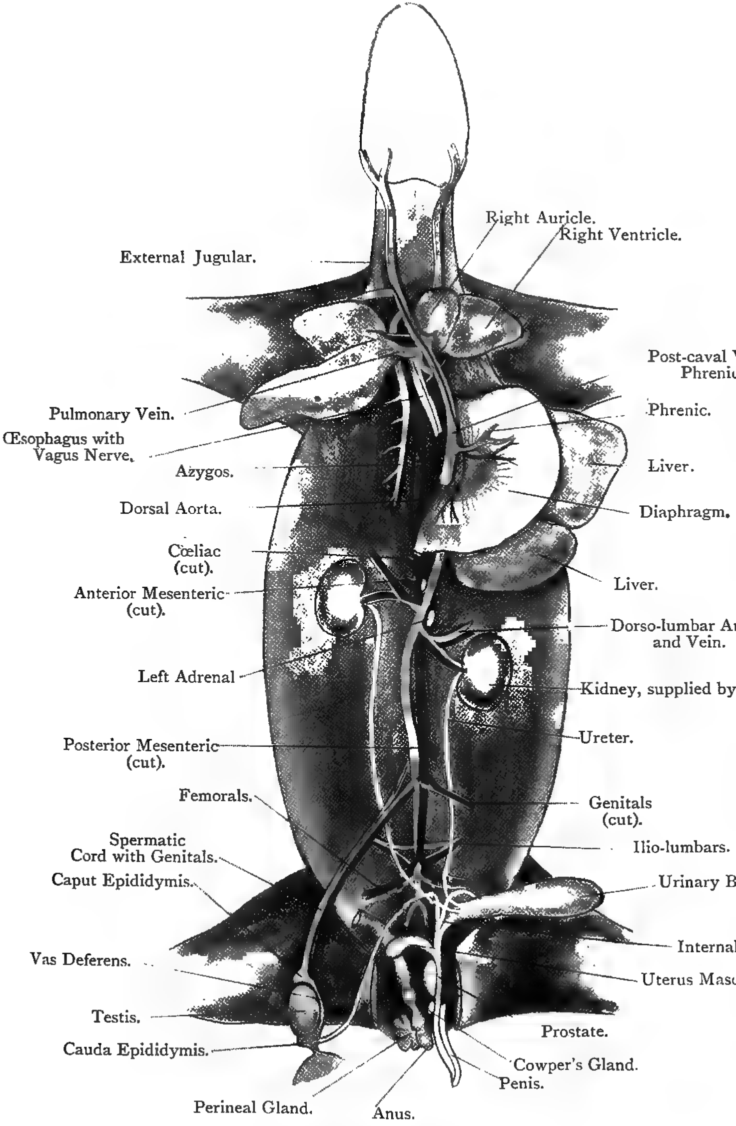
† The thoracic wall is drained by two small veins, the *anterior intercostal* and the *internal mammary* falling into the precaval on each side.

In comparing this arrangement with that of the pigeon, we notice the absence of renal portals and a different relationship of the posterior veins caused by the backward extension of the kidneys in the latter. Hence there is nothing in the rabbit approaching the "renal cycle" of the pigeon.

The arterial system has two parts. The pulmonary system consists of a pair of large but short *pulmonary arteries* leading from the right ventricle to the lungs. The left pulmonary artery is connected with the dorsal aorta by a transverse vessel, the *ductus arteriosus.* (Plate XIII.) It is only functional in the embryo, becoming a solid band in the adult.

The systemic system consists of two main arteries which separate soon after emergence from the left ventricle. The *right innominate* runs forwards and outwards, and divides into the right *carotid* to the head and right *subclavian* to the fore-limb and shoulder. The aorta bends forwards and outwards to the left, and gives off a *left carotid* to the head, then a left *subclavian*, and is continued backwards to the left of the mid-dorsal line through the diaphragm which it supplies by a small phrenic artery breaking up on the surface of the diaphragm. It lies dorsal to the postcaval to the hind-end of the body where it comes round and lies ventral to it. It gives off a median unpaired *cœliac* to liver, stomach and spleen, *anterior mesenteric* to the intestine and pancreas and *posterior mesenteric* to the rectum, paired *renals* and *genitals* to kidneys and genital organs, and then divides into two *common iliacs* which give off *ilio-lumbars* and in turn bifurcate into *femoral* and *internal iliac.* The persistence of the *left aortic arch* alone instead of the right, as in the pigeon, should be noted. Again, there is only one (right) innominate artery, the left carotid and subclavian communicating directly with the dorsal aorta instead of forming a separate left innominate, as in the pigeon. It will be remembered that in the frog the subclavians (or brachials) come off from the aortic arch on each side, so that the rabbit must be regarded as the more primitive in having only one innominate. However, the arrangement of carotids and subclavians varies very much throughout the *Mammalia.* Lastly, the very close correspondence of the arterial and venous system is striking. With the

Plate XII.—SECOND DISSECTION OF RABBIT. (*Ad nat.*)

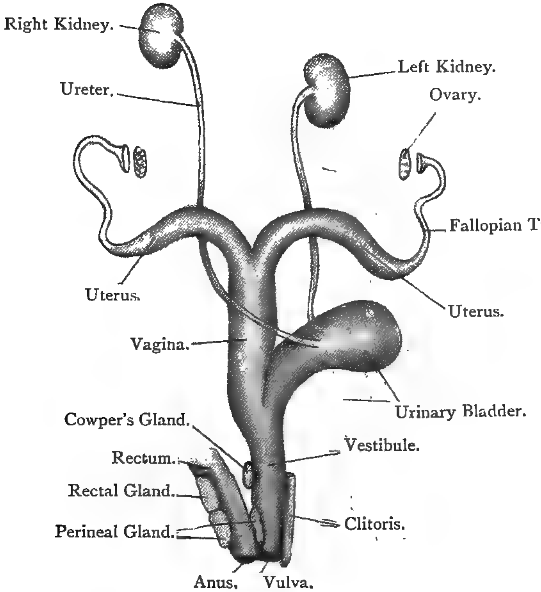


The alimentary system is removed by a cut through the œsophagus and the rectum, the liver and diaphragm are deflected over to the left. The pelvis is cu
left. Forwards the heart is ben
ıe right lung is pulled outwards

exception of the difference caused by the hepatic-portal system, the vein and artery to each organ are in close contact and agree in distribution.

The *thoracic duct* is the main vessel of the lymphatic system; it discharges into the left precaval and runs backwards beside the dorsal aorta.

Fig. 278.—Female Urogenital Organs of the Rabbit.
(*Ad nat.*)



The lower part is twisted to show lateral view; the upper part is a ventral view.

The *kidneys* lie in the dorsal region of the abdomen, the right further forward than the left. From each there runs back a delicate *ureter* opening into the base of the large thin-walled *urinary bladder*. From the bladder there runs backwards a *urethra*.

**Urogenital.**

In the male the *testes* are pale bodies lying in the *scrotal sacs*. These communicate with the abdominal cavity by *inguinal canals.* Through each of these canals there passes a *spermatic cord* with *genital artery and vein* to the testis from the lumbar region. The testis is partially surrounded by an *epididymis* consisting of coiled tubes, the *vasa efferentia,* which unite to form the *vas deferens.* This duct leaves the scrotal sac by the inguinal canal and passes up round the ureter of the same side, then backwards to open into the urethra. The testes in the young rabbit occupy the normal position in the neighbourhood of the kidneys, but by a process called the *descensus testiculorum* they pass downwards and into the scrotal sacs.

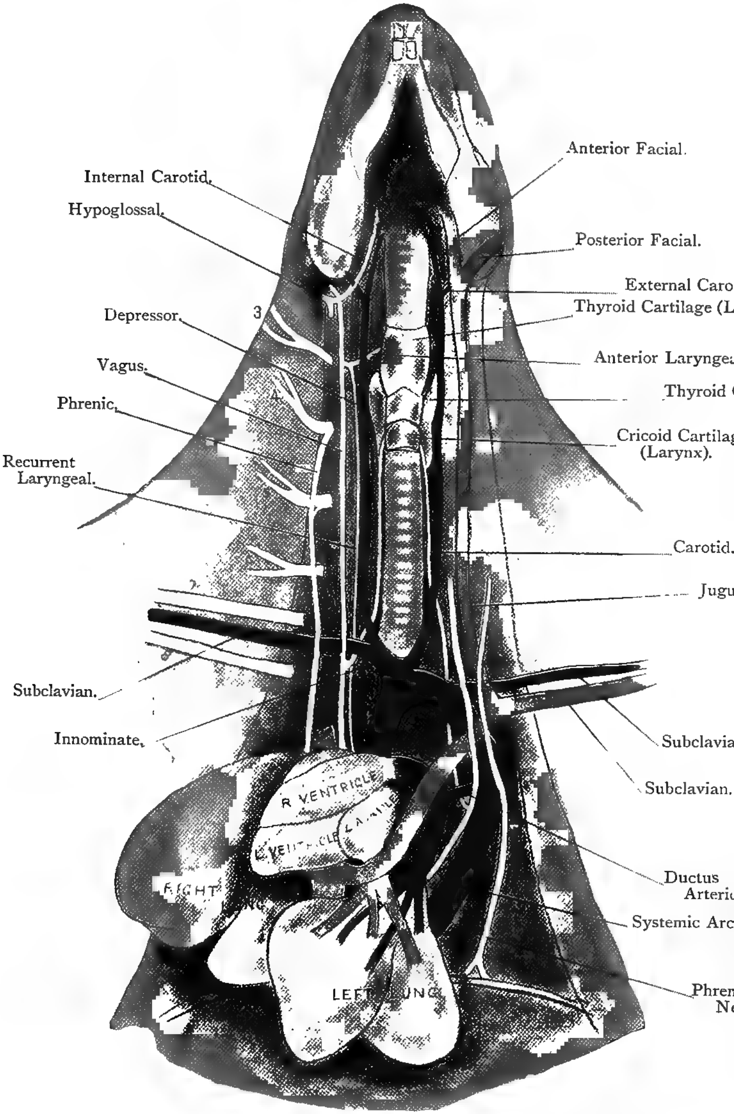
The swollen base of the two vasa deferentia, as they enter the urethra, is often termed the *uterus masculinus.* In the same position are the *prostate glands* opening into the urethra, and posterior to them are a pair of *Cowper's glands.* The urethra passes along the posterior surface of the *penis,* which is formed of vascular erectile tissue.

In the female the *ovaries* are small oval bodies attached by mesentery to the dorsal abdominal wall. The *oviducts* are paired tubes of the same size. Each has three parts, viz.:—the anterior portion or *Fallopian tube,* of small calibre, and opening into the abdominal cavity by a large funnel; the middle portion or *uterus,* which has thick muscular walls and is used for the retention of the young during gestation; the third portion or *vagina,* which in the rabbit is fused with its fellow, resulting in a single wide vagina, at the anterior end of which opens the *os* of each uterus, and posteriorly it leads into the urethra which is, in the female, known as the *vestibule.* There are *Cowper's glands,* as in the male, and a vestigial penis called the *clitoris.* The opening to the exterior is called the *vulva.*

**Nervous.**

The brain may be isolated by careful removal of the roof of the skull. It is chiefly remarkable for very large *cerebral hemispheres* which are connected across by a large band called the *corpus callosum,* for the lateral expansion and coiling of the cerebellum, for the division of the optic lobes into four, called the *corpora quadrigemina,* and for the presence of *twelve* cranial nerves, the *spinal accessory* and *hypoglossal* being added to the ten of the skate.

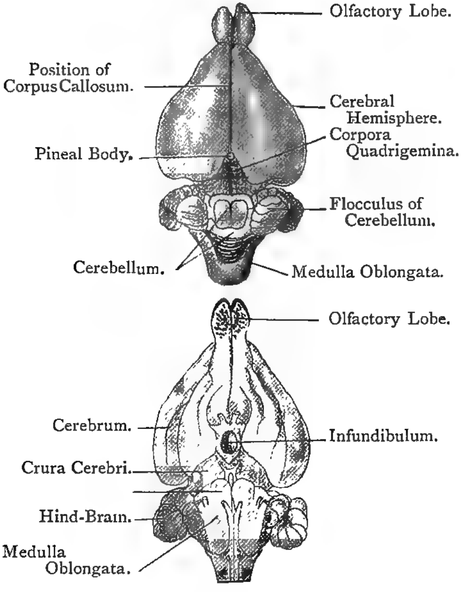
Plate XIII.—Third Dissection of Thorax and Neck of a Rabbit from the Ventral Side. (*Ad nat.*)



The ventral wall of the thorax is removed, the heart is thrown over to the rabbit's right, and the left lung is also drawn over to the right under the left phrenic nerve. The sympathetic nerve and internal jugular veins are omitted in order not
branches have been removed.
ins are all blue and the arteries

A description of the nerves cannot be entered into here, but a few of the more important are to be seen in the neck. (Plate XIII.) In this region we have already noticed the carotid arteries, the internal and external jugular veins, the œsophagus, trachea and phrenic veins. Just internal to the phrenic nerve and close beside the carotid artery runs the *vagus* (or tenth cranial). It has a slight ganglionic swelling, just opposite the larynx, and here gives off two branches—the *anterior laryngeal*, which runs into the larynx, and the *depressor*, which is a long delicate nerve running backwards to the heart dorsally to the carotid. The vagus is continued backwards into the thoracic cavity and along the œsophagus to the stomach. It gives off the *recurrent*

Fig. 279.—Rabbit's Brain.



A, Dorsal View.

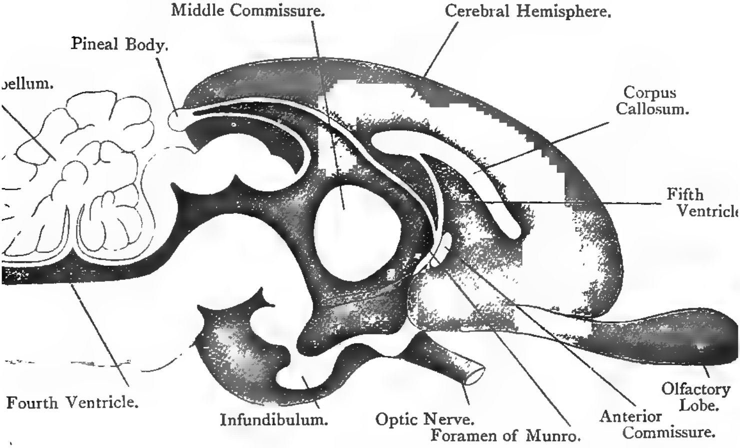
B, Ventral View.

*laryngeal*, a peculiar nerve which, on the right side, loops round the subclavian artery and, on the left side, passes round the *ductus arteriosus*. In each case it goes forwards beside the trachea to the larynx.

The *sympathetic* can be followed as a ganglionated cord between the vagus and its depressor branch, and the *spinal accessory* and *hypoglossal* can also be recognised supplying certain of the neck-muscles.

280.—A Median Longitudinal Section through the Rabbit's Brain.

(Mainly after Marshall.)



**Skeletal.**

The skeleton of the rabbit can be divided, as in preceding types, into axial and peripheral portions. It consists in the adult chiefly of bone and it presents the remarkable feature of *epiphyses*. An epiphysis is a cap of bone which, up to a certain age, can be detached from the main portion of the bone as it is united to it merely by cartilage. The meaning of these epiphyses will be pointed out later (see page 413).

*Skull.*—The skull has mainly persistent sutures. The characters of the teeth have already been noticed. The important mammalian features are the heterodont (incisors, canines and molars) and thecodont (in sockets) teeth, **Axial.** the bony palate formed of bony expansions of the maxillæ and palatines meeting in the middle line, two occipital condyles upon the exoccipitals, the suspension of the lower jaw by the squamosal, the single bone of the lower jaw and the three auditory ossicles.

The large size of the nasal chambers and nasal bones, the incomplete ossification of some bones, such as maxillæ and occipitals, the confluence of orbit and temporal fossa, and, above all, the character of the dentition, are features of the order *Rodentia*, whilst the presence of small second upper incisors and other lesser features are characteristic of the sub-order containing rabbits and hares.

The cranium of the skate could be recognised as formed of the cranium proper and the cartilages of the three sense-capsules. Similarly the bones of the rabbit's skull can be correlated with the cranium proper and the sense-capsules.

The former are arranged more or less in rings around the cranial cavity which facilitates their recognition.

The *occipital ring* is the most posterior. In many skulls it may be completely detached from the others. It is formed of a *supraoccipital*, paired *exoccipitals* and a *basioccipital*.

The *sphenoid ring* is formed of paired *parietals* above (and a small *interparietal*), paired *alisphenoids* laterally and a *basisphenoid*.

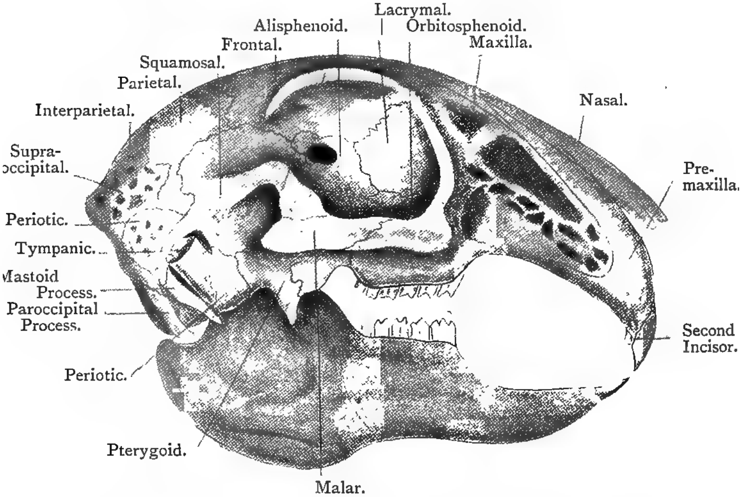
The *presphenoid ring* has a pair of *frontals* above, a pair of *orbitosphenoids* laterally and a *presphenoid* below.

The *ethmoid ring* has a pair of *nasals* above, a *mesethmoid* below, which lies between the two nasal chambers and broadens out posteriorly to form the *cribriform plate*, and a perforated bony septum between the cranial and nasal cavities.

The bones of the sense-capsules are closely united with those of the cranium proper. The auditory bones lie between the occipital and sphenoid rings. They consist of a *periotic* containing the inner ear and produced into a prominent *mastoid process*, and the *tympanic* which is swollen into a hollow auditory *bulla* and produced upwards therefrom as a bony auditory meatus. The eyes are embedded in orbits which are mainly formed by the *alisphenoids*, *orbitosphenoids*, *frontals* and other bones, but the anterior corner is completed by a *lacrymal bone* which develops especially in connection with the eye.

The nasal capsules have several bones which are thin and coiled in order to present a large surface. They are called the *turbinals* and are attached to the ethmoid, nasal and maxilla. Hence they are called *ethmo-*, *naso-* and *maxilloturbinals.*

Fig. 281.—Lateral View of Skull of the Rabbit. (*Ad nat.*)



These all form the cranium, and to them are added a number of bones which arise in connection with the first two visceral arches and form the main part of the facial region. The *premaxilla* and *maxilla* form all the anterior region of the skull below the nasal chamber. Above the maxillæ the small *vomers* are found. They are hidden by the palatine processes of the maxillæ. The *palatines* and *pterygoids* lie in the roof of the mouth. The *squamosal* is a large and important bone which lies between the auditory bones and the sphenoid ring; it has a glenoid cavity for the condyle of the lower jaw and is joined under the orbit to the maxillæ by a small *jugal* (or *malar*). This bony bar is called the *zygomatic arch.*

The *mandible* or lower jaw is in one piece or *ramus* on each side. It has a condyle for articulation with the skull, an *angle* at its posterior end and a *coronoid process* produced upwards in front of the condyle.

The *hyoid* consists of a central piece and two pairs of *cornua*, as in the frog.

Fig. 282.—Posterior View of Atlas Vertebra of Rabbit. (*Ad nat.*)

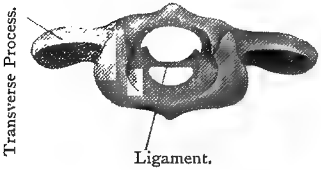


Fig. 283.—Lateral View of Axis Vertebra of Rabbit. (*Ad nat.*)

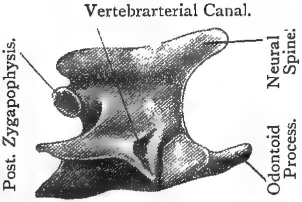
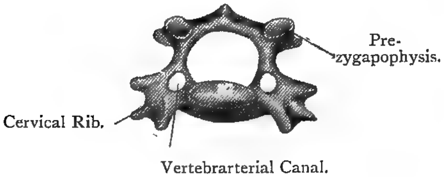


Fig. 284.—Anterior View of a Cervical Vertebra of Rabbit. (*Ad nat.*)



Lastly, in the middle ear is a chain of three ear-ossicles, the *malleus*, *incus* and *stapes*. The malleus is attached to the inner surface of the tympanum and the stapes to the *fenestra ovalis* of the inner ear.

The vertebral column consists of *cervical*, *thoracic*, *lumbar*, *sacral* and *caudal* vertebræ.

There are *seven cervicals*, as in nearly all mammals. The first is the *atlas* with two lateral wing-like cervical ribs, a small centrum and two hollow facets for the occipital condyles of the skull. The second or *axis* has a peg-like *odontoid process* which belongs by origin to the atlas. The other five have low neural spines and short centra. All the cervical vertebræ have *vertebrarterial* canals, produced by fusion of cervical ribs, as in the pigeon.

The *thoracic vertebræ* are *twelve*. All have long neural spines. The rib has in each case a *capitulum* articulating between the centra of two vertebræ and a *tuberculum* articulating with the transverse process of the hindmost of the two vertebræ (see page 418). The ribs meet below in the *sternum*, which is divided into a number of joints or *sternebræ*. The anterior end is known as the *manubrium* and the posterior end as the *xiphisternum*.

Fig. 285.—Lateral View of Thoracic Vertebra of Rabbit. (*Ad nat.*)

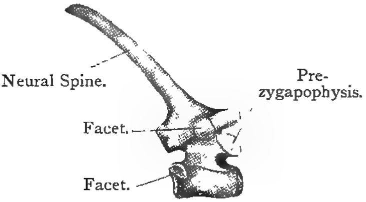


Fig. 286.—Anterior View of a Lumbar Vertebra of Rabbit. (*Ad nat.*)

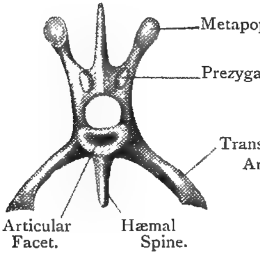
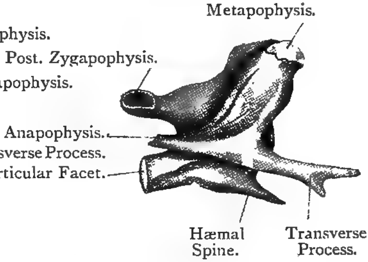


Fig. 287.—Lateral View of a Lumbar Vertebra of Rabbit. (*Ad nat.*)



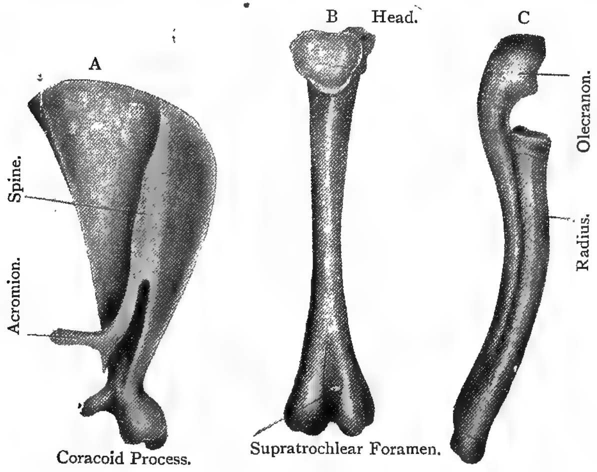
The *lumbar vertebræ* are *seven* in number They have large transverse processes which slope forwards and downwards. The neural spines are smaller than in the dorsal and there is a mid-ventral process or *hypapophysis*.

The *sacral vertebræ* are *two.* They are ankylosed together and are firmly joined to the ilium.

The *caudal vertebræ* vary in number up to *twenty.* The first few are ankylosed to the sacral vertebræ; the rest gradually become simpler till they are mere rods of bone representing the centra only.

Compared with that of the pigeon, the vertebral column of the rabbit exhibits far less adaptive modification, especially in the direction of fusions. With the exception of the first few caudals, there is no fusion of vertebræ, a condition probably due to the multiplicity of movement involved in the varied life of the rabbit.

Fig. 288.—Pectoral Girdle and Fore-limb of the Rabbit. (*Ad nat.*)



A, Scapula. B, Humerus. C, Radius and Ulna.

The pectoral girdle consists of a small vestigial *clavicle* connecting the sternum with the second element or *scapula* This is a large, triangular, flat bone with a glenoid cavity at one angle. Down the centre of one surface is a ridge or *spine*, culminating towards the glenoid cavity in an *acromion process* which usually has a backwardly projecting part or *metacromion.* The anterior or *coracoid* border of the scapula is continuous with a *coracoid process* projecting inwards. It represents a vestigial portion of the *precoracoid* bone.

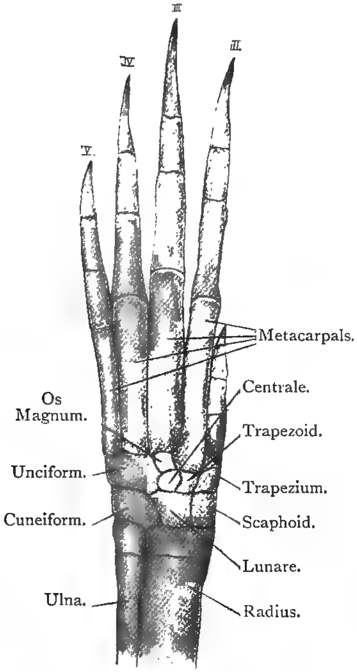


Fig. 289.—Dorsal View of Left Manus of Rabbit. (*Ad nat.*) (Slightly magnified).

The *humerus* has a large *head* and two prominent *tuberosities.* Distally it moves in the *trochlea* or articular surface of the fore-arm, above which is a small *supratrochlear foramen.*

The *radius* and *ulna* are distinct but closely united to allow of no pronation. The fore-limb is permanently supinated. The ulna is produced back beyond the radius to form the *olecranon process.*

The carpal bones are *nine*, closely bound together by ligament. The *proximal carpals* consist of *scaphoid*, *lunare* and *cuneiform*, and a small sesamoid (*pisiform*), together with a small *centrale.* The distal carpals are the *trapezium*, *trapezoid*, *magnum* and *unciform.*

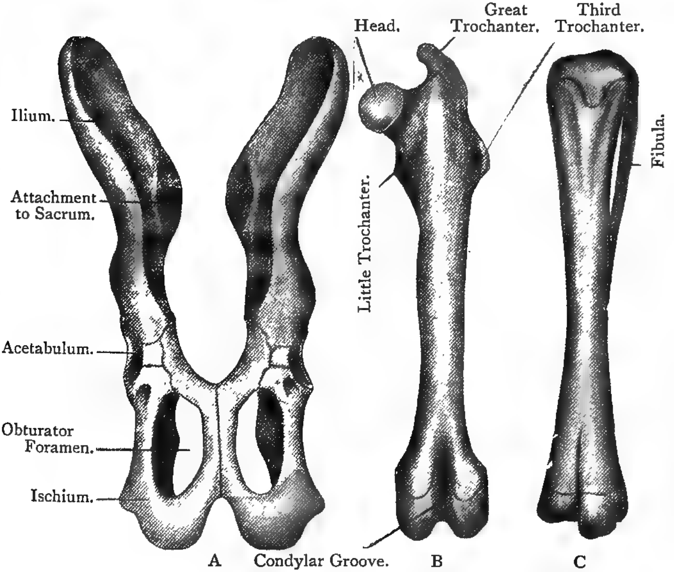
There are five *metacarpals*, each bearing a digit. The first digit has two phalanges and the others three.

The *pelvic girdle* has large *ilia* which run *backwards* to the *acetabulum.* The pubes are united ventrally to the *ischia*, thus enclosing on each side a large *obturator foramen.* The *symphysis* is *pubic* only.

The *femur* is long and has three trochanters, the *third trochanter* being on the outer side. The *tibia* is also long and is fused with the *fibula*, though the proximal end of the latter is separate for part of its course.

The *tarsus* consists of a condylar *astragalus* articulating with the distal end of the tibia, a long *calcaneum* produced backwards to form the *heel*, a small *navicular* in front of the astragalus, and a distal row of three bones. The *internal cuneiform* (see page 420) is apparently fused with the second metatarsal, but the *middle* and *external cuneiform* and the *cuboid* are distinct.

Fig. 290.—Bones of Pelvic Girdle and Hind-limb of Rabbit. (*Ad nat.*)

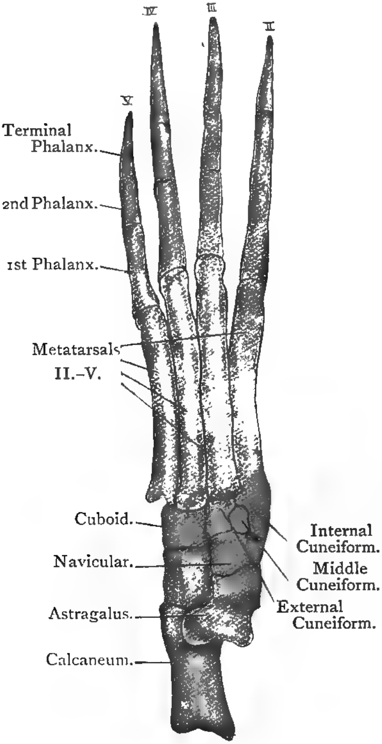


A, Pelvic seen in ventral view. B, Femur or proximal limb-bone. C, Distal limb-bones, tibia and fibula.

The first metatarsal and digit are absent, but the other *four* are long, and each bears a three-jointed digit.

The front-limb of the rabbit shows a primitive condition by the presence of a distinct centrale in the wrist, but the hind-limb is specialised in the loss of fibula and first digit. The third trochanter, however, appears to be an archaic character.

Fig. 291.—Dorsal View of Left Pes of the Rabbit. (*Ad nat.*) (Slightly magnified.)



**Development.**—The rabbit is like nearly all mammals, viviparous. Its period of gestation is thirty days and several young are produced at a birth. The placenta is *discoidal* and *deciduate.* (For details of mammalian development see Chapter XXVI.)

## PHYLUM CHORDATA.

1. **Cœlomate metazoa with bilateral symmetry.**
2. **Pharynx opens by paired lateral slits to the exterior.**
3. **A dorsal nervous system, and usually ventral circulatory centre (heart).**
4. **Notochord, a skeletal rod, arises from mid-dorsal line of the hypoblast.**
5. **Cœlom usually segmented into many parts.**

| Sub-Phylum I.—ATRIOZOA. | | Sub-Phylum II.—VERTEBRATA (Craniata). |
|---|---|---|
| Class I.—UROCHORDA (Tunicata). | Class II.—CEPHALOCHORDA. | |
| *Type—Ascidia.* | *Type—Amphioxus.* | *Types—Myxine to Lepus.* |
| 1. Body sac-like. | 1. Body fish-like. | 1. Body elongated (two pairs of limbs). |
| 2. Mantle and cellulose test. | 2. Simple ectoderm. | 2. Complex ectoderm (cuticle, epidermis). |
| 3. No segmentation of mesoderm or body. | 3. Mesoderm segmented into many parts. | 3. Mesoderm segmented into many parts dorsally, but continuous ventrally as pericardium and abdominal cavity. |
| 4. Notochord confined to tail and usually to larva. | 4. Notochord extends through whole length of body. | 4. Notochord extends as far forward as mid-brain, and replaced in most by vertebral column. |
| 5. Nervous system only a ganglion between mouth and anus in adult. Brain and spinal cord in larva. | 5. Small brain with single vesicle, and spinal cord. | 5. Complex brain with three primary vesicles and spinal cord. |
| 6. Sense organs rudimentary in adult, unpaired "eye" and "ear" in larva. | 6. Simple eyes and other sense organs. | 6. Three pairs of sense organs on head—olfactory, ophthalmic and auditory. |
| 7. Many gill-slits with atrium. | 7 Many gill-slits with atrium. | 7. Few gill-slits (8), which tend to disappear in higher classes. |
| 8. Heart ventral (reversible). | 8. Heart absent (contractile branchials). | 8. Large branchial ventral heart; left half becomes systemic in higher. |
| 9. Tadpole-like larva degenerates to adult. | 9. Free ciliated larva. | 9. Protected embryonic development. |
| 10. Sedentary or pelagic marine. | 10. Free marine. | 10. Free, aquatic and terrestrial. |

# CHAPTER XXIV.

## GENERAL FEATURES OF CHORDATA.

## PHYLUM CHORDATA.

The Phylum **Chordata** is in many respects the most important of the whole animal kingdom and contains an infinite variety of types from *Tunicata* to Man. It has five leading structural characteristics which are present throughout the group at one time in the life of each individual.

(1) *A hollow dorsal nerve-tube*, the anterior end of which is hypertrophied to form the brain. It arises from the epiblast.

(2) *The primary skeletal axis or notochord*, an elastic rod of chordoid tissue lying under the nervous system and arising from the hypoblast.

(3) *Paired pharyngeal clefts* formed from protrusions of the hypoblast in the anterior region of the alimentary canal.

(4) *A metameric segmentation of the mesoblast*, obscure only in the lowest class.

(5) A *ventral heart* or contractile circulatory organ (which may be multiple, as in *Amphioxus*), and a particular course of the blood-system, *i.e.*, forwards ventrally and backwards dorsally.

All the other phyla differ from *Chordata* in these characters and they are often contrasted with them as *Non-Chordata.*

It will be remembered that certain of the *Cœlenterata* present gastrovascular pouches which appear to be incipient cœlomic pouches. In the functions performed by their walls and in their hypoblastic origin they agree with the latter, but they are not completely separated from the gastric cavity and hence are not regarded as forming a third layer or mesoderm. In a similar way certain of the *Non-Chordata*, namely, a class of the *Archicœlomata*, called *Archichorda* (or *Hemichorda*), show several of the chordate characters in an incipient stage. The type of *Archichorda* described (*i.e.*, *Balanoglossus*) shows a series of pharyngeal clefts not essentially differing from those of *Amphioxus*, and these are also present in another member of the class. In addition, there is a dorsal nervous system, partially tubular, but there is no brain, and the whole nervous system is still in structural continuity with the epiblast (or ectoderm). Lastly, there are certain portions of the endoderm (or hypoblast), the epithelial cells of which undergo a modification into chordoid tissue histologically similar to that of the notochord.

In *Balanoglossus*, a pre-oral part called the *stomochord* (the "notochord" of some writers), the whole anterior wall of the pharynx, and an area in the intestine *(pygochord)* (and in its allies a pair of pharyngeal diverticula, called *pleurochords*) are of this nature. Hence the *Archichorda* resemble the true *Chordata* in having pharyngeal clefts, a dorsally-situated though simpler nervous system, and incipient chordoid structures.

In the other two features they differ from the *Chordata*, *i.e.*, they have no true metameric segmentation and no ventral heart. The circulation is usually forwards dorsally, but one member of the *Archichorda* has a reversible circulation like the *Tunicata.*

The *Chordata* fall very naturally into sub-phyla, *Atriozoa* and *Vertebrata.*

## SUB-PHYLUM I.—ATRIOZOA.

The *Atriozoa* are more lowly organised than the *Vertebrata.* The pharyngeal clefts are multiplied and the pharynx is specialised into a huge sac (or sieve) for obtaining food, with a complex apparatus of dorsal and ventral grooves and gland-cells. The water separated from the food-particles passes into a spacious *atrium* which arises from the epiblast. (Hence the name of the group). The notochord is never replaced by any other axial skeleton, and at most is surrounded by a membranous sheath. The brain has only a single internal cavity or vesicle, and the eye is single and of simple structure.

The development is external to the parent, purely larval (except for the very earliest stages), and there is a gastrula larva followed by the *chordula* larva.

The sub-phylum is entirely marine and mainly pelagic or sedentary.

It contains two classes—1. TUNICATA (UROCHORDA); 2. CEPHALOCHORDA.

### CLASS I.—TUNICATA.

*Ascidia* was the type of this class and is representative of the simple sedentary *Tunicata.*

They chiefly differ from the *Cephalochorda* in the simple and doubtfully segmented nature of the mesoderm, involving an absence of nephridial excretory organs and of perivisceral cœlom. Their real relationship to the other class is shown most clearly by the structure of the larval form rom the chordula onwards. In some respects the larval ascidian attains a higher level of chordate structure than *Amphioxus*.

Like most sedentary forms the *Tunicata* show a tendency to reproduction by budding, and to its natural corollary, the formation of *colonies*. These colonial types are called *compound ascidians*, the individuals being usually embedded in a common test, and sharing a common atrial cavity. Most are sedentary, but some (*e.g.*, *Pyrosoma*) are pelagic. This compound form is a large bell-shaped organism with a huge atrial cavity in its interior. It is strongly phosphorescent. Amongst other pelagic forms are *Appendicularia*, remarkable for retaining its notochord down the centre of a vibratile tail throughout life and possessing a number of other simple features and *Salpa*, which shows a well-marked *metagenesis* or alternation of generations.

## CLASS II.—CEPHALOCHORDA.

This class contains only *Amphioxus* and a few other genera which do not differ essentially from it. Hence the characters of the class are those of the type. We may specially notice as differences from *Vertebrata* the production of the notochord to the extreme anterior end of the body, the absence of paired sense-organs, of a median heart and of jaws, the different method of feeding therein involved, and the whole structure of the pharynx and atrium.

On the other hand it approaches the *Vertebrata* nearer than do the *Tunicata*, in the structure of the mesoderm, highly developed into segmented myomere muscles, a perivisceral cœlom and numerous nephridial excretory organs, the definite direction of circulation in the blood-vascular organs, and the clear indication of a hepatic-portal system.

In a very general way the method of locomotion is *vertebrate* and the method of feeding *atriozoan*.

## SUB-PHYLUM II.—VERTEBRATA.

The *Vertebrata* have been illustrated by no less than seven types taken from the six classes. They show a remarkable gradation in structure, which has only one break involved in passing from aquatic to terrestrial habitat.

The general characters of the *Vertebrata* separating them from the *Atriozoa* are as follows:—

1. A complex skin or external covering to the body.
2. A brain with three primary vesicles.
3. Three pairs of cephalic sense-organs.
4. The notochord surrounded, and in most cases replaced, by a mesoblastic skeleton of cartilage, and in higher types, of bone.
5. The presence of ingestive organs, in the form of jaws or teeth, in correlation with which the pharyngeal clefts are purely respiratory (gill-slits) and the endostylar apparatus becomes vestigial.
6. In all but the lowest class there are two pairs of paired limbs and a series of cartilaginous visceral arches.

### ORGANS OF VERTEBRATA.

We may now briefly review the chief organs of *Vertebrata.*

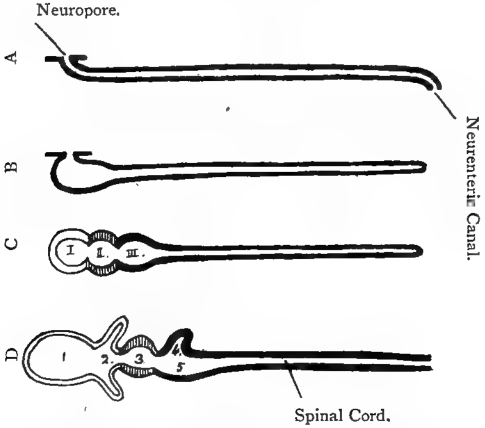
**Skin.**—The *skin* is formed of two distinct parts termed the *epidermis* and *dermis.* The epidermis is formed of a *basal epithelium* resting upon the dermis, which represents the primary epiblastic layer of the embryo and of a mass of cells above it which have been produced by proliferation. This mass can be defined as consisting of a lower portion of growing cells, called the *mucous layer*, and an upper superficial layer of compressed horny cells, called the *corneous layer.*

The dermis is derived from the mesoblast and is formed of connective tissue and muscle intersected by nerves and blood-vessels.

There are usually skin-glands formed from the mucous layer, and there is commonly an *exoskeleton* consisting of local productions of horny material, such as scales, claws, horns, feathers, or hairs.

**Nervous System.**—The *brain* arises as a swelling of the anterior portion of the dorsal nerve-tube, the posterior portion remaining as the spinal cord. The single swelling soon becomes constricted into three *primary vesicles* called the *fore-brain*, *mid-brain*, and *hind-brain*. The fore-brain then gives off the two *optic vesicles* as described below, and constricts into two *secondary vesicles* called the *cerebrum* and the *thalamencephalon*. The mid brain remains simple and gives rise to the *optic lobes*, and the hind-brain forms the *cerebellum* and *medulla oblongata*. Hence the brain has now five parts in succession, *i.e.*, cerebrum, thalamencephalon, optic lobes, cerebellum and medulla oblongata. The original cavity of the brain remains to a large extent in these parts. The cavities in each half of the cerebrum are known as the *lateral ventricles*, each communicating by a *foramen of Munro* with that of the thalamencephalon or the *third ventricle*, and that of the *medulla oblongata* or the

Fig. 292.—Four Stages in the Development of the Vertebrate Brain.



I., Fore-brain. II., Mid-brain. III., Hind-brain.

A, A tube with opening at each end.
B, A swollen brain at the anterior end.
C, Formation of the three primary vesicles.
D, Formation of the five secondary vesicles.

1, Cerebrum.
2, Thalamencephalon.
3, Optic Lobes.
4, Cerebellum.
5, Medulla.

*fourth ventricle*. The part in the optic lobes becomes constricted into a small canal or *iter* leading from third to fourth ventricles.

Fig. 293.—Diagram of the Vertebrate Brain.
(Mainly after Huxley.)

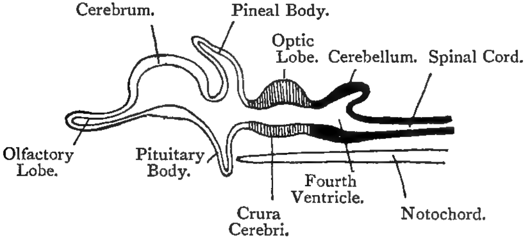
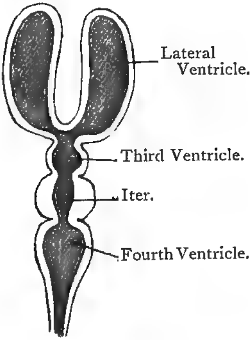


Fig. 294. — Diagrammatic Median Section through a Vertebrate Brain, showing the Ventricles.



The dorsal wall of the thalamencephalon is produced into a process called the *pineal body*, which, in some cases, shows evidence of being a *vestigial eye*. The ventral wall is also produced into a process called the *infundibulum*, coming into relation with the *pituitary body* (*v.i.*); the lateral walls become thickened and form the *optic thalami*. Thus the brain becomes a complex organ consisting of a linear series of specialised portions; but a further complication takes place in the flexure of one part upon another. In the highest types (mammals) the brain is twice flexed upon itself and its origin from a single tube is thus disguised.

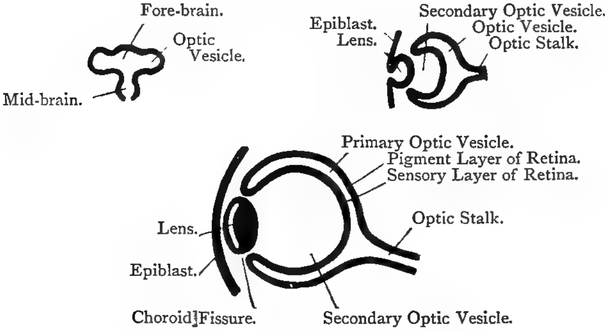
From the brain there arise at least ten pairs of cranial nerves which are remarkably constant in their relationship. The fore-brain gives rise to the olfactory (I.) and optic (II.), the mid-brain to the oculomotor (III.) and trochlear (IV.), and the hind-brain to the trigeminal (V.), abducens

(VI.), facial (VII.), auditory (VIII.), glossopharyngeal (IX.) and vagus (X.). In *Amniota* two more are added — the spinal accessory (XI.) and hypoglossal (XII.).

From the spinal cord there arises a series of spinal nerves, each of which has a dorsal (sensory) and ventral (motor) root, the two uniting soon after emergence from the spinal cord.

**Sense-Organs.**—The first sense-organs or olfactory organs arise as a pair (single in *Cyclostomata*) of epiblastic pits at the anterior end of the head. They form the *olfactory sacs* with a sensory epithelium. The fore-brain in development grows out in a pair of olfactory lobes which come into intimate contact with the sensory epithelium by means of the olfactory nerves. The lobes may be of great length, as in the skate. In the *Amniota* the surface of the olfactory sacs is kept perpetually moist by gland-cells, and they acquire internal openings or *internal nares* into the buccal cavity. They then form a passage for the current of respiratory air.

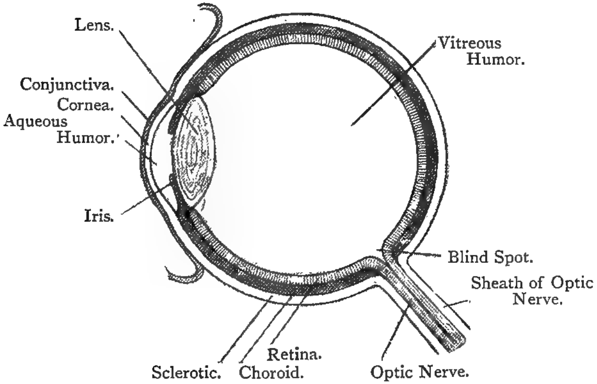
Fig. 295.—Three Stages in the Development of the Vertebrate Eye.



The second sense-organs or *eyes* arise from three sources. The fore-brain grows out laterally into two primary *optic vesicles* towards the skin. These take the form of a round vesicle connected with the fore-brain by a narrow stalk, called the *optic stalk*. The outer half of the vesicle then becomes pressed in, like an invaginating blastula, and the rim so produced gradually constricts to a small aperture, like the blastopore of a gastrula. Hence the sac is now a two-layered *optic cup*, like a gastrula, and contains a cavity, the *posterior chamber* of the eye. The outer layer becomes the *pigment-layer*, and the inner becomes the *sensory-layer*, of the retina. Meanwhile, the epiblast on the lateral wall of the head opposite the optic cup invaginates a small vesicle, which becomes the *lens of the eye* and fills up the small aperture of the optic cup.

Fig. 296.—DIAGRAM OF THE VERTEBRATE EYE.

(Seen in median section.)



The sensory cells of the retina send out nervous processes, which grow along the optic stalk and eventually reach the brain where they end in the optic lobes. These processes arise from the ends of the retinal cells which are nearest the posterior chamber; and the actual sensory elements, called *rods* and *cones*, arise from their deeper ends towards the pigment-layer. Hence the light has to pass through the nervous layer to reach the sensory layer, a peculiarity of the vertebrate eye. If it be recollected that the brain is invaginated from the dorsal epiblast and the eye is an invaginated part of the brain, it will be clear that the rods and cones really lie on the morphological outer surface, the normal situation for sensory elements.

The third element of the eye is mesoblastic ; it consists of a *choroid* coat carrying blood-vessels and partially covering the lens as the *iris*, and the *sclerotic*, a hard cartilaginous capsule enveloping the eye. In front of the lens it is transparent and forms the *cornea*, the *anterior chamber* being formed between it and the lens.

To this we must add the *eye-muscles* which are inserted in the sclerotic and serve to move the eye. They have been noticed in the skate and do not differ essentially in any type.

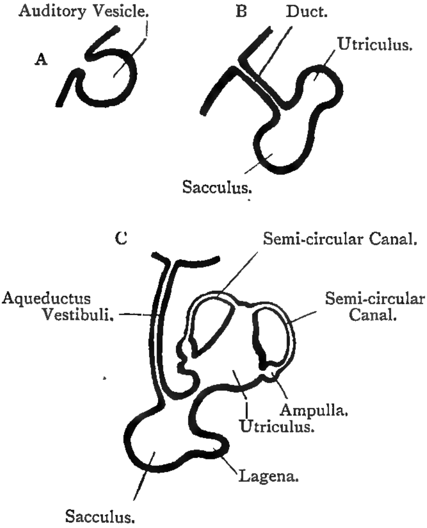
Obliquus superior innervated by 4th nerve.
Obliquus inferior innervated by 3rd nerve.
Rectus superior innervated by 3rd nerve.
Rectus inferior innervated by 3rd nerve.
Rectus internus innervated by 3rd nerve.
Rectus externus innervated by 6th nerve.

Accessory organs, such as eyelids and lacrymal glands, are added in terrestrial types.

The third sense-organs, or *auditory sacs*, appear to be a single much hypertrophied pair of *lateral-line sense-organs*, organs which were noticed in the skate but are not found as such in terrestrial *Vertebrata*. The auditory sacs arise as paired pits of the epiblast, far back on the head. Each pit swells out as an auditory sac, its connection with the epiblast becoming constricted into a thin duct, the *aqueductus vestibuli*. The walls of the sac then grow out into three (one in *Myxine*) *semi-circular canals*, long tubes which run in a semicircle in three separate planes and open at each end into the sac. Their bases are swollen into ampullæ, to which the 8th nerve gives off numerous branches. The sac itself is now known as the *vestibule*. In many fishes, *e.g.*, the skate, its cavity remains connected with the exterior by the *aqueductus vestibuli*. In the skate this *inner ear* (or *membranous labyrinth*) lies close to the hyomandibular cartilage, near which is the spiracle. Vibrations of the water may be transmitted through the hyomandibular to the inner ear.

In the frog and higher types the auditory sac becomes constricted into two portions called the *utriculus* and the *sacculus*. The utriculus gives rise to the semi-circular canals, and the sacculus to a coiled *cochlea*. The *aqueductus vestibuli* remains closed and is known as the *ductus endolymphaticus*.

Fig. 297.—Development of the Vertebrate Ear.



A Epiblastic invagination. B, Division into superior and inferior parts. C, The ear as in the skate (*cf.* Fig. 230, p. 323).

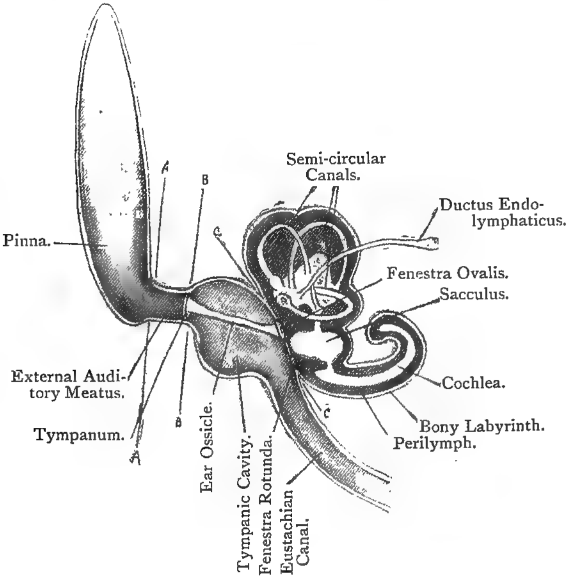
But the most important modification is involved in the formation of the *middle ear*. The cleft corresponding to the spiracle of the skate appears to be modified into a tube, closed at the surface in the frog by a membrane or tympanum, but still opening into the throat by the *Eustachian aperture*. The hyomandibular appears to become the *columella* which leads from the tympanum to the inner ear, and transmits the vibrations of the air thereto.

In the pigeon a further complication is involved in the formation of the *outer ear*, represented by an *external auditory meatus* leading from the exterior to the tympanum; and, lastly, in the rabbit, the *pinna* is added.

In the mammals the columella appears to be represented by three *auditory ossicles*, as noticed in the rabbit.

These three sense-organs, their accessories, and the brain mark out the *head* of the *Vertebrata.*

Fig. 298.—A Diagram of the Vertebrate Ear.



The whole diagram represents the ear of the rabbit (except that only one ear-ossicle is indicated); all to the right of AA represents the ear of the pigeon; to the right of BB represents the frog with middle and inner ear only; and the ear of the skate is represented by the part to the right of CC, forming the inner ear only.

**Skeletal Organs.**—The skeleton of *Vertebrata* shows a succession of three kinds, which replace each other in time throughout the classes and in the development of the higher individuals. These are the membranous, the cartilaginous and the bony. All arise from the mesoblast: the first is continuous, the second is largely segmented and the third is completely segmented.

In *Myxine* we find the membranous skeleton enveloping the notochord or primary chordate skeletal axis and the nerve-cord, and continued into the septa between the myomeres. There is little progress here beyond *Amphioxus*.

Cartilaginous nodules in the vertebral column, a cartilaginous cranium, and other parts appear in the lampreys, and a more or less complete cartilaginous skeleton is found in the skate.

In bony fishes and in the *Amniota* the cartilage becomes supplemented and eventually replaced by a bony skeleton.

Bone is produced by the secretory activity of certain cells called osteoblasts, and bones are known as membrane-bones or cartilage-bones, according to their origin. The membrane-bone is produced at once in the connective or membranous tissue, whereas the cartilage-bone is preceded by cartilage which has to be removed piecemeal as the bone is produced. The distinction is merely arbitrary, and is somewhat the same as the difference between building a roof with single slates in situ (cartilage-bone) and constructing an entire roof (as do many primitive peoples at the present day), and then lifting it into position (membrane-bone). The latter is, in each case, the more primitive method. The final result in each kind of bone is the same, and the two kinds cannot be structurally distinguished.

Complete ossification is usually effected fairly late in life, mainly because cartilage can grow more readily than bone. In nearly all the *Mammalia* most of the bones have separate caps or epiphyses at each end, probably to allow free use of a formed joint in the early stages, whilst the parts between the epiphyses and the main bone are still growing cartilage. In late life the epiphyses usually fuse on to the main bone.

The replacement of cartilage by bone is effected from certain centres, called centres of ossification, and the history of these throws light upon many obscure points in the skeletal structure. The simplest plan for the ossification of a long bone would be to institute a single centre of ossification, say in the mechanical centre, and thence to form bone to either end. But bone is a harder and more resistant substance than cartilage, and it is often more to the advantage of the organism that the parts which are subjected to special strain should first be ossified. Hence the ends of the long bones, which form the joints, and very often other parts, such as trochanters and tuberosities acting as points of attachment for muscles or tendons, have separate centres of ossification. When the cartilage ceases to grow, then the ossification proceeding from each centre, the bony elements meet and a single complete bone results. If, as in mammals, the bony elements are separated for a long time by a thin layer of growing cartilage, then the elements are separated in the dried skeleton by "sutures" and may fall apart. Hence the caps or epiphyses already referred to. But the final result is a single bone of the same size and shape as the cartilage.

In many cases the single piece of cartilage may be replaced permanently by two or more bones with a joint between them. Cartilage is elastic, and a piece of cartilage may therefore "give" to certain strains, by virtue of its elasticity, sufficiently to dispense with the necessity for a joint. Bone, however, is far more rigid, and hence a single elastic cartilage, such as the palatoquadrate bar, is replaced by at least three bones—the palatine, pterygoid and quadrate—which are more or less movable on each other. The replacement of the hyomandibular cartilage of lower types by three (or four) ossicles of the ear is probably another instance.

The skeleton can be conveniently considered under two heads:—1. The axial skeleton, skull and vertebræ. 2. The appendicular skeleton, limbs and limb-girdles.

Axial.—The skull has a double origin, being really formed of two parts which are almost entirely distinct in the fishes. These are (1) cranium; (2) the visceral arches.

The cranium arises essentially as a protecting mass to the underlying brain, and the visceral arches arise primarily as strengthening bars between the branchial clefts. The first two of these arches alone take any part in the formation of the skull.

(1) *The Cranium.*—In the earliest stages the brain is enclosed on all sides by a membranous sheath which also

envelops the three pairs of vertebrate sense-organs. The notochord runs in the ventral wall of this membranous cranium as far as the mid-brain, terminating behind the infundibulum (Fig. 293, page 407). The first cartilages to appear are two pairs of plates alongside of the notochord. The first pair extends forwards on either side of the infundibulum as the *trabeculæ*, the hinder pair,

Fig. 299.—Development of Vertebrate Cranium.
Dorsal View of Embryo.

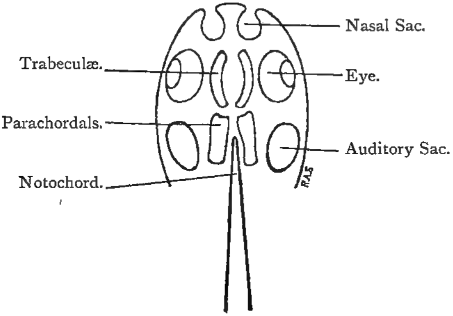
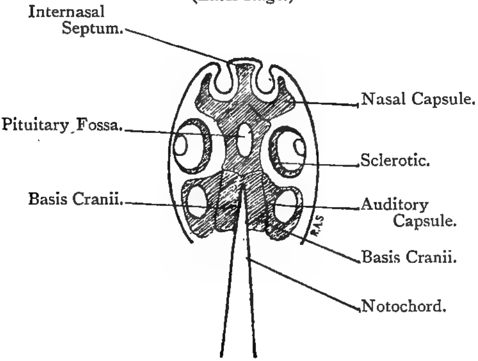


Fig. 300.—Development of Vertebrate Cranium.
(Later stage.)



or *parachordals*, soon fuse above and below the notochord to form the *basis cranii.* The trabeculæ then meet in front under the fore-brain to form a median plate, called the *ethmo-nasal septum.* All three pairs of sense-organs now acquire cartilaginous sense-capsules, which, with the exception of that of the eye (or sclerotic) fuse on to the primitive cartilaginous cranium, or *basal plate*, formed by the trabeculæ and parachordals. The basal plate then grows up on either side to enclose the brain. The edges meet dorsally in the occipital region and also forwards in the ethmoid region. Thus is formed the cartilaginous or *chondro-cranium.*

In the sharks and skates this condition remains, but in *Amphibia* a number of bones are added, and in the higher classes the bones almost completely replace the cartilage, forming a complete *osteo-cranium.* This osteo-cranium is produced partly by membrane-bones, which sink in, and partly by cartilage-bones. The bones of the osteo-cranium are arranged more or less in rings, a system which gave rise, in the hands of Goethe, Oken and Owen, to the beautiful vertebral theory of the skull. The hindmost ring is the occipital, with a *basioccipital*, *two exoccipitals* and a *supraoccipital.* The second ring is the *sphenoid*, with a *basisphenoid*, two *alisphenoids* and a pair of *parietals.* In front of this is the presphenoid ring, with *presphenoid* (at base), paired *orbitosphenoids* and a pair of *frontals.* The ethmoid ring completes the front-end with a *mesethmoid* and *nasals.* Between the occipital and sphenoid rings are the *periotic*, a bony capsule of the ear,* and the large *squamosal.*† Connected with the orbit, and lying at the anterior corner of it, is the small *lacrymal.*‡ Lastly, immediately below the mesethmoid, in the roof of the mouth, are the *vomers*, unpaired in mammals, and the *parasphenoid.*

We have already seen that the skull is, in the course of its development, preformed in membrane, and the greater part of it in cartilage. The cartilage is then gradually replaced by bone, a stronger and harder substance, by the process of ossification described above. If ossification

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* The periotic may be represented by as many as five separate *otic* bones, as in the cod (p. 336).

† The "temporal" bone of human anatomy is the fused periotic, tympanic and squamosal.

‡ The lacrymal is one of a series of circumorbital bones (*cf.* cod).

were to commence at one part of the skull, say the hind-end, and work forwards, the one part of the skull would become ossified too soon to allow the necessary growth in size, and the rest would ossify too late to form an efficient protective cranium. Hence ossification begins at various points simultaneously. These points are called centres of ossification, and their position is determined by mechanical conditions. Radiating in all directions from these centres, each bone is gradually produced until it comes to touch its fellow. Hence the ossification of the skull is effected by "piecework," divided amongst the centres of ossification; and in the cranium, in which a general protective function is requisite, the "pieces" are divided fairly accurately into successive rings, each of which is again subdivided into three or four. Thus we seek to explain the "segmental" formation of the bony skull as due rather to an orderly mechanical method of producing an osseous cranium from cartilage, than as indicating a primary origin of the skull from vertebræ. The method of ossification of a vertebra is due to a similar cause.

If all the cartilage becomes ossified, a continuous bony cranium is the result, incapable of further increase in size; but in most *Amniota* the bones remain for a long time (until late in life) separated by a thin layer of growing cartilage which leaves a "suture" in the dry skull. This enables every bone to continue increasing in size and with them the entire cranium.

(2) *The Visceral Arches.*—The first two cartilaginous visceral arches of the fishes are called the *mandibular* and the *hyoid.* Each has an upper and lower half on each side. The upper half of the mandibular arch is called the *palatoquadrate* bar and the lower the *mandible*, and the two are bent upon each other to form upper and lower jaw. The upper half of the hyoid arch is the *hyomandibular* cartilage which is attached to the otic or ear-region of the skull; the lower is the *hyoid* cartilage. These visceral arches are attached by ligament to the cranium in the lower types, but in the higher the bones which replace them form the very important facial part of the skull. The *palatoquadrate* cartilage is replaced by the *palatines*, *pterygoids* and *quadrates*, and, in addition, the *premaxillæ*, *maxillæ* and *jugals* are added in connection with it. The mandibular cartilage is replaced by the *mandible* and the hyomandibular cartilage by the hyomandibular bone.

The succeeding arches are called *branchial arches*. There are five in the skate, four in *Teleostomi*, and in all fishes they serve as a support to the gills and walls of the pharynx. In the *Amniota* they mainly disappear. The first branchial usually remains in part as the *posterior cornu* of the hyoid, the second and third form the *thyroid*, and probably the *arytenoid cartilages* of the larynx.

THE VERTEBRÆ.—A typical vertebra consists of a *centrum* or main axis, above which is a bony *neural arch* covering in the spinal cord. It is often surmounted by a more or less prominent median *neural spine.* From each side of the neural arch there usually protrudes a lateral process known as the *transverse process.* In the anterior part of the vertebral column the vertebra usually bears a rib, which is articulated to the centrum by its head or *capitulum* and to the transverse process by its *tuberculum.* The rib may, however, become completely fused on to the vertebra (cervical), or it may be attached only to the transverse process, or may become fused with the transverse process (lumbar and sacral). In the region behind the sacrum there is often a hæmal arch, but in mammals this is only found in a few types in the form of *chevron* bones which articulate *between* the vertebræ. In *Mammalia* the centra have epiphyses or caps of bone, and these are usually flat, though they may be opisthocœlous in some of the cervicals. At the front and hind-end are anterior and posterior *zygapophyses* which serve as articulations between the vertebræ.

The vertebræ are usually divided into—(1) cervical, (2) thoracic, (3) lumbar, (4) sacral and (5) caudal. The cervicals are defined as lying between the skull and the first thoracic, or the first vertebra that has a pair of ribs which meet the sternum. The thoracic vertebræ bear ribs which meet the sternum. In all the higher *Vertebrata* the sternum is formed from the fusion of the distal ends of the ribs.

**Development.**—The embryo has a notochord, around which is formed a continuous mesoblastic membranous or skeletogenous sheath. This sheath extends dorsally round the neural tube (*cf.* cranium). Paired masses of cartilage then appear above and below in the sheath. Their bases fuse across from side to side and dorso-ventrally to form the cartilaginous centrum, and the dorsal arches grow up round the spinal cord to form the neural arch. Ossification then takes place, there being usually several centres of ossification.

APPENDICULAR. — All *Vertebrata* above *Cyclostomata* (and exceptions) have two pairs of limbs and limb-girdles, an anterior or pectoral and a posterior or pelvic.

The girdles in a general way usually present three parts, cartilaginous in lower types, bony in higher. These are the following :—

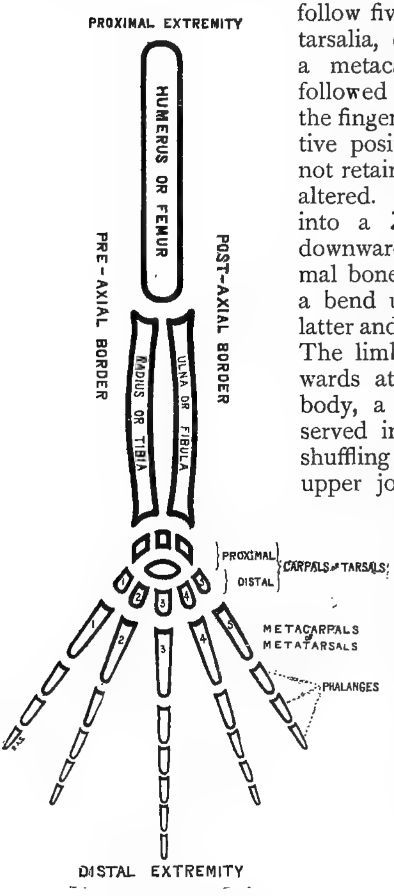
| | *PECTORAL GIRDLE.* | *PELVIC GIRDLE.* |
|---|---|---|
| Antero-ventral. | Precoracoid. | Pubis. |
| Postero-ventral. | Coracoid. | Ischium. |
| Dorsal. | Scapula. | Ilium. |
| Cavity for articulation of the limb. | Glenoid. | Acetabulum. |

Although these two girdles can be thus directly compared, they become very dissimilar in higher types. The pectoral girdle has a membrane-bone, the *clavicle*, which replaces the precoracoid. This joins the sternum, and hence the pectoral girdle becomes connected *ventrally* with the axial skeleton; but in the pelvic girdle the dorsal element or ilium becomes attached to the vertebral column, forming a sacrum, and the pubes and ischia tend to fuse ventrally.

The limbs are in most *Pisces* formed on the type called *ichthyopterygium*, consisting of one or more basal pieces (*cf.* Skate) bearing a row of distal elements or *fin-rays*. (See *Pisces.*) In the other *Vertebrata* the limbs are of the type called a *cheiropterygium* or pentadactyle limb. In describing this type we may first explain the following terms :— Both limbs in their supposed primitive position hang down on either side of the body, and if we draw an imaginary axis down the centre of the limb, certain parts of the limb are nearer the head, these being termed *preaxial*, whereas those nearest to the hind-end of the animal are called *postaxial.* Again, the part of the limb which is closest to the body is termed the *proximal* end and the part furthest away the *distal* end, and generally any point described as *distal* lies further out than one called *proximal.* The typical cheiropterygium has a single proximal limb-bone, called in the fore-limb the *humerus*, in the hind-limb the *femur*. Then follow two distal limb-bones in each case; the preaxial is the *radius* in the fore-limb, the *tibia* in the hind-limb; whilst the postaxial are respectively the *ulna* and the *fibula*. The small bones which follow are the *carpalia* or wrist-bones and the *tarsalia* or ankle-bones.

he proximal carpal bones are the radiale, intermedium ıd ulnare, together with the centrale (which in some cases is paired), whereas the proximal tarsals are tibiale, intermedium and fibulare, and also a centrale. In each limb there follow five distal carpalia and tarsalia, each of which bears a metacarpal or metatarsal, followed by the phalanges of the fingers or toes. The primitive position of the limbs is not retained, but they become altered. Firstly, they are bent into a Z-shape by a bend downwards between the proximal bones and the distal and a bend upwards between the latter and the carpals or tarsals. The limbs still protrude outwards at right angles to the body, a condition still preserved in many reptiles with shuffling gait. Secondly, the upper joint (knee or elbow) becomes deflected inwards towards the body, the knee *forwards* and the elbow *backwards*, bringing the post-axial bones to the outside. The feet are at the same time, in each case, twisted forwards through 90° so as to face forwards. In the hind limb the foot and the upper part of the limb are therefore both bent

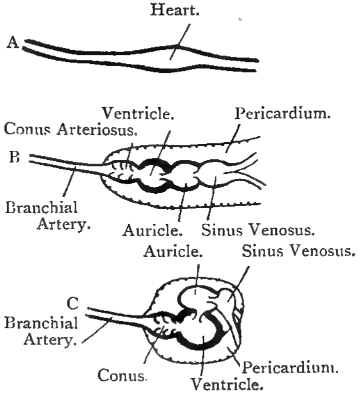
Fig. 301.—Diagram of the Pentadactyle Limb.



forwards through the same angle, but in the fore-limb the elbow is bent backwards and the foot forwards, resulting in a twisting of the two distal limb-bones (*radius* and *ulna*). Thus is produced the important movement of *pronation.* In a great number of mammals which use their fore-limbs almost entirely for progression the bones are permanently pronated, but in others the radius rotates and allows of supination and pronation at the desire of the animal.

**Blood-vascular system.**—The heart arises* as a contractile portion of the ventral vessel running forwards to the gills. It soon becomes constricted into an anterior *ventricle* and a posterior *auricle.* It then becomes bent upon itself in an S, hence the auricle comes to lie dorsally, and finally anteriorly, to the ventricle. Accessory to this two-chambered heart in the fishes are the *sinus venosus* or dilated part of the veins opening into the auricle, and the *conus arteriosus* or valved portion of the ventral aorta leaving the ventricle. This heart is entirely *systemic.* In the mud-fishes and *Amphibia* the auricle becomes divided into two by a median septum, the left auricle receiving blood from the lungs only. In the pigeon and rabbit the ventricle also is divided by a median septum, and then the respiratory and systemic currents are completely divided, the right side of the four-chambered heart acting as a respiratory heart and the left as a systemic.

Fig. 302.—DEVELOPMENT OF THE VERTEBRATE HEART.



A, A swelling on ventral vessel. B, Constriction into chambers. C, Twisting into an S.

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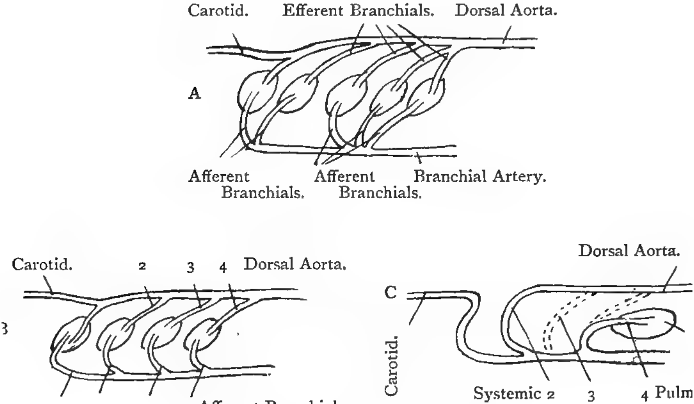
* The heart in many cases has a double rudiment in the embryo.

In the skate the blood from the heart passes by *ventral aorta* to the gills by five afferent branchials, an thence by five efferent branchials to the dorsal aorta There are in fishes never less than four branchials When the gills are lost in terrestrial animals the afferent become directly continuous with the efferents, and th arches so formed are called arterial arches.

Fig. 303.—LATERAL VIEWS OF ANTERIOR ARTERIAL SYSTEM O VERTEBRATES.



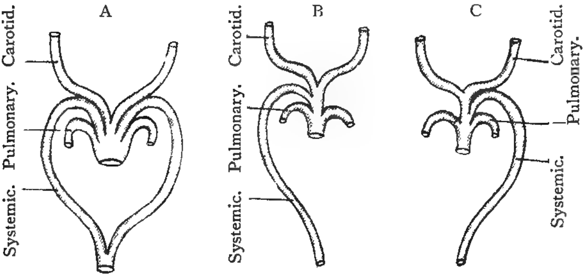
A, Skate. B, Teleostome. C, Frog.

In the frog there are four arterial arches at an early stag but later the first remains as the *carotid arch*, the secon persists as the *systemic*, the third is said to atrophy, and th fourth forms the *pulmonary*. The connections betwee these arches persist as membranous vestiges called *ductu Botalli*.

In reptiles much the same arrangement holds, but i birds the left systemic is lost, whilst in mammals the rig atrophies.

In the venous system the principal change is the replac ment in vertebrates above fishes of the *paired cardinals* b the unpaired *postcaval.* We have already noticed in the rabbit, as in all mammals, that the right cardinal persists as an *azygos vein* (page 387).

Fig. 304.—The Arterial Arches of Vertebrates. Ventral view.

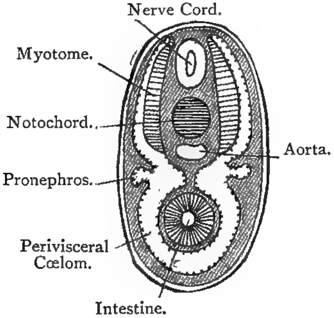


A, Frog and reptiles. B, Birds. C, Mammals.

**Cœlom.**—The cœlom or primary cavity of the mesoderm arises throughout the *Vertebrata* as a *schizocœle,* the mesoblast splitting into somatic and splanchnic layers.

Fig. 305.—Diagrammatic Transverse Section of a Vertebrate Embryo.

(Mainly after Van Wijhe.)



Nevertheless it has the same relationships as in the *enterocœlic* cœlom of *Amphioxus.* As in the latter, the myocœle (or avity of the myotome) early disappears and the ventral ement alone persists as a continuous *perivisceral* cavity.

Fig. 306.—Diagrammatic Transverse Section through a later Vertebrate Embryo.

(Mainly after Van Wijhe.)

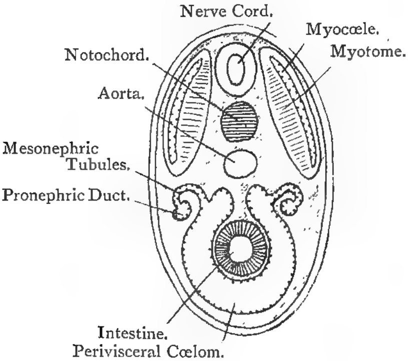
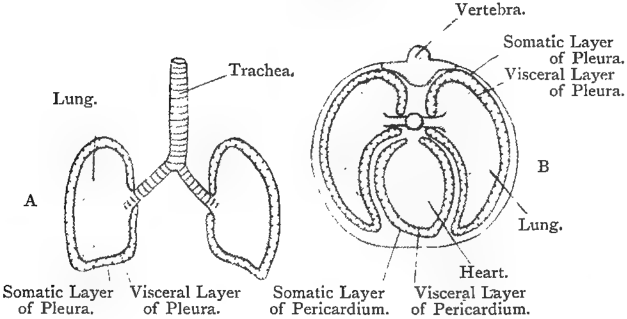


Fig. 307.—The Parts of the Cœlom in the Thoracic Cavity of a Mammal.

(After Wiedersheim.)



A, The lungs. B, Cross-section of the thorax.

n the cavity lie the heart and all the alimentary organs. ach is surrounded by a splanchnic layer of the cœlomic lining (or peritoneum) which in most cases forms a *mesentery* dorsally where the splanchnic layer joins the somatic. The perivisceral cavity becomes divided into *pericardial* and *abdominal* cavities, and in mammals there is a further separation of two pleural cavities.

**Alimentary System.**—The most outstanding feature of the vertebrate alimentary system is the presence of paired *pharyngeal clefts* which arise as hypoblastic pockets, growing out into contact with the epiblast and then opening to the exterior. In fishes these pharyngeal clefts function as gill-slits, the hypoblastic epithelium growing out into gill-filaments. The first pharyngeal cleft appears in the skate to have already lost its branchial function, and serves only as a spiracle or aperture for introduction of water. In many fishes the mouth is used for this purpose and the first cleft is then given up.

In the terrestrial *Vertebrata* the first pharyngeal cleft persists as the Eustachian canal and middle ear whilst all the others atrophy. They are found more or less distinctly in the embryo, but are merely vestigial organs.

In the mid-ventral line of the pharynx in vertebrate embryos there arises a groove having the same relationships as the endostyle of *Atriozoa.* As development proceeds, however, it becomes completely separated from the pharynx and gives rise to the *thyroid gland.* The *thymus* also appears to arise by several rudiments in connection with the gill-slits. The extreme anterior part of the alimentary canal is formed by an epiblastic ingrowth called the *stomodæum ;* this gives off a dorsal diverticulum called the *hypophysis* which may be homologous with the subneural gland of the *Tunicata.* Its distal end becomes detached and, coming into close relationship with the infundibulum of the brain, forms the *pituitary body.*

The alimentary canal is in its earliest condition a simple tube, but certain parts, such as the pharynx and stomach, develop by rapid growth into large sac-like swellings. The *lungs,* in terrestrial forms, arise as a single ventral diverticulum of the œsophagus which forks into two, and each becomes distended into a sac. The sac becomes the lung and the connecting stalk persists as the trachea and bronchi. Behind the stomach the intestine buds out a ventral diverticulum which forms the liver, its stalk becoming the bile-duct;

and the *pancreas* arises from several dorsal processes in the same region. The essential epithelium of the gland in each case arises in this way, the bulk of the organ being composed of mesoblastic connective tissue and blood-vessels.

**Urogenital organs.**—The urinary organs show a succession in the group of three separate series—the *pronephros*, *mesonephros* and *metanephros.*

The pronephros is always situated far forward in the cœlom. It is functional in *Myxine* and in the tadpole of the frog. It consists typically of three or more paired tubules opening by funnels into the cœlom and leading to the exterior by a paired lateral pronephric duct. The mesonephros arises behind the pronephros and replaces it in development. It is formed of a number of tubules arising from the cœlom and becoming connected with the pronephric duct. The duct then splits into two, one of which remains functional in the female as the *Müllerian* duct or oviduct, and the other becomes the *Wolffian* or *mesonephric* duct, functioning in the female as a ureter, in the male as a *ureter* and as a *vas deferens.* It is enabled to do this by certain of the mesonephric tubules growing out towards the testes, becoming connected with them and forming the *vasa efferentia.* The other mesonephric funnels close in adult life. This condition is found in the frog.

In the skate and in *Amniota* the *metanephros* arises as a set of tubules posterior to the mesonephros. They become connected to the cloaca by ureters, and the mesonephros then atrophies so far as the excretory function is concerned. It persists in the male rabbit as the *epididymis.* In the metanephros the tubules have no funnels. The exact meaning of this successive replacement of one kind of excretory organ by another throughout the sub-phylum is unknown.

**Development.**—The types of development already outlined are very diverse, but it is possible to trace a phyletic sequence from one to the other.

In young forms, even more than in adults, because the reproductive element is not present, the nutritive conditions are the secret of the structural modifications, and we can discern in the vertebrate series no less than five different forms of nutrition in regular sequence. They are as follows:—

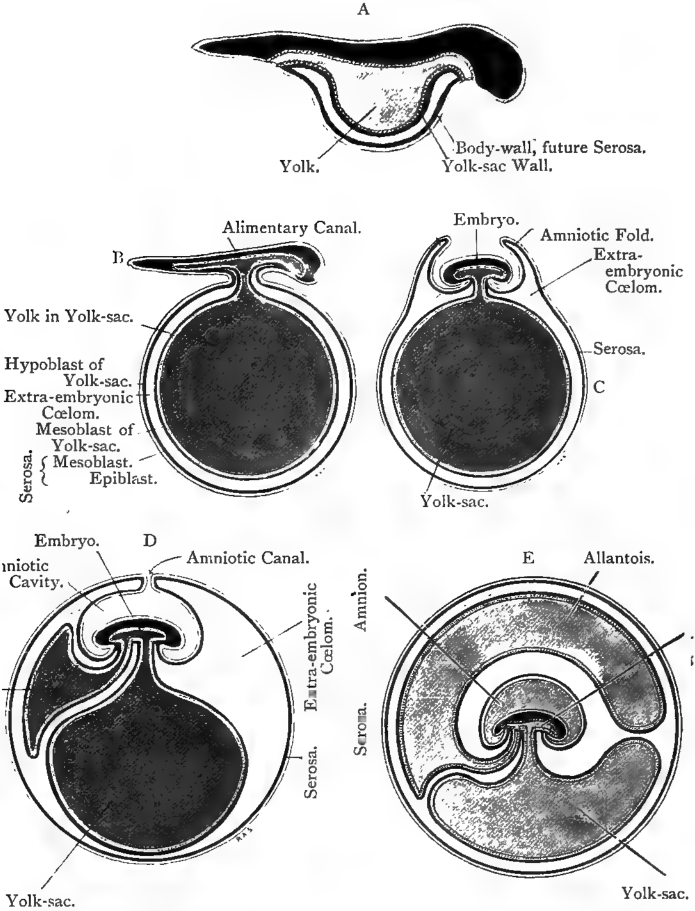
1. FREE OR LARVAL NUTRITION.—This is found at a very early stage in *Amphioxus* and later in fishes and *Amphibia.* In it the larva or young form catches its own food with mouth and ingestive organs. It is practically the only mode of nutrition adopted by *Amphioxus.*

2. YOLK OR LECITHAL NUTRITION.—The young form is supplied by the parent with an inert mass of yolk or fatty material, and whilst the yolk lasts it is mainly enclosed in the egg-membrane and is known as an embryo instead of a larva. The yolk is stored primarily in the alimentary canal which causes the latter to protrude as a large bag or sac called the *yolk-sac.* In certain fishes and *Amphibia* the lecithal form of nutrition is succeeded directly by the larval nutrition, the mouth and other ingestive organs becoming functional at the completion of yolk-absorption. In other words, the young frog, for example, is supplied with yolk till shortly after hatching, when the mouth opens and a vegetable diet is then resorted to.

The lecithal form of nutrition culminates in elasmobranch fishes, in *Sauropsida* and in *Monotremata* amongst mammals. Like the larval nutrition, it is entirely given up in the rest of the *Mammalia.*

3. ALBUMINAL NUTRITION.—In *Amphibia,* such as the frog, the egg itself is surrounded by a clear hyaline mass of an albuminous substance which swells up after oviposition and serves as a protection to the embryo. It does not appear in the frog to be used as nutriment, but in the *Sauropsida, e.g.,* chick, the same material surrounds the true egg as a mass of albumen between it and the shell. As in the frog, this material is produced by a series of glands in the lower part of the oviduct. Here, however, the albumen is not required for protection as this function is performed by the shell, but it is absorbed by the embryo towards the later days of incubation when the lecithal nutrition is terminating. Little is known about the absorption of this albumen. The serosa may play some part, but the basal part of the yolk-sac, in contact with it, is said to become the absorbing area, and the nutriment would thus find its way to the embryo through the medium of the yolk-sac. Little is known concerning

Fig. 308.—THE EVOLUTION OF THE FŒTAL MEMBRANES OF VERTEBRATA.



A, Stage of the Frog with only small Yolk-sac ; B, Stage of the Skate ; , Stage of Developing Amnion ; D, Stage as in many Reptilia, the amnion and serosa are not completely separated (*cf.* also MONOTREMATA) ; E, A Typical Sauropsid.

Epiblast is represented white, mesoblast black and hypoblast dotted.

the albuminal nutrition of the mammals, though in the *Metatheria*, at least, it appears to be an important factor in the nourishment of the young, and in many *Eutheria*, in which the lecithal nutrition is entirely replaced, it probably plays an important rôle. There are numerous glands of the oviduct, uterine glands, which probably secrete the albumen. The albuminal nutrition is therefore the second form of nutriment supplied by the parent to the embryo.

4. LACTEAL NUTRITION.—This is the production of "milk" by mammary glands. The "milk" is elaborated by skin-glands and is supplied, not to the embryo, but to the young animal after birth; hence no special organ beyond the mouth and alimentary canal is needed. Traces of this form of nutrition are found in the *Sauropsida* (pigeon's "milk") and in the *Prototheria*, but it attains its greatest development in the *Metatheria*, in which it follows very closely upon the albuminal nutrition. It is found usually in the *Eutheria*, but is in them being replaced by the last method of nutrition.

5. HÆMAL NUTRITION.—In this form the young animal feeds directly upon the blood of the mother by absorption through the blood-vessels of the yolk-sac and of the allantois. The maternal vessels form with those of these two organs a complex vascular organ called a *placenta*. The yolk-sac placenta is found in *Metatheria* and, exceptionally, the allantoic, but neither is sufficiently elaborated to replace to any extent the lacteal; whereas in the *Eutheria* this hæmal nutrition is much the most important, though preceded by an albuminal and succeeded by a lacteal.

**Fœtal Membranes.**—The distension of the ventral wall of the body by an accumulation of yolk produces a large sac-like protuberance of the intestine, called the *yolk-sac*, covered by the distended body-wall forming the *serous membrane* or *serosa*. In the *Amniota* other two fœtal membranes are found. The *amnion* is a protective membrane produced from the serosa and similarly formed of epiblast and somatic mesoblast, whilst the *allantois* is a median ventral process of the intestine and is similarly formed of hypoblast and splanchnic mesoblast. In *Sauropsida* the allantois acts as a urinary bladder and a respiratory organ, whilst in mammals (*q.v.*) it takes part in the formation of the placenta.

**Conclusion.**—It is clear that the study of comparative anatomy and of development throughout the sub-phylum of *Vertebrata* can scarcely be over-estimated as a means of interpreting the complex and often puzzling structure of the highest vertebrates.

Certain organs appear to have retained the same function throughout, such as the brain and heart, and we may only trace the lines of growing complexity from a simple tube to the intricate mechanism of such organs as found in man. But others show a still more remarkable history, involving a change of function, which in some instances may almost be regarded as loss of function (though it is daring to assume that an organ can be structurally existent after *all* function has disappeared). We may recall our teeth traced back to placoid scales, the thyroid and thymus to glandular organs of the atriozoan pharynx, the inner ear to one of a series of aquatic sense-organs, the middle ear to one of a series of visceral clefts and the jaws and the ear-ossicles to parts of a segmented series of visceral arches.

These and numerous other instances of the same kind teach us that a true knowledge of anatomy can only be obtained by a due appreciation of what we have been as well as what we are.

[TABLE.

## SUB-PHYLUM VERTEBRATA.

| Class I.<br>CYCLOSTOMATA.<br>*Type—Myxine.* | Class II.<br>PISCES.<br>*Types—Raia, Gadus.* | Class III.<br>AMPHIBIA.<br>*Type—Rana.* | Class IV.<br>REPTILIA.<br>*Type—Lacerta.* | Class V.<br>AVES.<br>*Type—Columba.* | Class VI.<br>MAMMALIA.<br>*Type—Lepus.* |
|---|---|---|---|---|---|
| 1. Naked glandular skin. | 1. Scales. | 1. Naked glandular skin. | 1. Epidermic scales and dermal scutes. | 1. Feathers. | 1. Hairs and skin glands (especially mammary glands). |
| 2. No limbs. | 2. Paired fins. | 2. Pentadactyle limbs. | 2. Pentadactyle limbs. | 2. Fore-limbs form wings. | 2. Pentadactyle limbs. |
| 3. Respiration by gills. | 3. Gills. | 3. Gills and lungs (skin). | 3. Lungs and air-sacs. | 3. Lungs and air-sacs. | 3. Lungs. Breathe by ribs and a diaphragm. |
| 4. Lateral line sense-organs. | 4. Lateral line sense-organs. | 4. Lateral line sense-organs in young. | 4. No lateral line sense-organs. | 4. No lateral line sense-organs. | 4. No lateral line sense-organs. |
| 5. Median fin with fin-rays. | 5. Median fin with fin-rays. | 5. Median fin in young. | 5. No median fin. | 5. No median fin. | 5. No median fin. |
| 6. Unpaired nasal sac. | 6. Nasal sacs with no internal nares. | 6. Internal nares. | 6. Internal nares. | 6. Internal nares. | 6. Internal nares with bony palate. |
| 7. Two-chambered heart and several continuous arterial arches (6-7), anterior and posterior cardinal veins. | 7. Two-chambered heart with 4-5 arterial arches, anterior and posterior cardinal veins. | 7. Three-chambered heart with three separate arterial arches, a postcaval. | 7. Three-chambered heart with three separate arterial arches, a postcaval. | 7. Four-chambered heart with two complete arches, aortic only on right, a postcaval. | 7. Four-chambered heart with two complete arches, aortic only on left, a postcaval. |
| 8. Skeleton cartilaginous. | 8. Skeleton, cartilage and bone. | 8. Skeleton, bone and cartilage. | 8. Skeleton mainly bone. | 8. Skeleton mainly bone with air sinuses. | 8. Skeleton mainly bone with epiphyses. |
| 9. No true teeth. | 9. Teeth on jaws and pharynx. | 9. Teeth on jaws and palate. | 9. Teeth on jaws and palate, acrodont or pleurodont. | 9. No teeth. | 9. Teeth on premaxilla, heterodont and thecodont. |
| 10. No visceral arches, vertebræ, sympathetic nerves, pancreas nor spleen. | 10. Mandible of many pieces, suspended by quadrate, hyomandibular, or both. | 10. Mandible of many pieces, suspended by quadrate, hyomandibular forms, columella auris. | 10. Mandible of many pieces, suspended by quadrate, hyomandibular forms, columella auris. | 10. Mandible of many pieces, suspended by quadrate, hyomandibular forms, columella auris. | 10. Mandible of one piece, suspended by squamosal, three auditory ossicles. |
| 11. Ten cranial nerves and inconstant temperature. | 11. Ten cranial nerves and inconstant temperature. | 11. Ten cranial nerves and inconstant temperature. | 11. Twelve cranial nerves and inconstant temperature. | 11. Twelve cranial nerves and constant hot temperature. | 11. Twelve cranial nerves and constant warm temperature. |
| 12. Fertilisation external, no amnion nor allantois, no genital ducts, oviparous. | 12. Fertilisation mostly external, no amnion nor allantois, oviparous. | 12. Fertilisation external, no amnion nor allantois, oviparous. | 12. Fertilisation internal, amnion and respiratory allantois, oviparous. | 12. Fertilisation internal, amnion and respiratory allantois, oviparous. | 12. Fertilisation internal, amnion and nutritive allantois (placenta), viviparous. |

# CHAPTER XXV.

## CLASSES OF VERTEBRATA.

The *Vertebrata* are naturally divided into the aquatic or predominantly aquatic types called *Anamnia* and the typically air-breathing terrestrial forms called *Amniota*.

The names are derived from the absence and presence respectively of an enveloping fœtal membrane called the amnion.

In addition the *Anamnia* always possess, at one time in their life, fins, gills and lateral line sense-organs.

The *Anamnia* have three classes—

1. CYCLOSTOMATA.
2. PISCES.
3. AMPHIBIA.

The *Amniota* also have three classes—

4. REPTILIA.
5. AVES.
6. MAMMALIA.

### CLASS I.—CYCLOSTOMATA.

The *Cyclostomata* were at one time, like *Amphioxus*, included in the fishes, but the important differences from the latter necessitate a separate class. In many respects they are the most primitive of all the *Vertebrata*, whilst, as must of necessity be the case, they also exhibit a degree of specialisation.

In their external appearance they approach the fishes, especially the eels and other elongated types, but the entire absence of limbs is remarkable. There is no evidence that *Cyclostomata* ever possessed these organs. Again, they resemble fishes in the presence of lateral sense-organs, a median fin with fin-rays, and in their method of respiration by gills situated upon gill-slits. There are no jaws nor other free visceral arches, the deficiency being supplemented by a suctorial mouth and by a branchial basket-work. There is no vertebral column, and at most an incomplete cartilaginous cranium. In accordance with this the notochord and its thickened sheath form the skeletal axis throughout life.

The olfactory sac is single and does not open directly to the exterior, but into a long *pituitary sac* formed of the enlarged *hypophysis*. The hypophysis usually opens into the stomodæum from which it originates, but in the course of development (in the lamprey) a large upper lip is formed behind the opening of the hypophysis, and pushed out to such an extent as to carry the base of the hypophysis on to the dorsal surface of the head. As we have seen the hypophysis acquires an internal opening into the pharynx in *Myxine* but not in the Lampreys. The olfactory capsule is free from the cranium.

The auditory organ never has three semi-circular canals. The brain shows a very small cerebellum and is of small proportionate size. The optic nerves do not cross, and there is no sympathetic nervous system nor spleen.

In some forms the pronephros persists throughout life, the tubules opening into the pericardium. There are no genital ducts, the sexual elements leaving the cœlom by pores.

## ORDER I.—*Petromyzontes.*

The Lampreys are active free-swimming forms with predatory habits. They have dorsal fins, well-developed eyes, and have two semi-circular canals to the ear. The pituitary sac is blind. The skeleton is a slight advance upon that of *Myxine* as there are paired lateral nodules of cartilage representing vertebræ. There is also a complete branchial skeleton, but no buccal cirri nor cartilages.

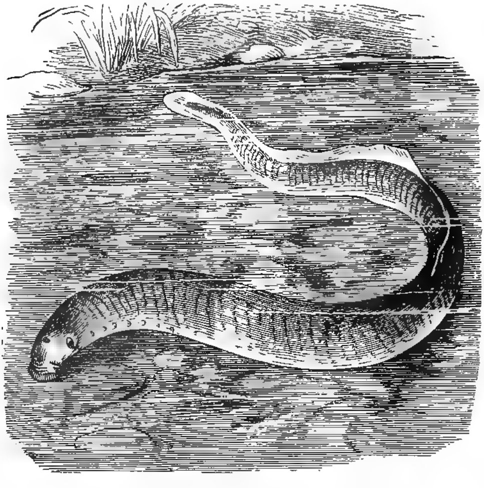
The seven gill-pouches open separately to the exterior laterally, and internally they all open into a respiratory tube which communicates anteriorly with the œsophagus. The intestine contains a spiral valve. The sexes are distinct.

The Lampreys are widely distributed in the sea and in fresh water. They develop by an early embryonic stage and later larvæ. The larva is known as *Ammocœtes*. It differs from the adult in several important particulars, *e.g.*, the eyes are rudimentary, and the gill-pouches open directly into the œsophagus.

### ORDER II.—*Myxinoidei.*

The Hag-fish (*Myxine*) has been described. The other genus is the large *Bdellostoma* which has separate external branchial openings. Both are marine.

Fig. 309.—THE RIVER-LAMPREY (*Petromyzon fluviatilis*) × ⅔.



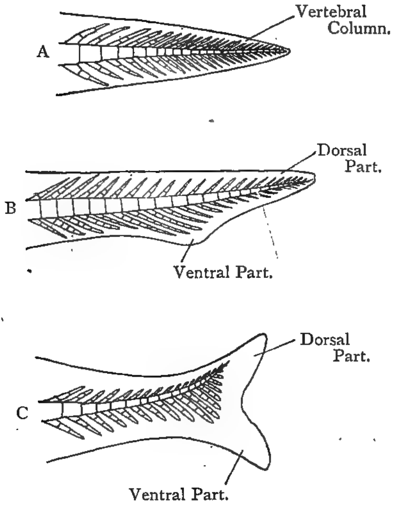
Note the single median fin and tail, the sucker and the ventro-lateral row of branchial openings behind the head.

A small fossil from the Devonian (*Palæospondylus*) has some claims to be regarded as a fossil Cyclostome.

### CLASS II.—PISCES.

The fishes are much more heterogenous in structure than the last class. They have paired fins and median fins supported on fin-rays. The median fin may be perfectly continuous, with dorsal, ventral and caudal portions, as in the sand-eel, or it may be broken up into numerous dorsal fins, a caudal and numerous anal fins. The caudal fin may be one of three kinds. The simplest, found in larval fishes, is the *protocercal*. In this the "tail" or prolongation of the body lies symmetrically in the centre of a symmetrical fin. In the *heterocercal* caudal fin an anal fin is added ventrally, so that the whole caudal fin thus formed is asymmetric with a large dorsal portion into which the "tail" is continued. This is found in most sharks. The *homocercal* caudal fin is itself symmetrical, the ventral portion being of the same size as the dorsal, but the "tail" is bent up into the dorsal half, showing that this type has a secondarily acquired symmetry through the heterocercal stage. Most *Teleostomi* have this type of tail.

Fig. 310.—TAILS OF FISHES.

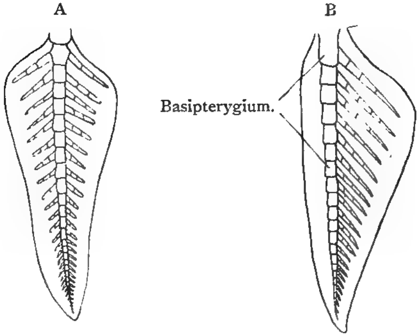


A, Protocercal. B, Heterocercal. C, Homocercal.

The paired fins show similar modifications. The *archipterygium* is found in the *Dipnoi* and consists of a median axis with symmetrical lateral rays (*cf.* the protocercal tail). The *ichthyopterygium* consists of one or more basal parts bearing secondary rays only on the outer border. In the pectoral fin there are commonly three primary basal pieces (*cf.* skate) and in the pelvic only one.

Fishes are usually covered or protected with *scales*, of which there are usually distinguished four kinds. The *placoid* scale has a bony base and bears a spine, usually found in *Elasmobranchii*; the *cycloid* is a flat circular plate arising in the dermis: with its ally, the *ctenoid*, which has a toothed edge, it is found chiefly in the *Teleostei*. Lastly, the *ganoid* scale is a hard rhomboidal plate closely apposed to its neighbours and occurring in the certain archaic fishes of the Teleostomi.

Fig. 311.—Fins of Fishes.



A, Archipterygium. B, Uniserial type of ichthypterygium, pelvic fin of Skate.

All fishes have gills borne upon four or more gill-slits. The slits may be widely apart and opening separately, as in *Elasmobranchii*, or they may be close together and covered by a flap or operculum, as in the other orders.

There is an extensive system of lateral line sense organs innervated chiefly by the Vth, VIIth, and Xth cranial nerves. All fishes have a well-developed vertebral column and visceral arches; the first arch is always modified into upper and lower jaws. As in *Amphioxus* and the *Cyclostomata*, the greater portions of the body and the longitudinal muscles form the organs of locomotion. In the great majority of fishes the heart is two-chambered and respiratory, and the posterior venous system consists of paired cardinal veins or sinuses.

Development is mainly embryonic, the egg containing much yolk, but a free larval form is found in many.

## ORDER I.—*Teleostomi*.

The *Teleostomi* are called the "bony fishes" because their skeleton is almost entirely formed of bone. Hence a cod's skull is a very different structure from that of a skate, for it consists of a great number of bones which, to a large extent, fall apart when the connective tissue is destroyed by boiling.

The *Teleostomi* usually have cycloid, ganoid or ctenoid scales, but some have none. The tail is nearly always homocercal. The genital organs communicate with the exterior by genital ducts in both sexes, and the genital and anal apertures are separate, hence there is no cloaca. The gills are enveloped in a bony operculum. In connection with the œsophagus many have a large air-bladder lying under the vertebral column. In the brain the cerebrum is very small; the optic lobes and the cerebellum are large. The kidneys are purely mesonephric. Development is embryonic in its earlier stages, but the young are hatched as larvæ with a large dependent yolk-sac. The eggs in many marine types are pelagic, but in the freshwater forms and some marine they are demersal or deposited on the bottom: they are small and numerous.

The *Teleostomi* show a peculiar combination of structural characters, some, such as the ossification of the skeleton and the absence of a cloaca, placing them above the *Elasmobranchii*, whilst the condition of the urinary organs and the brain are at a decidedly lower level.

They are world-wide in distribution, and are freshwater, pelagic, littoral, katantic and abysmal in habitat.

They are divided into two unequal divisions — the *Crossopterygii*, mainly extinct but including *Polypterus* of the Nile, and the *Actinopterygii* which embrace the remainder. These are in their turn divided into three sub-orders :—

1. The *Chondrostei* are mainly extinct types, together with the sturgeon of sub-arctic regions and one or two species found in North America. Their skeleton is cartilaginous.

2. The *Holostei* include the bony pike *(Lepidosteus)* of North America and several extinct forms. The skeleton is osseous and there is a spiral valve in the intestine.

3. The *Teleostei* * constitute an immense number of well-known fishes. Their skeleton is osseous, they usually have horny (cycloid or ctenoid) scales, they have no conus arteriosus to the heart and no spiral valve in the intestine. Their principal groups are as follows :—

1. *Physostomi* (air-bladder communicating with the œsophagus), most freshwater fishes and common marine forms, such as herring, sprat, eels.

2. *Anacanthini* (air-bladder closed, the fins are soft), comprising cod, haddock and the flat-fish. (In the flat-fish the air-bladder is absent.)

3. *Acanthopteri* (fin-rays are spiny, air-bladder closed), including perch, mackerel, gurnard.

4. *Plectognathi* and 5. *Lophobranchii*, two small groups with very specialised members. The *Plectognathi* usually have a hard bony exoskeleton and few powerful teeth with certain bones of the jaw fused. The *Lophobranchii* have tufted gills and may assume peculiar shape and habits ; they include the pipe-fishes and the sea-horses.

## ORDER II.—*Elasmobranchii.*

This order includes the Sharks and Skates. Their tail is heterocercal, the scales are placoid. The gill-slits are

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* The archaic freshwater types like the sturgeon, bony-pike, and *Polypterus* all the extant *Teleostomi*, except *Teleostei*) used to be combined in an order called *Ganoidei*, but their genetic relationships to the *Teleostei* are now recognised.

separate and widely apart with no operculum. The skeleton is cartilaginous and the palatoquadrate is free from the cranium. There is a spiral valve to the intestine. A cloaca is present and the kidney is mainly a metanephros. Development is purely embryonic, the egg has much yolk and the young is not hatched till like the adult.

The *Elasmobranchii* are marine. The sharks are mostly pelagic and the skates and rays mainly littoral or katantic.

### ORDER III.—*Holocephali.*

A small order formed to contain *Chimæra* (the King of the Herrings) and its allies. They resemble the last order in their cartilaginous skeleton and some other structural features, but differ in having an operculum covering the gill-slits, a protocercal tail and no cloaca. The palatoquadrate (upper jaw) is completely fused to the cranium.

The few genera are widely scattered, one being a deep-sea type.

### ORDER IV.—*Dipnoi.*

The *Dipnoi* or mud-fishes differ from the other orders of fishes in the possession of true lungs in addition to their gills, and in the partial division of the auricle into two, thus producing a three-chambered heart; the nasal sacs have internal nares. The paired fins are archipterygia, *i.e.*, a central axis with rays on each side; the caudal fin is protocercal. There is a spiral valve and a cloaca and the skeleton is partly cartilaginous and partly bony.

Like the more primitive of the *Teleostomi*, the *Dipnoi* are freshwater forms and have a discontinuous distribution. *Ceratodus* is found in Australia, *Protopterus* in the Nile and *Lepidosiren* in the Amazon.

## CLASS III.—AMPHIBIA.

The *Amphibia* form a transition class from the two preceding to the three following terrestrial classes. The frog is about the most terrestrial of all the class. Gills, median fins and lateral line sense-organs are found throughout life in some, only in the larval stages in others. The paired limbs are pentadactyle. Lungs are present in the adult, and the nasal sacs have internal nares through which air is supplied to the lungs. The heart is three-chambered and there is a postcaval vein replacing the cardinals. The skeleton is partly cartilaginous. There is always a cloaca. The eggs are fertilised externally and there is usually a metamorphosis.

The order *Anura* includes the frogs and toads, with no tail and with no gills in the adult. The *Urodela*, such as the newts and salamanders, retain their tail and aquatic habits throughout life; whilst others, such as *Proteus* (a blind form found in the subterranean caves of Austria), retain also their gills. Hence the gilled *Urodela*, the *Urodela* which lose their gills and the *Anura* form a complete series illustrating the changes from an aquatic to a terrestrial life.

There is also a small third order of *Gymnophiona* with no limbs.

## Class IV.—Reptilia.

The *Reptilia* are a class of animals very definitely marked off by structural features at the present day, but the fossil forms show a gradation into *Amphibia* and *Mammalia;* and some of these even exhibit characters approximating to those of birds. During the secondary epoch, especially in the Trias, the reptilian was the dominant vertebrate type, and, as such, exhibited as wide adaptive modification as do the dominant mammals of the present day. Large reptiles ruled the sea, the land and the air, and some attained an enormous size. Since then the *Reptilia* have declined in numbers and in size, and only five comparatively small orders remain.

These all differ from the *Amphibia* in never at any time in their life possessing gills, fins, or lateral sense-organs, in having an embryonic development involving internal fertilisation and usually an oviparous habit. The embryo is enveloped in a fœtal membrane called the *amnion*, and has also a large excretory and respiratory organ, the *allantois*. (These fœtal membranes, as well as the yolk-sac already noticed in the skate, have been more fully described in the chick, p. 380.)

Again, the reptiles have twelve cranial nerves, the spinal accessory and hypoglossal being added to the ten of *Amphibia.* and the skeleton is much more completely ossified than is the case in the latter. The body is usually protected in an exoskeleton of scales or scutes, which is either purely epidermic and cuticular in nature, or is dermal and formed of bony tissue

In the skeleton the reptiles have the typical pentadactyle limbs and the ankle-joint is intertarsal. The shoulder-girdle usually has clavicles and episternum as well as the three primary bones—the precoracoid, coracoid and scapula. In the pelvic-girdle the ilium usually fuses with two sacral vertebræ and there are usually epipubic bones. There are often a number of membrane-bones called *abdominal ribs.* In the skull the quadrate suspends the lower jaw which is composed of several bones; the teeth are polyphyodont and homodont and are attached to the surface of the bone (acrodont) or at the side (pleurodont), and they may occur on the palatines, pterygoids and vomers, as well as the premaxillæ, maxillæ and dentary. The skull has a single occipital condyle, formed largely by the basioccipital but partly by the exoccipitals, and the facial portion of the skull is much larger and broader than the cranial. There is often a peculiar *transverse bone* connecting the maxilla and the pterygoid. There is only one ear-ossicle, the *columella auris.*

Most of the reptiles resemble the amphibians in the three-chambered heart, the three complete aortic arches and the condition of the circulatory system.

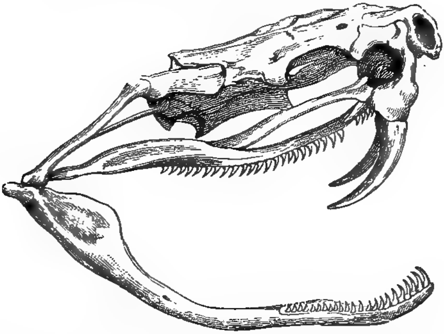
## ORDER I.—*Rhynchocephalia.*

*Sphenodon* (or the New Zealand Lizard) is a lizard-like animal, found in New Zealand, possessing a series of primitive structural peculiarities which lead zoologists to place it in an order by itself. The principal of these are the amphicœlous vertebræ, the presence of intercentral elements between the vertebræ and of teeth on the palatines and vomers (young).

## ORDER II.—*Lacertilia.*

The lizards have an exoskeleton of horny epidermic scales which are periodically shed. Most have two pairs of walking limbs and a long tail. The teeth are either fused to the upper surface of the jaw (acrodont), or to the lateral surface (pleurodont). The lizards are distinguished from their nearest allies, the snakes, by the almost universal presence of four limbs, by the bones of the skull being immovable, and the mandibular rami being fused together. They also have eyelids. Lizards are widely distributed, but found in most profusion in equatorial regions. The common slow-worm (with no limbs) and the sand lizard are British examples.

Fig. 312.—LATERAL VIEW OF SKULL OF RATTLESNAKE (*Crotalus*).



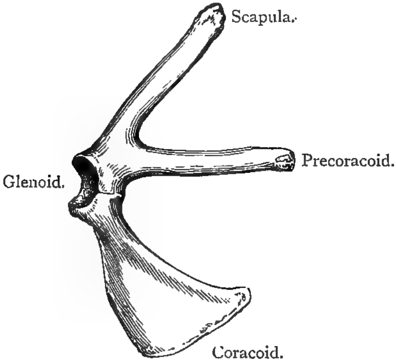
Note the freely movable quadrate with pterygoid continued into small palatine in front and joined to the maxilla by a long transverse bone. Maxilla bears the fang.

### ORDER III.—*Ophidia.*

The snakes have an exoskeleton of epidermic scales. They have no limbs, but progress by a movement of ventral scales, to the inner surface of which the distal ends of the numerous ribs are attached. Hence there is no sternum. The vertebræ usually have extra articular facets (zygosphene and zygantrium). The eyes have no eyelids. But in addition a unique method of locomotion, the snakes exhibit a peculiar method of feeding. The quadrate is loosely hinged on the skull, and the maxillæ, palatines and pterygoids are all freely movable. In addition, the mandibular rami are loosely united by ligament. Hence the snakes have an enormous "gape," and can "swallow" entire animals which exceed their own diameter. All *Ophidia* are carnivorous.

The non-poisonous groups usually have two rows of long recurved teeth on the maxillæ and the palatines and pterygoids respectively. Between these rows fits the row of teeth on the mandible. In the poisonous group the maxilla is freely hinged, and bears a single large fang or grooved tooth connected with the poison-gland, a modified salivary gland. There are also a few teeth on the pterygoids, palatines and mandibles. On closing its jaw, the snake's maxilla with its fang is swung up into the roof of the mouth by the automatic movement of the quadrate, pterygoid, transverse bone and maxilla.

Fig. 313.—Right Shoulder Girdle of a Tortoise.

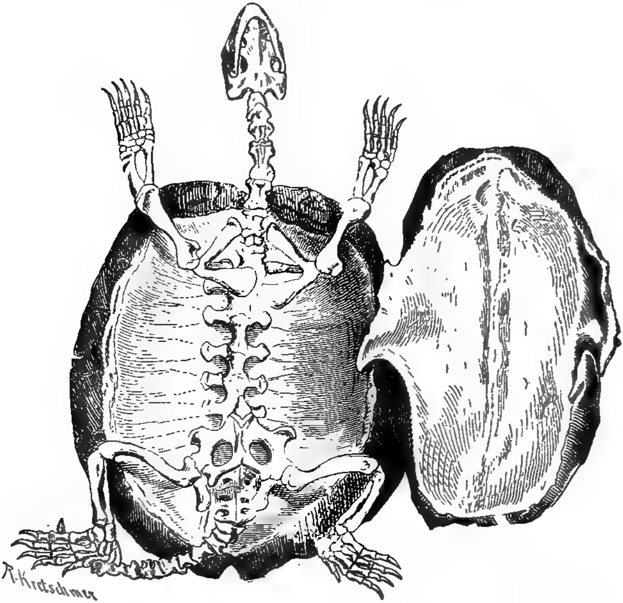


The snakes may therefore be said to exhibit extreme specialisation for a unique method of locomotion, involving loss of limbs and limb-girdles, and for an equally remarkable method of feeding.

## Order IV.—*Chelonia.*

The *Chelonia* comprise the tortoises and turtles. They have an exoskeleton of horny epidermic plates, to which is added an underlying dermal layer of bony scutes. The whole body is enveloped in this hard protective case, which is formed of a dorsal *carapace* and a ventral *plastron*, joined together laterally. The carapace usually has a median row of neural plates resting over the neural region, a lateral row of *costal* plates modified from the ribs, and a distal row of *marginal* plates. The plastron seems to be made up of a pair of *clavicles* and an *episternum* anteriorly and a number of *abdominal ribs* posteriorly. The "case" of the *Chelonia* is evidently to a large extent composed of a number of pre-existing structures. Inside the case the vertebræ, as might be supposed, are vestigial, with the exception of the cervicals and caudals. All four limbs are present and

Fig. 314.—Skeleton of a Tortoise.

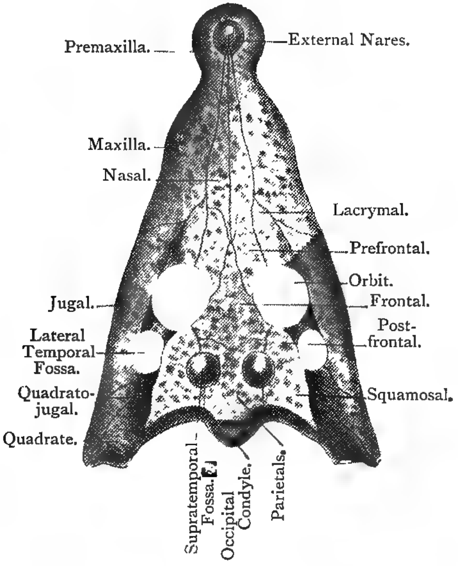


The plastron has been cut away on the right side of the body and thrown over to the animal's left. Note the carapace and plastron, flexible cervical and caudal, but ankylosed dorsal, vertebræ.

protrude from between the carapace and plastron. The skull shows the bones all immovably fixed. There are no teeth, their functions being performed by sharp horny ridges. All *Chelonia* are herbivorous.

The tortoises are terrestrial and have a convex carapace. The turtles are aquatic and the carapace is more flat, often comparatively soft or leathery in texture. Many turtles are truly pelagic.

Fig. 315.—Dorsal View of a Crocodile's Skull × 1/6. (*Ad nat.*)



Note the pitted bones, the wide "gape" from the two quadrates, and the pre- and post-frontal bones.

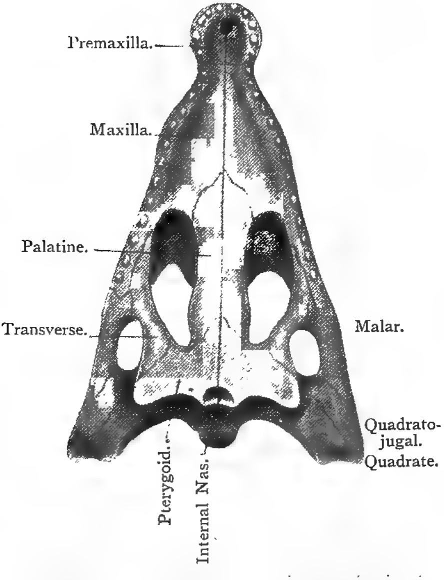
## Order V.—*Crocodilia.*

The crocodiles are in many respects the most highly organised of reptiles. They have an exoskeleton of bony scutes covered by epidermic scales. Both limbs are present and the skull-bones are immovable.

The crocodiles resemble the *Mammalia* in the following characters :—

1. The teeth are thecodont (in sockets) and confined to maxilla, premaxilla and dentary.
2. The maxilla and palatine form a bony palate.
3. The heart is four-chambered, a septum dividing the ventricle into two.
4. There is an incomplete diaphragm.

Fig. 316.—VENTRAL VIEW OF CROCODILE'S SKULL × $\frac{1}{8}$. (*Ad nat.*)



Note the thecodont teeth in single row on premaxilla and maxilla, the backward position of the internal nas, the transverse bone, single occipital condyle and quadrate-suspensorium.

True crocodiles are found in the rivers of tropical Africa and in central America. The *alligators* are found in the Southern States, West Indies and South America. The *gavials* are small *Crocodilia* found in the Ganges and its tributaries.

Among the enormous number of extinct *Reptilia* we may here merely notice a few.

The *Pterodactyles* (order *Pterosauria*) were winged reptiles, with the wing formed of a membrane stretched from the enormously elongated fifth digit. They had a skull somewhat like that of a bird, but with teeth.

The *Ichthyosauria* were large fish-lizards with long tail and the limbs modified into flippers. The skull had a rostrum like that of the porpoise. *Ichthyosaurus* is a common example.

The *Dinosauria* were large terrestrial reptiles, some of which show structural features resembling birds. *Iguanodon* is perhaps the best known.

Lastly, the *Theromorpha* appear to be reptiles showing remarkable resemblances to mammals, especially in the heterodont dentition; some of this group also point to relationships with fossil *Amphibia*.

## CLASS V.—AVES.

Birds are closely allied to the reptiles in their structure, but they are so completely adapted for an ærial habit that there is no difficulty in at once distinguishing them. They resemble the reptiles, especially in their skeletal structure, the similar bones of the skull, the suspension of the mandible by the quadrate, the many elements of the mandible, the single ear-bone or columella and the absence of epiphyses. In addition, they have the same oviparous habit, with meroblastic segmentation, and the same fœtal membranes. These and other similarities are sometimes emphasised by the grouping of the two classes together under the head of *Sauropsida*.

On the other hand, the birds show the following adaptations to an ærial habit. The fore-limbs are not used for terrestrial locomotion, as in reptiles, but are formed into wings, the method of formation involving the entire loss of the two postaxial digits and a great reduction of the preaxial. Probably at first each digit had its separate tuft of flight feathers or *alula*, but in all modern birds the alula of the first digit alone remains, those of the second and third combining with the flight-feathers of the ulna to form

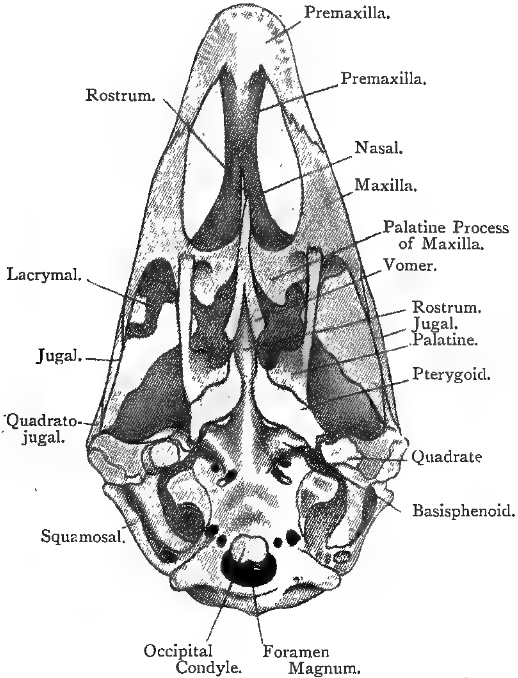
Fig. 317.—ARCHÆOPTERYX × ½.
(From cast of Berlin Specimen in the Edinburgh Museum of Science and Art.)

Note the teeth, the free metacarpals, the three clawed digits, the abdominal ribs and the elongated tail.

## ORDER I.—*Ratitæ.*

These are nearly all large birds which all show a degeneration of the wings, in some cases to mere vestiges, in correlation to which the carina of the sternum is lost, giving it a rounded appearance. The hind-limbs are always large and powerful. These birds exhibit certain structural features which may be regarded as of a primitive nature. The feathers have no hooked barbules, and, as a rule, they are evenly scattered over the surface of the body. The bones of the skull are mostly still separated by sutures, and the

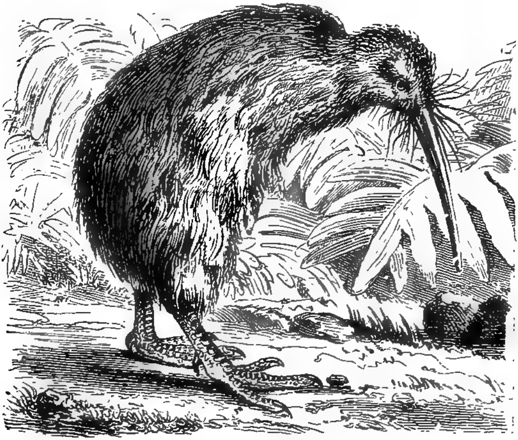
Fig. 318.—VENTRAL SURFACE OF THE SKULL OF AN OSTRICH × ½. (*Ad nat.*)



Note the absence of teeth, single occipital condyle and quadrate-suspensorium.

quadrate has only a single articulation with the skull. The *Ratitæ* illustrate discontinuous distribution. The ostrich (*Struthio*) is found in Africa and South-Western Asia. It has only two toes—a large fourth and a small fifth. The American ostrich (*Rhea*) has three toes and is found in South America. The Cassowary (*Casuarius*) and Emu (*Dromæus*) are found in the Australian region and the small Kiwi (*Apteryx*) in New Zealand. On this latter island are also found the remains of the recently extinct Moas (*Dinornis*), huge wingless birds. Others have been found in Madagascar.

Fig. 319.—THE KIWI (*Apteryx*) × 1/5.



A "wingless" bird of New Zealand. The wings are vestigial and hidden below the feathers.

## ORDER II.—*Carinatæ.*

The *Carinatæ* comprise the remainder of modern birds. Considering the enormous number of species and wide distribution, they present remarkably few structural differences which are available for classification. In one or two fossils, such as the Cretaceous *Hesperornis* and *Ichthyornis*, teeth still survive.

They are classified by reference to the arrangement of the feathers, the structure of the skull and of the alimentary organs.

# CHAPTER XXVI.

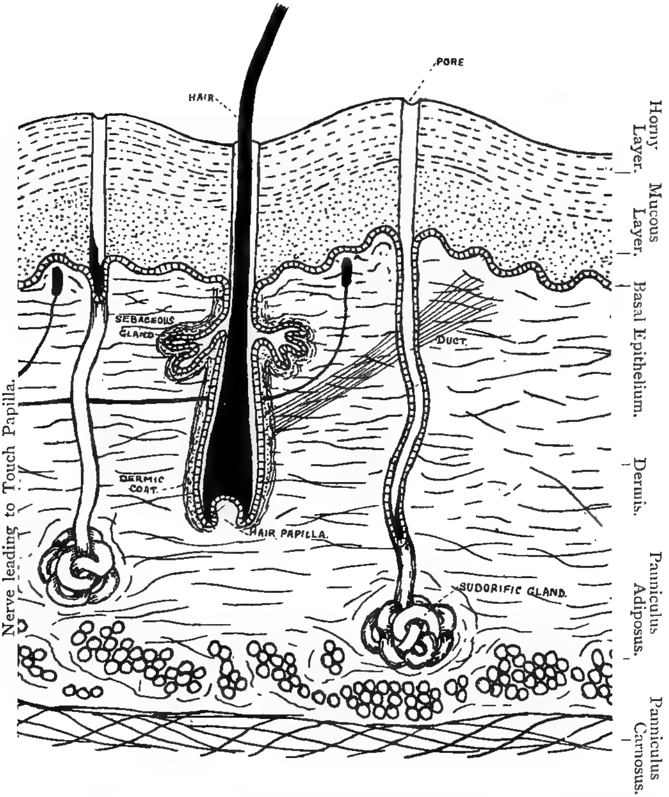
## GENERAL FEATURES OF MAMMALIA.

### CLASS VI.—MAMMALIA.

The **Mammalia** are the last class of the *Vertebrata*, and as they indubitably stand at the head of the animal kingdom, both structurally and intellectually, they will be specially treated here. Special emphasis is laid upon the skeleton, because the skeleton of a vertebrate is always a permanent embodiment of the part played by its former possessor in the arena of life.

SKIN.—The skin of mammals conforms to that of vertebrates in general, hence two layers of the epidermis can be distinguished—the outer horny layer or *stratum corneum* and the inner mucous layer or *stratum mucosum*. The base of the mucous layer which rests upon the dermis consists of a single layer of epithelial cells, the basal epithelium, which by tangential divisions (parallel to the surface) are perpetually giving rise to more cells in layers above them. The lower of these cells are still living and protoplasmic, but those nearer the surface have undergone a cornification, by which the protoplasm is replaced by horn or *ceratin*. The cells thus cornified are no longer living, but are continually being shed in detail upon the surface. Thus the whole surface of the mammal is enveloped in a thin, flexible layer of *ceratin*, the corneous layer, produced by the underlying mucous layer of living protoplasmic cells. The dermis, as in other vertebrates, consists of a dense mass of connective tissue, blood-vessels, nerves, muscles, fat and skin-glands. With the first three we are not here concerned, but one of the essential features of the class *Mammalia* is the development of the three latter. The muscle is present beneath the skin, connecting it tightly with the body below, as a thin sheet known as the *panniculus* *carnosus*, whilst the fat is concentrated as a layer at the base of the dermis, called the *panniculus adiposus*. This layer is enormously developed in most aquatic mammals

Fig. 320.—Section Through the Skin of a Mammal.



(whales and seals). The skin-glands really belong by origin to the *stratum mucosum* of the epidermis and arise from it in the embryo; but as development proceeds they protrude downwards into the dermis and become much coiled in order to increase the secretory surface. Their connection with the epidermis is, however, retained by the ducts which pass outwards, their cavities opening freely to the exterior on the surface of the skin. The great development of skin-glands is a marked feature of the *Mammalia.*

We may distinguish two different kinds—(1) the *sudorific* or *sweat-glands* and (2) the *sebaceous glands.*

1. The sudorific glands are developed by local ingrowth of the basal epithelium of the mucous layer. They lie deep in the dermis and excrete water, with inorganic salts in solution (sweat), discharged freely on to the surface of the skin. The sudorific glands are of the tubular type, coiled and unbranched.

2. The sebaceous glands are also produced from the basal epithelium of the mucous layer, but are only developed in connection with hair-pits or follicles. Sebaceous glands are usually of the acinous or branching type, and they secrete *sebacin*, a fatty substance, the primary function of which is to lubricate the hair. They also differ from the sudorific glands in being *necrobiotic*, *i.e.*, the sebacin is produced from dead cells.

HAIR.—A hair is a structure found only in the *Mammalia* and it can only very doubtfully be compared with feathers or epidermic scales. It is essentially epidermic and its first trace in development is a small process or hair-germ formed from the mucous layer. This protrudes inwards into the dermis and elongates rapidly. Its base then becomes pushed into a pit within which the dermis protrudes, and at the apex of this pit the basal epithelium gives rise by rapid growth to a central axis of cells. The basal pit becomes the *dermal papilla* and the medullary axis gives rise later to the *medulla* of the hair. Around the medulla, between it and the basal epithelium, a thin layer or cylinder of the mucous layer becomes cornified, produced above the end of the medulla up to the surface of the corneous layer. Later on this cylinder divides into two so that a cylindrical cavity is produced. This cavity becomes continuous with the exterior and terminates above the papilla. It differentiates the whole follicle into a hair in the centre and the *root-sheaths* around it. The basal epithelium, next the dermis, *carnosus*, whilst the fat is concentrated as a layer at the base of the dermis, called the *panniculus adiposus*. This layer is enormously developed in most aquatic mammals (whales and seals). The skin-glands really belong by origin to the *stratum mucosum* of the epidermis and arise from it in the embryo; but as development proceeds they protrude downwards into the dermis and become much coiled in

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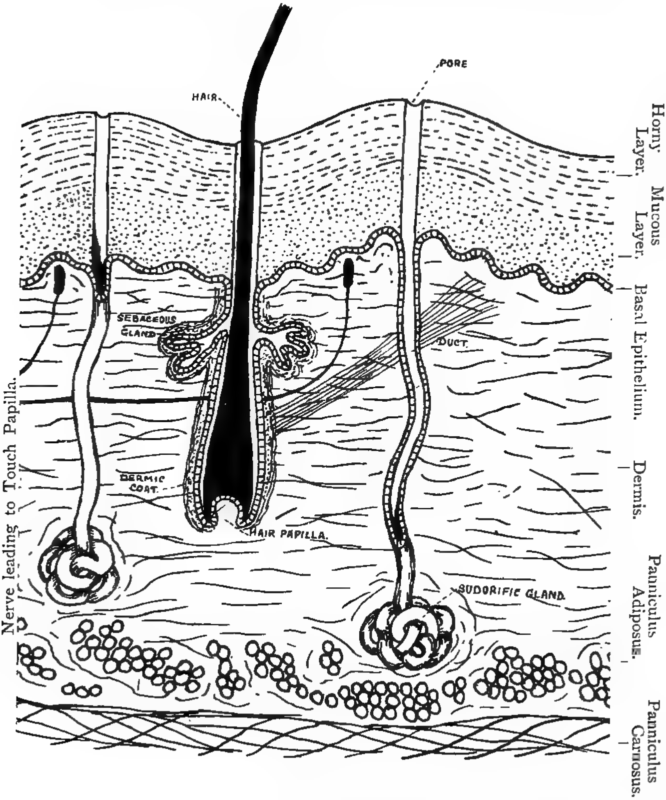

order to increase the secretory surface. Their connection with the epidermis is, however, retained by the ducts which pass outwards, their cavities opening freely to the exterior on the surface of the skin. The great development of skin-glands is a marked feature of the *Mammalia.*

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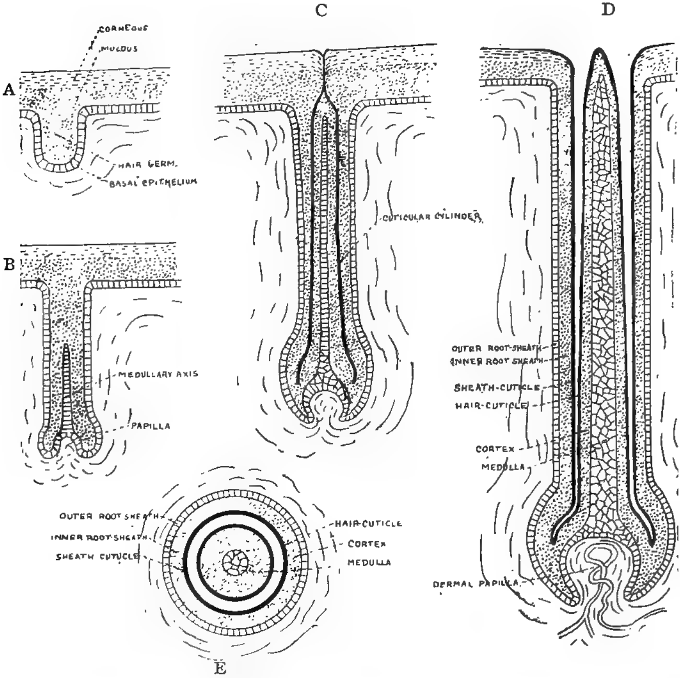
Fig. 321.—Diagrammatic Sections Illustrating the Development of a Hair.



A, The hair-germ. B, Formation of papilla and axis. C, Formation of cuticular cylinder. D, Splitting of cuticular cylinder and formation of hair. E, Transverse section of D.

have air-vacuoles amongst them, giving rise in many cases to white hair.

The dermis surrounding the hair-germ is gradually differentiated into a follicle. Its base protrudes into the hair-papilla, forming the dermal papilla with blood-vessels, and the rest forms a more or less distinct dermic coat outside the root-sheaths. It may have an inner circular layer of connective tissue and an outer longitudinal. Lastly, muscles called the *arrectores pili* are attached to the coat and serve to erect the hair.

Hairs differ very much in structure and texture and in some aquatic mammals they are almost entirely absent.

Other epidermic structures of the same nature, *i.e.*, localised cornifications of the epidermis, are nails, claws, spines or bristles, horns, and even scales, as in the pangolins; horny teeth occur in the duckmole and the *Sirenia.*

Hairs form a very efficient and light covering for the body and are a protection mainly from climatic conditions. Indirectly, however, they constitute an important protection from foes, as they are nearly always of a colour in harmony with surroundings. Thus it is asserted that because of their stripes the tiger and zebra in natural surroundings are difficult to discern, whilst the spots of the axis deer are said to exactly simulate the lights and shades formed by the sun shining through leaves. The white colour of arctic animals is another example, and a still more remarkable instance is that of seasonal coloration, found in temperate regions. In many of the fur animals, such as the polecat, weasel and ermine, the hair is of a brownish or black shade, except in winter, when it becomes a pure white. In many marsupials (*Metatheria*) the stripes are confined to the hind-quarters, as these parts are most exposed when the animals are curled up asleep, and from this direction an enemy can easily approach unseen.

MAMMARY GLANDS.—The mammary glands are of universal occurrence throughout the *Mammalia.* They are skin-glands, usually situated on the ventral or lower surface of the animal, and their secretion (milk) is used for the nourishment of the young. Whilst thus physiologically distinct, they do not appear morphologically to be organs *sui generis.* In the *Monotremata* the mammary glands are modified from sudorific or sweat-glands, so that the "milk" in these forms is sweat and is said not to differ essentially in composition from this excretory product: in *Metatheria* the mammary glands are said to be a mixture of sudorific and sebaceous glands; whilst in the higher mammals (*Eutheria*) they consist purely of sebaceous glands and the milk becomes a highly nutritive product. The mammæ or teats form a like series, as there are none in the *Monotremata*, temporary teats only in the *Metatheria* and permanent ones in the *Eutheria*.

The evolution of mammary glands probably commenced before that of the viviparous habit. We can see how the ventral surface of the parent lent itself first for the incubation of the eggs and later for the tending of the young. The desire of the young for fluid would naturally be satisfied by the local glands, and if we may suppose that the duties of incubation and nurture were shared by both sexes, we can to some extent understand how the males of many mammals still have mammæ and functionless mammary glands. After the viviparous habit was developed the male, divested of his share in the incubation, would gradually give up the mammary function as well.

The mammæ in modern mammals vary much in position, though all situated upon the ventral surface. They may be *pectoral*, *axillary*, *abdominal* or *inguinal* according to their position on the breast, under the armpit, along the abdomen and in the groin respectively.

TEETH.—The teeth are well developed in most mammals, though some types, such as whales, ant-eaters, *Monotremata* and others, appear to have lost them. The characters of mammalian teeth may be summed up in the expressions—*thecodont*, *heterodont*, *diphyodont*, to which we may add a limitation to a single row on the premaxillæ and maxillæ above and to the dentary below. In a *thecodont* dentition the teeth are held in definite sockets in the bone; a *heterodont* dentition is one in which the teeth differ markedly amongst themselves in size and shape; and, lastly, in a *diphyodont* dentition there are two sets of teeth succeeding one another in the life of the individual. [We may recall that the teeth of most reptiles are fused to the bone (*acrodont* or *pleurodont*), they are usually of the same size (*homodont*), there are several series of teeth (*polyphyodont*), and the teeth often occur upon the palatines, pterygoids or vomers in addition to the premaxillæ and maxilla. The crocodile, as in other anatomical features, approaches the mammal in having one row of thecodont teeth which are slightly heterodont.]

DEVELOPMENT OF A TOOTH.—A typical mammalian tooth arises from an *enamel-organ* consisting at first of a protrusion of the mucous layer of the epidermis downwards into the dermis. This becomes pushed in on the under side and the dermis thus protrudes into it as a small "dentine-germ." The mucous epithelium, bordering the dermis, commences to be modified by calcification into a hard dense enamel, whilst a layer of odontoblasts or cells of the dermis becomes active and gives rise on its outer side, near the enamel, to a bony *dentine* less dense than the enamel. In the centre the formation of dentine does not take place, so that a pulp-cavity remains. In the great majority of teeth this cavity becomes constricted and nearly closed and no further production of tooth-substance takes place; but in teeth which grow from persistent pulps, or continue to grow throughout life, the pulp-cavity remains widely open and the enamel-germ and odontoblasts continue to produce fresh enamel and dentine respectively.

To the teeth of many mammals is added a third substance called *cement*. This surrounds the dentine at the base of the tooth or lies between the enamel-crests on the upper surface of the tooth. It is produced by the dermis. As development proceeds the tooth forces its way to the surface and later its base becomes surrounded by bone, forming the socket.

In most flesh-eating animals the enamel remains intact throughout life, but in vegetable-eaters the crown of the tooth, especially in the case of the molars, becomes worn away, and as the cement and dentine wear more rapidly than the enamel, the latter forms ridges which assist in mastication. We may note in this typical development of a tooth that it is a joint production of epidermis and dermis. The development is in essential features similar to that of a placoid scale (Elasmobranch fishes) and it is usual to regard the two structures as homologous.

In the great majority of mammals the teeth are heterodont, *i.e.*, differ markedly in shape and size in the different parts of the jaws. It is found impossible to directly compare the teeth of the same shape throughout the class as this would be a very unnatural grouping and would lead to confusion. For the determination of dental homologies we have to resort to other means. In the upper jaw the teeth are borne upon premaxilla in front and maxilla behind. All the teeth borne upon the former are called *incisors*. This name is given to them because, as a rule, they are chisel-shaped. They may, however, be of a very different shape, and their homology depends not upon their shape but upon their position on the premaxilla. The tooth immediately behind the suture between premaxilla and maxilla is known as the *canine* tooth because it is typically developed in dogs. It is usually a long single-rooted fang, but is often absent or of a different shape. The remainder of the teeth on the maxilla are called *molars* because they are mostly for grinding or cutting food ; they are usually many-cusped and have several roots. Some of the molars are further distinguished from the rest as *premolars* (see next page).

In the lower jaw the teeth are all upon one bone, so that the only criterion for distinguishing the kinds of teeth is by their position relative to the upper teeth.

An incisor tooth is hence a tooth borne by the premaxilla or by the mandible exactly opposite it. A canine tooth is a tooth borne by the maxilla immediately contiguous to the suture between premaxilla and maxilla, or by the mandible immediately opposite to and biting immediately in front of it.

SUCCESSION OF TEETH —In the majority of mammals there is a modification of the *polyphyodont* arrangement of reptiles and the succession is reduced to two (*diphyodont*). The first series of teeth is known as the *lacteal* or *deciduous* series, which are sooner or later replaced by absorption of their roots and the pushing-up of the permanent series from below. The incisors and canines usually correspond in number in each series, but the deciduous molars are not so numerous as the permanent ones. Thus there results a distinction between the permanent molars, the front ones only being preceded by deciduous molars. The former are known as *premolars* and the latter as *molars proper*.

There are many exceptions to the diphyodont condition, and even in typical forms there is often a retardation in appearance of the hind-molars (*cf.* wisdom-teeth) which simulates the beginning or the vestige of another series.

A dental formula is often used as a symbol of the dentition of a mammal.

The evolution of a dental formula may be illustrated as follows :—

### DENTAL FORMULA OF MAN.

$$1.\ \textit{Incisors}\,\frac{2-2}{2-2},\ \textit{canines}\,\frac{1-1}{1-1},\ \textit{premolars}\,\frac{2-2}{2-2},\ \textit{molars}\,\frac{3-3}{3-3} = 32.$$

The four figures mean right and left half of upper and lower jaw.

$$2.\ i.\,\tfrac{2}{2},\ c.\,\tfrac{1}{1},\ pm.\,\tfrac{2}{2},\ m\ \tfrac{3}{3}.$$

Here the names are represented by initials, and it is recognised that in the greater proportion the right and left half are similar ; and, lastly, a knowledge of simple arithmetic is assumed and the total is omitted.

$$3.\ \frac{2123}{2123}.$$

As the teeth are always quoted from in front backwards, the initials are superfluous and a very short, compact symbol is the final product.

As already indicated, the structure of the teeth and that of the limbs form the two most diagnostic features, so that the importance of correctly interpreting the dentition of a mammal as far as possible at sight can hardly be over-estimated.

The incisor and canine teeth remain more or less simple throughout the majority of the *Mammalia*. In *Hyrax*, *Galeopithecus* and some rodents the incisors have their edges indented to form small cones, but these are exceptional. Again, the canines may resemble premolars in shape and may have more than one root (*Pliohyrax*, *Erinaceus*). The cheek-teeth or premolars and molars show infinite variety in shape and size according to the uses to which they are put.

The complex types are derived from the more simple by the formation of cusps or tubercles which may fuse to form ridges and crests.

We may notice a few of the more important changes :—

1. It is usually assumed that the earliest mammals had a homodont dentition like that of reptiles, each tooth being a simple cone. Those of the upper jaw fitted between those of the lower jaw, forming a "rat-trap" arrangement, very efficient for seizing prey, but of little use for purposes of mastication. This first type is called a *haplodont* dentition and is still found in the toothed whales (see Porpoise)..

2. The next differentiation is the origin of small secondary cones upon the sides of each tooth, typically one on each side of the primary cone, though the whole margin may be serrated. These secondary cones move upon those of the next tooth and considerably add to the "tearing" and rending capacity of the teeth. Typically there is one cone on each side of the primary one, hence this type is known as the *triconodont* dentition. In the upper jaw the primary cone is known as the *protocone*, the anterior secondary one as the *paracone* and the posterior as the *metacone*. Those of the lower jaw are known as *protoconid*, *paraconid* and *metaconid*.

3. In the next type the secondary cones move out of the same line as the main cone, those of the lower jaw moving inwards and those of the upper jaw outwards. The three cones or tubercles are now arranged in a triangle. The dental surface has no less than three interlocking rows of tubercles, the outer formed by the paracones and metacones, the middle by the protoconids, and the inner by the protocones with the paraconids and metaconids. This type is known as the *tritubercular* and is a very important one. It occurs in many modern mammals with little modification, such as certain *Insectivora* and *Carnivora*, and is also very general amongst the mesozoic metatherian mammals and modern *Polyprotodontia*.

From the tritubercular type onwards we may trace three series. In one there is specialisation for a true carnivorous type producing the *secodont* or cutting dentition. In this the cones become connected by ridges which retain a sharp edge, acting as cutting organs. (*Carnivora.*)

In the second the cones remain blunt and increase considerably in number. In later life their surfaces are ground away and there may further be important fusions forming blunt ridges. This is the *bunodont* series, found in herbivorous and omnivorous mammals.

In the third the general tubercular character is retained though other cones may be added. This is probably to be traced to the retention of a similar mode of nutrition and the examples are naturally to be found in the *Insectivora*. In both jaws there arises posterior to the protocone (or protoconid) a fourth cone called the *hypocone* (or hypoconid). All four become regularly arranged, giving a quadruple row of trap-like tubercles. This type is called the *quadritubercular*, often complicated by further smaller tubercles forming a *multitubercular* arrangement. The quadritubercular condition is well seen in the hedgehog.

In both the other series a hypocone also arises and in the lower jaw it may be double.

Thus a quadritubercular condition is produced in the bunodont series by a similar development of a hypocone and hypoconid. The hypoconid is developed in such a position that it moves up into the depression in the primary triangle of the upper jaw, whereas the hypocone is, like the protocone, between the primary triangles of the lower jaw. The consequence is that, when a lateral motion is given to the lower jaw and transverse columns are formed by fusion across of the tubercles, the upper jaw has a normal fusion of protocone with paracone, and metacone with hypocone, but the lower jaw has a fusion of protoconid and metaconid to form the anterior transverse ridge, whilst the posterior is formed by the hypoconid and subsidiary cones, the paraconid disappearing altogether. Thus is produced the *bilophodont* type with two transverse ridges, those of the upper jaw alternating with those of the lower. This important type is found in kangaroos and in tapirs and forms the starting point of the perissodactyle series. Further differentiation of the grinding molars is in the direction of complex foldings which tend to increase the number and extent of enamel-ridges. (See Horse and Ox.)

**Summary.**—In the cheek-teeth of mammalia we can distinguish the following series :—

1. Haplodont—single series of simple conical teeth (*Odontoceti*).
2. Triconodont—single series of teeth with three cusps or cones (Triassic *Metatheria*).
3. Tritubercular—series with three cusps, usually with two in different position from the other, the whole forming a triple series (Triassic *Metatheria*).
4. Quadri- and multitubercular—series with four or more cusps forming four or more series and retaining typical (insectivorous) characters (*Insectivora*).
5. Secodont series, with cusps united by sharp ridges and often increased in number—carnivorous (*Carnivora*).
6. Bunodont series, with cusps separated and often increased in number, blunt and crushing—omnivorous or herbivorous. (*Suidæ, Ursidæ, Primates.*)
7. Bilophodont and other types, increase of tubercles, transverse and longitudinal ridges formed by fusion, complex folding and the crowns worn flat during life—herbivorous (*Ungulata*, *Rodentia*).

BRAIN AND NERVOUS SYSTEM.—The characters distinguishing the brain of mammals from that of the other *Vertebrata* are not so striking as one would perhaps be led to assume, considering that mammals largely owe their supremacy to development of the mental faculties. The brain develops in a typical vertebrate manner, and we may here merely note the following characteristics :—

1. The cerebral hemispheres are large and encroach backwards over the thalamencephalon and the optic lobes. In the higher types their surface becomes much convoluted and they cover the cerebellum.

2. The cerebral hemispheres are united across the middle line by the *corpus callosum.*

3. The optic lobes become divided to form four, the *corpora quadrigemina.*

4. One of the most striking characters of the mammalian brain is the great increase in proportionate size that has taken place in comparison with the brain of extinct forms. The brain of the Eocene mammals was far smaller in proportion to the total bulk than that of modern forms. This is probably due to the fact that since that epoch the race has not been so much to the strong as to the "cunning."

In the same way, if we compare the weight of a mammal's brain with the total weight of the body, we find that there are three important laws.

Firstly, in equally organised animals the relative weight of brain decreases with increase in size. Thus the smallest animals tend to have proportionately heavier brains. The relative brain-weight of a cat is given as $\frac{1}{106}$, whereas that of a tiger is $\frac{1}{546}$. On account of this law, we find that the relative brain-weight of man ($\frac{1}{45}$) is exceeded by that of the lesser shrew ($\frac{1}{23}$) and the whiskered bat ($\frac{1}{42}$).

Again, the relative brain-weight increases very rapidly in proportion to the organisation of the animal and in animals of equal size it varies with the organisation.

Thus we may cite from Dubois the following equal-sized species:—

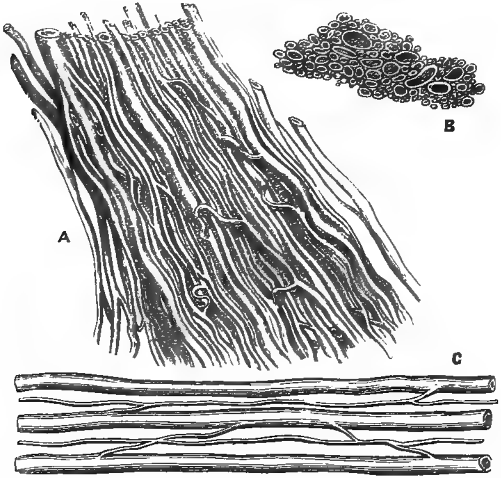
| | | |
|---|---|---|
| Siamang (Simiidæ) | Primates, | $\frac{1}{73}$ |
| Budlug (Cercopithecidæ) | | $\frac{1}{126}$ |
| Civet-Cat, | Carnivora, | $\frac{1}{202}$ |
| Javan Pangolin, | Edentata, | $\frac{1}{615}$ |

If the effect of the varying size of mammals be eliminated, a table showing degree of "cephalisation" can be formed, and this agrees generally with the recognised succession of the mammalian orders, the Metatheria, Edentata, Rodents and Insectivora taking the lowest places, followed by Ungulata, Cetacea, Carnivora and lower monkeys, and, lastly, anthropoid apes and man.

Thirdly, taking extinct mammals into account, it would appear that in mammals of similar size and bodily organisation the relative brain-weight increases with the time, as we have seen that the greatest advance from Eocene times has been cerebral.

Blood-Vascular System.—The heart and circulatory system do not show any great adaptation throughout the class. The heart is always four-chambered and the systemic arch is only found on the left. In various regions of the body there are developed fine meshworks of blood-vessels termed *retia mirabilia.* These are found at the bases of the limbs in many arboreal animals which have to hang from boughs, in which case they appear to counteract the retarding effects of gravity upon the circulation (*cf.* Sloth). They also occur in whales, possibly for the storage of arterial blood to allow of a long sojourn under water.

Fig. 322.—A Rete Mirabile.



A, General appearance. B, Cross-section of the blood-vessels. C, Anastomosis of smaller and larger vessels. (After Murie.)

Respiratory System.—The lungs lie freely in the thoracic cavity, being completely surrounded by the pleura, and respiration is effected by the ribs and intercostal muscles, supplemented by the *diaphragm,* as in the rabbit. The diaphragm is foreshadowed in types like the crocodile, but it is typically a mammalian organ in its perfect condition.

The temperature of reptiles is directly dependent upon that of their surroundings, but that of mammals and birds is *constant*—that is to say, the heat-producing agencies of the body are so adjusted that the body-temperature is maintained at a certain mean average. That of birds is much higher than that of mammals, and for this reason the body-temperature of birds is sometimes described as hot and that of mammals as warm. The special point, however, is in each case the constancy of the temperature, whatever the environment. In this respect, as in many others, the *Prototheria* and *Metatheria* approach the reptilian condition.

ALIMENTARY SYSTEM.—The same general plan of alimentary system holds throughout, though certain changes are found in correlation to special methods of feeding. A number, such as the anteaters, pangolins and *Echidna*, have an elongated protrusible tongue and highly developed salivary glands, the saliva being used to make the tongue sticky, by which means the ants and other insects may be readily caught.

The stomach is more or less simple in some forms but extremely complex in others. The complexity is of two kinds. The first is its division into two or more chambers which are easily visible externally and the second involves the distribution of the glands. A more or less prominent part of the stomach which immediately succeeds the œsophagus has an entire absence of glands and is lined only by stratified epithelium. The whole stomach is of this nature in *Ornithorhynchus*. Again, this area is followed typically by an area containing *cardiac glands*, another containing *fundus glands* and, lastly, by the hinder portion containing *pyloric glands*. The fundus glands may often be absent.

The first division of the stomach is effected by a constriction dividing it into *cardiac* and *pyloric* chambers, as in certain rodents. In most cases the cardiac portion has no glands, whilst cardiac and pyloric glands are found in the pyloric portion. In others, as the porpoise (p. 546), there are three chambers, consisting of a non-glandular cardiac part, a second chamber with cardiac glands and a small third and fourth with pyloric glands. In the Ruminants there are typically four chambers, of which the two first are non-glandular, as is also the third (see Ruminantia, page 514). It is difficult to find any general law regulating the amount of complexity of the stomach. In a very wide sense, the carnivorous animals have the simpler and the herbivorous have the more complex stomach, but there are many exceptions to these, such as the whales.

The intestine is usually long in the herbivorous mammals and comparatively short in carnivorous, and the same applies especially to the cæcum which may be entirely absent in certain *Carnivora*.

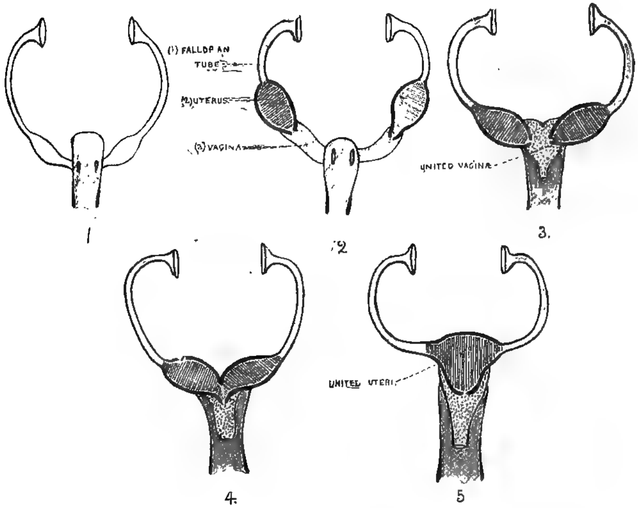
Lastly, we may notice that in the great majority of mammals the anus opens to the exterior independently of the urogenital sinus, no cloaca being present.

UROGENITAL SYSTEM.—The urogenital organs show a transition series as the viviparous habit is acquired and elaborated. In the oviparous *Monotremata* the oviducts are like those of reptiles, simple throughout and opening separately into the urogenital sinus. In the higher types the oviduct becomes differentiated into (1) the upper part or *Fallopian tube*, (2) the middle part or *uterus* and (3) the lower part or *vagina*. At the same time there takes place a fusion of the two oviducts in the middle line. In the majority of the *Metatheria* there is little or no fusion, so that there are two uteri and two vaginæ, but in the *Eutheria* the two vaginæ are always fused into one. Lastly, in all the higher *Eutheria* the two uteri are more or less fused into one, transition forms giving rise to the types of uterus called bicornuate and bi-bipartite.

In the male there is a corresponding progress in the evolution of the penis and the urogenital system generally. It is evident that the viviparous habit requires a complete internal fertilisation, even more than in the terrestrial oviparous forms. The penis in the *Sauropsida* is merely the specialised ventral wall of the cloaca, which is only partially protrusible; on its dorsal surface is a groove, the penial urethra. In the *Monotremata* the penial urethra has become a tube along the dorsal surface of the penis, which, however, communicates freely behind with the cloaca as well as with the urogenital sinus. In the *Marsupialia* the urogenital sinus and the penial urethra are continuous and completely apart from the rectum, but the distal end of the penis is still surrounded by the same sphincter muscle as the anus (*cf.* female), whereas in the *Eutheria* the penis is perfectly distinct and free from the anus (the space between the two being the perinæum) and is more complex in other ways than that of the lower types. The main point to notice is the gradual separation of rectum and urogenital canal from a common cloaca, a process akin to that seen in the female.

SKELETON.—The skeleton in *Mammalia* is almost entirely bony, but the bones mostly have *epiphyses*. These, as already explained in the general features of *Vertebrata* (page 413), are produced by the persistence of a thin layer of unossified cartilage during life.

Fig. 323.—DIAGRAM OF MAMMALIAN FEMALE UROGENITAL ORGANS.



1, The Prototheria. 2, The Metatheria. 3, The Eutherian bipartite uterus. 4, The Eutherian bicornuate uterus. 5, The Eutherian simple uterus.

The general characters of the mammalian skull have been noticed in the rabbit. The facial and cranial portions are completely joined together. Specially interesting are the parts connected with the suspensorium and the ear-ossicles.

In *Sauropsida* the quadrate suspends the mandible, but in the mammals the squamosal bone grows down to meet the dentary and forms a fresh articulation, so that the quadrate is no longer necessary for this function, and passes backwards to form the *tympanic bone* which surrounds the outer part of the ear.*

The lower jaw also appears to consist of a single bone on each side.

In this connection we may note that the squamosal articulation has the condyle on the movable part, whereas the quadrate articulation of *Sauropsida* has the condyle on the quadrate or immovable part. The first has a mechanical advantage which may partially account for the substitution.

Other special points we may note in the skull of the mammal are these:—The skull is suspended to the first vertebra by two condyles borne on the two exoccipitals. The maxillæ and palatines meet their fellows across the roof of the mouth to form a bony palate, so that the nasal cavity only communicates with the buccal cavity by small *naso-palatine foramina* in front and by the internal nares behind. The maxilla and squamosal are connected across under the orbit by the malar or jugal, forming a bridge of bone called the *zygomatic arch* (or suborbital bar). Ridges for the insertion of muscles may be formed, such as the *sagittal crest* along the median dorsal line and the *occipital crest* at right angles to it in the occipital region. These are best developed when a heavy "bite" is required. The tympanic bone very commonly expands into a swollen *bulla tympani* below the ear, enclosing the tympanic cavity or middle ear.

THE VERTEBRÆ.—The cervical vertebræ are usually seven in number† and are distinguished from all other vertebræ by having a pair of lateral foramina as well as the large central one. These are known as the *vertebrarterial canals*, because the vertebral artery runs through them. They are formed by the cervical rib, with its head forked into capitulum and tuberculum, becoming fused on to the

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* This is one of several views as to the fate of the quadrate in mammals. Many hold that it forms the incus.

† Exceptions are found in the *Edendata* and *Sirenia*. *Bradypus* has eight or nine, *Tamandua* eight, *Cholœpus* and *Manatus* six.

vertebra and hence enveloping the artery in a complete bony ring. (Camels form a remarkable exception to this rule.)

The thoracic vertebræ bear the functional ribs. They may be known in mammals by the articular half-facet on the centrum for the capitulum of the rib. As a rule in mammals the capitula of the ribs articulate *between* the vertebræ (*cf.* chevron-bones), hence the half-facet. The transverse process also has a facet for the tuberculum. In many thoracic vertebræ the neural spines are very long. The thoracic vary in number throughout the orders.

The lumbar vertebræ approximate at the anterior end to the thoracic in character, but they have no free ribs. The ribs are fused on to the transverse processes, thus producing large flat lateral wings which are usually known as "transverse processes." The neural spines are never long in the lumbar vertebræ.

The sacrum is formed of two primary sacral vertebræ which are firmly welded together and to the ilium. They also contain rib-elements in the short transverse processes (still seen in crocodiles). There are usually in *Eutheria* one or more caudal vertebræ more or less welded into the sacrum.

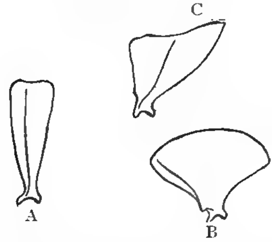
The caudal vertebræ vary enormously amongst mammals in size and number, just as the "tail" also varies. They are usually more or less simple rod-shaped bodies. In the aquatic forms, such as *Sirenia* and *Cetacea*, the tail is hypertrophied and the vertebræ, as also in some terrestrial forms, *e.g.*, Kangaroo, bear chevron-bones or ventral arches articulating between the centra. In a good number of mammals the tail forms a valuable accessory limb, more especially in the arboreal types. The muscles of the prehensile tail are strengthened and the end of the tail is wound round a bough sufficiently firm to bear the weight of the animal, thus freeing the limbs for other purposes. The forests of South America present us with a remarkable abundance of forms with prehensile tails, some examples being the spider-monkeys, tree-porcupines, tree anteaters, opossum-rats and opossums.

In some *Anthropoidea* the tail is vestigial, reduced to half-a-dozen fused vertebræ called the *coccyx*, which no longer protrudes from the surface as a "tail" but may even occasionally become fused to the sacrum.

The Limb-Girdles.—The girdle of the fore-limb or pectoral arch closely approximates to the reptilian type in the *Monotremata*, but becomes more specialised in the *Marsupialia* and *Eutheria.*

In the *Monotremata* the coracoids are large and meet the sternum. They bear on their inner border a pair of precoracoids. There is also a T-shaped episternum. In the *Metatheria* and *Eutheria* the coracoids atrophy, as also the precoracoids. Amongst other vestiges of these bones there is a process upon the scapula, the *coracoid process,* which is said to be the distal end of the precoracoid, the true coracoid being represented by a small bone taking part in the formation of the glenoid cavity.

Fig. 324.—Three Types of Mammalian Scapula.



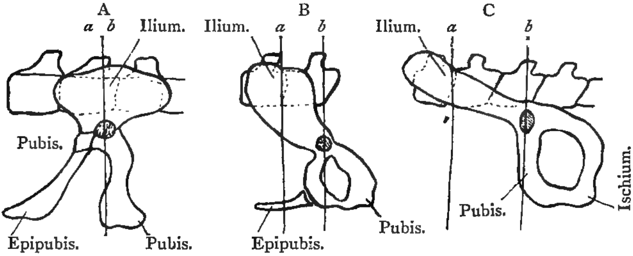
A, Cursorial. B, Aquatic or natatorial. C, Arboreal.

Hence in nearly all mammals the scapula alone is left to bear the fore-limb, especially as in a great number the clavicle atrophies. The scapula is correspondingly highly developed. It is a large, triangular-shaped, flattened bone, with a bony ridge down its outer surface called the *spine*, terminating in a free process, the *acromion*, to which the distal end of the clavicle is attached, when present.

In the running types (*Ungulata*), in which the limb has little diversity of movement, the clavicles go and the scapula is long and tapering, with short suprascapular border. In the climbing types (*Primates*), with varied movements of the fore-limb, the scapula is an approximation to an equilateral triangle whilst in the swimming types (whales, seals) the scapula is broadened out, shortened lengthwise, with long suprascapular border. The spine is pushed forwards, so that the postscapular fossa is very large and the prescapular fossa is small.

The pelvic arch in mammals is fairly constant in its structure. The ilium always becomes firmly attached to one or more of the vertebræ. It always slopes backwards from its junction with the sacrum to the acetabulum, whereas the acetabulum is usually immediately below the ilium in reptiles. The *Monotremata* in this respect approximate to the reptiles, the angle between the axis of the ilium and that of the sacrum being less acute.

Fig. 325.—LATERAL VIEWS OF—A, CROCODILE'S PELVIS; B, PELVIS OF PROTOTHERIA; AND C, THAT OF EUTHERIA.



*a* = Perpendicular axis through acetabulum. *b* = Perpendicular axis through sacrum.

In mammals the pubes unite with the ischia on each side and thus enclose a large hole or foramen, the *obturator foramen*. In most the pubes meet across the middle line to form a *symphysis pubis* and the ischia also meet to form an ischial symphysis, but in several types (*e.g.*, man) the ischia no longer meet across the middle line, the pubes forming the whole symphysis. A small acetabular bone is also very generally present and usually fuses with one of the other elements.

In *Metatheria* and *Prototheria* there is a pair of *epipubic* bones running forwards from the pubes, which serve, at least in the former, for support of the pouch. Similar epipubic bones are found in certain reptiles (*e.g.*, *Hatteria*).

STERNUM AND RIBS.—The sternum in mammals arises from the fusion of the distal extremities of the ribs and is usually segmented into a series of joints or so-called "sternebræ." The anterior end is called the *manubrium* and the posterior end is the *xiphoid process.* The ribs are many in number and articulate by a capitulum *between* the vertebræ and a tuberculum on the transverse process. This peculiar articulation of the ribs is explained thus:—In certain fossil reptiles the vertebræ are double; each has a centrum and an intercentrum which are equal in size. The rib articulates primarily with the intercentrum by its capitulum. In extant reptiles the intercentrum disappears and the rib acquires a secondary connection (the tuberculum) with the transverse process; the capitular attachment may then, in some cases, be given up. In mammals the rib also acquires a secondary connection with the transverse process, but although the intercentrum disappears, as in modern reptiles, the capitular attachment still remains at the spot between the centra at which the intercentrum has disappeared.

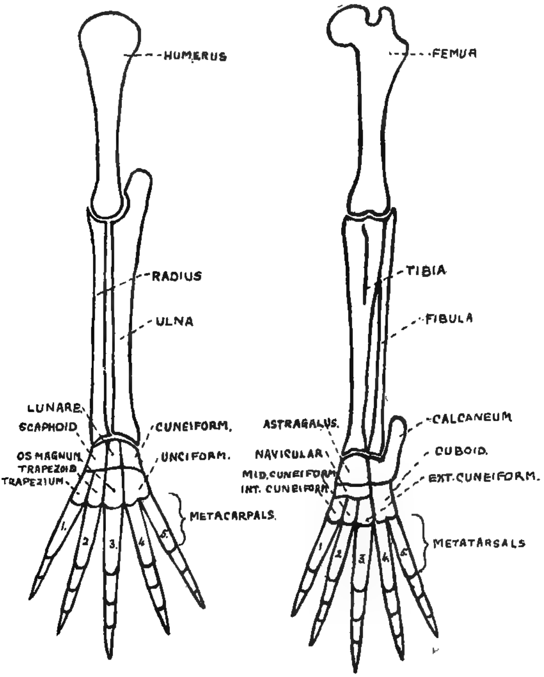
The intercentra are represented in mammals by the *intervertebral discs* which are only very rarely (*cf.* Mole) ossified.

The cervical ribs are completely fused on to the vertebræ and are no longer recognisable as such. The ribs in *Mammalia* have an important function in connection with respiration. They are moved upon the vertebræ by the *intercostal* muscles. When the ribs are raised the cubic capacity of the thorax increases and inspiration takes place, conversely when they are depressed. This action is supplemented by the movements of the diaphragm forming the posterior wall of the thorax.

The thorax can be enlarged in two ways. In the dog, horse and most quadrupeds the ribs are much bent, and they move forward in such a way that the "narrow" chest of these animals enlarges laterally, whereas in man the sternum is raised and pushed outwards, so that the chest is, in this case, expanded vertically.

LIMBS.—In the mammalian fore-limb the three proximal carpals are known as *scaphoid*, *lunare* and *cuneiform*, the centrale is often absent, and the distalia are known as *trapezium*, *trapezoid*, *os magnum* and *unciform*, the last being the fourth and fifth distal bones fused. There is very often another bone, the *pisiform*, usually attached to the postaxial border of the cuneiform. It may be a sesamoid or possibly a carpal bone. In the hind-limb the proximal tarsals are always three in number, the radiale and intermedium are fused to form *astragalus* and the fibulare is known as the *calcaneum*. The centrale persists on the preaxial side as the *naviculare*. The distalia are the *internal*, *middle* and *external cuneiform* and the *cuboid*, the last being the fourth and fifth distalia fused together. In mammals the main joint of the hind-limb and foot is between the crus or tibiofibula and the proximal tarsals, hence it is a

Fig. 326.—DIAGRAM OF THE TYPICAL MAMMALIAN FORE- AND HIND-LIMB.



Note fusion of fourth and fifth distalia and limited number of phalanges.

*crurotarsal* joint, whereas in reptiles and birds the main joint is an intertarsal joint.

In both limbs of mammals the number of phalanges is normally two in the first digit and three in each of the others.

In the various orders we shall notice that there may occur fusions of certain bones, loss of others and modifications of others, but when once this type be learnt and retained in one's mind, there is no difficulty in interpreting aright the most modified mammalian limb.

As general rules for the identification of the bones we may lay down the following (see Fig. 326):—

1. *Humerus and Femur.*—The proximal limb-bones (*humerus* and *femur*) are long bones and have *an articular condyle at each end.* Towards their proximal ends they have a "ball" which moves in the socket of the limb-girdle, and two or more processes called *tuberosities* (humerus) or *trochanters* (femur). At the distal extremity they both have a sigmoid condyle or *trochlea.* The humerus may be distinguished from the femur by its large shallow condyle, whereas the femur has a rounder condyle raised on a "neck." The humerus *usually* has a conspicuous deltoid ridge on its preaxial border. The proximal end of the humerus (or femur) can always be distinguished from the distal by the *condylar* or ball-and-socket joint in the former and the sigmoid or *bilateral* joint in the latter.

The humerus often has a small foramen on the inner or postaxial side of the sigmoid condyle termed the *entepicondylar foramen.* It seems to have occurred very generally amongst Eocene mammals, such as *Condylarthra*, *Tillodontia* and *Typotheria*, and is very generally found amongst *Metatheria*, *Edentata*, some *Carnivora*, most *Insectivora*, *Lemuroidea* and *Cebidæ.*

This foramen should be carefully distinguished from the *supratrochlear foramen* in the median line above the trochlea and produced by incomplete ossification.

The *third trochanter* of the femur has much the same interest as the entepicondylar foramen. It is on the postaxial border (*cf.* Horse) and is present in *Condylarthra*, *Tillodontia*, *Typotheria*, *Creodonta* and other extinct types. It also occurs in *Dasypodidæ*, *Orycteropodidæ*, many *Rodentia*, most *Insectivora*, in *Perissodactyla* and (small) in *Hyracoidea.*

2. *Distal limb-bones.*—The distal limb-bones have a *hollow articular facet at each end* when they are fully developed. At the proximal extremity they receive the condylar ends of the proximal limb-bones; at the distal end they receive the condyles of the proximal carpals.

The two most important bones are the preaxial (or the *radius* and *tibia*), and the ulna and fibula are, in a great number of cases, merely vestiges fused on to their respective preaxial bones, forming a single radioulna or tibiofibula. The proximal ends of the radius and ulna both take part in the formation of the facet or sigmoid notch in which the condyle of the humerus moves, and the ulna is always produced backwards as an *olecranon process* for the insertion of the triceps muscle. This olecranon part of the ulna remains in cases where the ulna atrophies, hence the radioulna or ulna has its facet deep and not quite at the proximal end of the bone. Distally both radius and ulna have shallow facets for articulation with the proximal carpals.

*Tibia and Fibula.*—The proximal ends of the tibia and fibula both usually take part in the formation of the shallow facet of the knee-joint upon which moves the distal end of the femur.

Their proximal end therefore has a *shallow* facet which is *at the extreme end.* Notice that of the two girdle-joints; that of the fore-limb or the glenoid joint is less deep than that of the hind-limb or the acetabulum. But in the case of the limb-joint that of the fore-limb or elbow-joint is much deeper than that of the knee-joint. By keeping these points in mind there should be no difficulty in recognising a radioulna from a tibiofibula or an ulna from a tibia.

*Manus and Pes.*—The wrist-bones or carpus and the ankle-bones or tarsus require special study to be distinguished one by one, but the astragalus and calcaneum are always fairly characteristic, the former bearing a well-developed sigmoid head for the tibia and the latter being produced into the heel in which is inserted the tendon of Achilles.

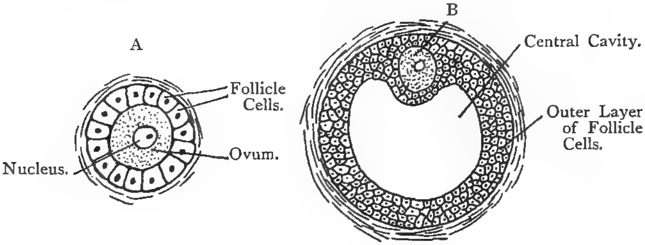
The metacarpals and metatarsals are remarkably developed in the *Ungulata.* In correlation with a reduction in the number of the toes, those remaining are correspondingly increased in size, forming the cannon bones of the horse and ox. These have the appearance of the true long-bones of the limbs, but they may at once be recognised by having a hollow facet at one end (proximal) and a bilateral condyle at the other end (distal).

DEVELOPMENT.—In studying mammalian development we have to keep in mind that the larval and lecithal nutritions have been given up and that there is a succession of three forms of nutrition—the albuminal, the hæmal and the lacteal. The *Prototheria* are oviparous, *i.e.*, the young are discharged from the body as eggs surrounded by a shell, and further development takes place outside the body of the parent; but the great majority of the *Mammalia* are viviparous, *i.e.*, the young are retained during early stages in a special part of the oviduct, called the uterus, and are "born" later.

MATURATION AND PRODUCTION OF THE OVUM.—The eggs arise in the ovaries which are paired. The outer epithelial layer of the ovary is the *germinal epithelium*, and from it the eggs sink into the underlying connective tissue surrounded by a mass of follicle-cells which are usually regarded as nutritive. These cells increase in number and the whole follicle grows rapidly. A split occurs between them, so that in a fully-formed "Graafian follicle" the ovum lies towards the centre surrounded by certain of the follicle-cells. A large cavity separates them from the outer layer of follicle-cells which form the outer tunic of the follicle and the two layers are connected by strands.

When ripe, the follicle bursts and discharges the ovum at the surface of the ovary, whence it passes into the oviduct through its fimbriated opening. The ripe egg has a hyaline membrane around it, the *zona radiata;* and inside this there is the delicate vitelline membrane. The mammalian egg so produced is always of minute size, often about ·1 mm. in diameter (about the same as *Amphioxus*). Maturation is effected by the extrusion of two polar bodies and fertilisation takes place high up in the Fallopian tube.

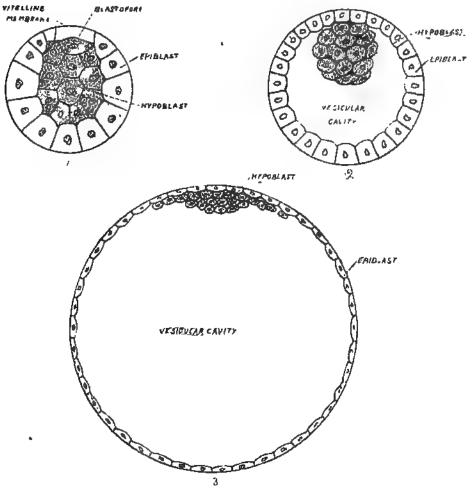
Fig. 327. –The Mammalian Graafian Follicle in the Ovary.



A, Early stage. B, Later.

Segmentation.—The egg immediately commences to segment whilst it passes down the Fallopian tube. There is no yolk and the segmentation is total and nearly equal. The first division is into two blastomeres, of which one is very slightly the smaller. Each divides into two and then into four. The larger cells then become tucked inside the smaller, which on their part divide more rapidly and spread round them. Thus there is produced a stage in which the larger or hypoblast cells are enclosed on every side by the smaller or epiblast, except at one pole, the blastopore. It is difficult to withhold from this stage a homology with the gastrula of lower types, such as *Amphioxus*. It is sometimes called a "metagastrula." The embryo has now reached the uterus and then commences a remarkable process. The blastopore closes, and the whole embryo increases rapidly in size. The epiblast-cells become flat and continue to divide, keeping pace with the great increase in size, but the hypoblast-cells remain in a small heap at the blastoporic pole. Thus is produced the so-called *blastocyst*, its large cavity filled with a colourless fluid.

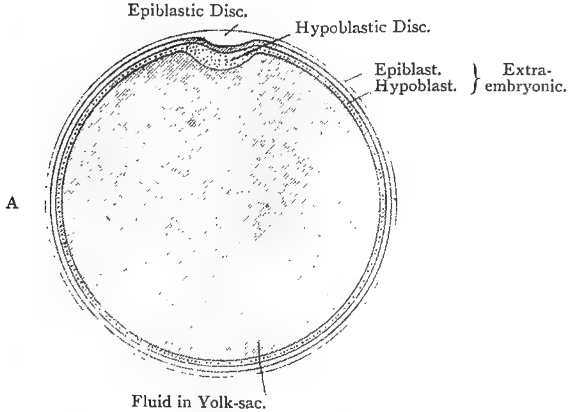
Fig. 328.—Three Early Stages in Development of Rabbit. (After Van Beneden.)



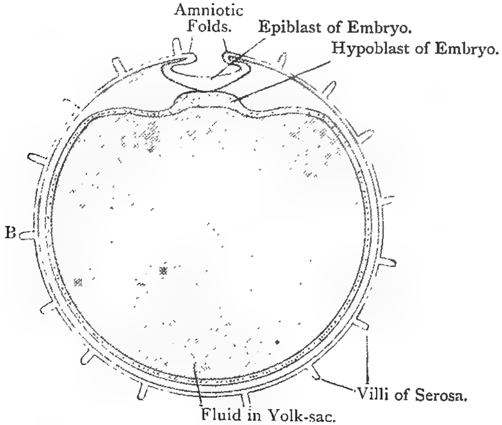
1, The metagastrula; 2, the commencement of the rapid enlargement of the egg; 3, the fully-formed blastocyst.

The hypoblast-cells may now increase and commence to spread round the inner surface of the vesicle, or, as in the hedgehog, they may split to form an internal cavity or sac and then expand. In either case the same result is attained

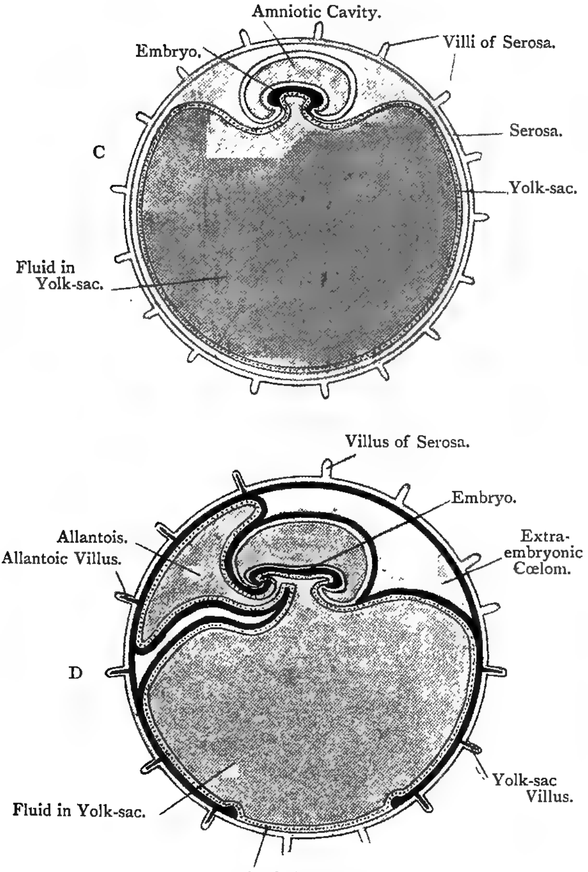
Fig. 329.—DIAGRAMS OF THE FŒTAL MEMBRANES OF A MAMMAL.



A, The diploblastic embryo of a mammal in section.



B, A later stage with serosa villi and a developing amnion.



Epiblast is white, Mesoblast black, Hypoblast dotted.

—the blastocyst becomes two-layered or diploblastic throughout. Both epiblast and hypoblast form thin-walled spheres, with a disc or cap of cells at the blastoporic pole. The hypoblast remains for the present in this condition, but the epiblast divides in a variety of ways to give rise to the *embryonic epiblast*, the *amnion* and the *serosa*. In perhaps the simplest (pig, rabbit) the disc sinks in towards the underlying hypoblast and the walls coming up on either side as folds meet above and fuse. The disc then becomes the embryonic epiblast, the inner walls of the folds become the *amnion* and the outer form part of the *serosa*. Thus the central disc is solely the *embryonic epiblast* and the rest of the epiblast or *extra-embryonic epiblast* forms the serosa and the amnion. In a similar manner the hypoblast-disc forms the *embryonic hypoblast* and the remainder, the *extra-embryonic hypoblast*, forms the *yolk-sac* only.

The embryo is formed from the epiblastic and hypoblastic discs, the former bending over and surrounding the latter. The hypoblast also bends up to form the alimentary canal, and both epiblast and hypoblast become nipped off from the amnion and yolk-sac, respectively, by folds. The mesoblast arises between these layers around a primitive streak at the blastoporic pole, and the organs arise from the three layers very much as in the chick. We may here merely recall the fact that the epiblast gives rise to epidermis, nervous system and stomodæum; the hypoblast to the epithelium of the alimentary canal and appended glands and organs; and the mesoblast to the muscles, skeleton, connective tissue and blood-vascular system.

The mesoblast later grows outwards from the embryo to cover the embryonic membranes, creeping out as a sheet over the surface of the amnion and yolk-sac and eventually reaches the serosa. The outer layer of mesoblast now invests the amnion and the upper part of the serosa, whilst the inner layer covers the upper half of the yolk-sac. At the edge the two layers meet and extend as an unsplit sheet of mesoblast still further down between the yolk-sac and the serosa. Further down still the serosa and yolk-sac are still closely apposed and there is no mesoblast. Hence the blastocyst wall is now formed (1) at its upper half by a wall of epiblast and a single layer of mesoblast, the completed serosa; whilst (2) below the equator there is a broad zone consisting of the epiblast of serosa, a double layer of mesoblast and a layer of hypoblast (yolk-sac), all in close contact; and (3) the lower pole or cap consisting of epiblast (serosa) and hypoblast (yolk-sac). This is an exceedingly characteristic stage in most mammals and it is also present in the chick; but whilst in the latter the mesoblast extends to the lower pole and then splits all round to form a completed serosa and yolk-sac, each with its mesoblast wall, in the mammal the mesoblast remains at this stage throughout fœtal life.

The lower disc (3) forms the *prokalymma or absorptive disc for albuminous nutrition*, the zone (2) forms later the *yolk-sac placenta for hæmal nutrition* and the upper half (1) will undergo further changes. Whilst this development has been going on within the blastocyst, the serosa has been pushing out processes which come in contact with the wall of the uterus and moor the blastocyst to the uterus. They may in some mammals extend all over the surface and seem in some cases to assist in absorption of nutritive fluid; hence this serosa, without its mesoblastic sheath, has been termed the "*trophoblast*." In others they form a girdle, or they may be concentrated at one part.

In the region of the prokalymma both epiblast and hypoblast become modified into thickened active layers, probably to subserve albuminal nutrition. Meanwhile from the hind-gut of the embryo there arises in the mid-ventral line a small outgrowth, which grows rapidly and pushes out into the space between serosa, amnion and yolk-sac. As it is a production of the gut-wall, it has from its first origin *an inner wall of hypoblast and an outer wall of mesoblast.* It is known as the *allantois* and soon spreads over the dorso-posterior part of the embryo, coming to lie in close contact with the serosa in this region. In the chick it grows till it covers practically the upper half of the blastocyst-wall or serosa, and in *Prototheria* it occupies the whole *right* half of the cavity. (See below.) The mesoblast of the allantois and that of the yolk-sac now develop complete systems of arteries and veins, the former being the *allantoic* arteries and veins and the latter the *vitelline.*

The vitelline blood-vessels ramify all over the placental zone, and vascular villi or processes are thrust out into the serous villi, coming into intimate contact with the uterine blood-system. Thus is formed the true *yolk-sac placenta* and a hæmal nutrition, which rapidly replaces in function the prokalymma and its albuminal nutrition.

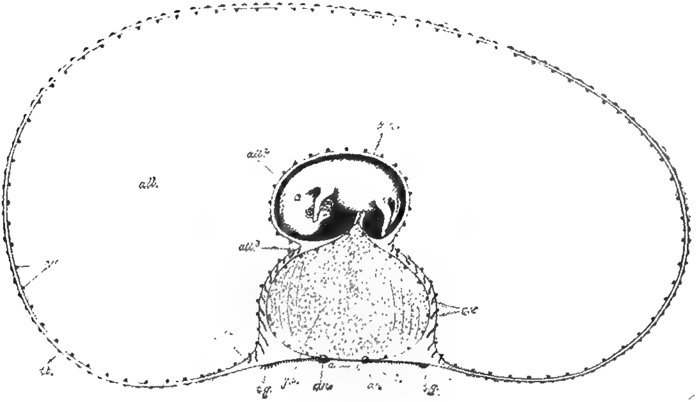
The yolk-sac placenta is a functional organ in the *Metatheria*. In them the zonal placental area extends upwards till it covers the greater part of the upper half of the blastocyst and probably largely replaces the prokalymma at the lower pole. The allantois in *Metatheria* degenerates and eventually loses its connection with the serosa, though in certain forms it may remain attached over a small disc-like area and form, indeed, a true allantoic placenta.

In the *Eutheria* this state of affairs is carried still further, and the allantois spreads over a large area of the serosa, throws out villi and forms a large *allantoic placenta.* The yolk-sac in these forms degenerates; it eventually loses its connection with the serosa and lies as a small vestige beside the allantoic stalk. Indeed, it is questionable how far in *Eutheria* the true yolk-sac placenta is formed, for the allantois is developed at a very early stage and tends to become functional as the organ of hæmal nutrition, whilst the prokalymma is still functional. In many *Eutheria* the allantois lines the whole inner surface of the serosa in late stages, just as the yolk-sac tends to do in the case of the *Metatheria* (*cf.* Figs. 331 and 342).

The allantoic placenta attains a far higher standard of perfection than the yolk-sac placenta. In shape we have seen that it originates as a sac or disc (*discoidal*) from which it may spread over the equator to form the *dome-shaped;* the villi may then disappear at the pole and produce the *zonary*, or the spreading may extend to the other pole and form the *diffuse*, a modified form of which is the *cotyledonary* in which the villi are aggregated into tufts.

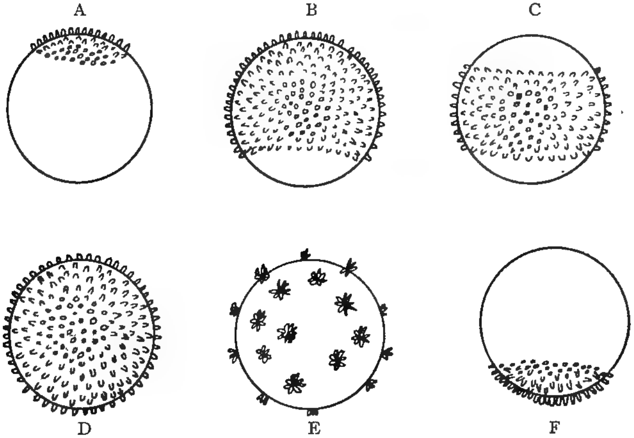
Again, the villi may remain more or less simple processes protruding into the maternal tissues, so that at birth they can be withdrawn from their pockets, leaving the maternal tissues intact, or they may become extremely complex and branching and so inextricably interwoven with the maternal tissues that parts of the latter have to be shed at birth. The former type of placenta is termed *non-deciduate* and the latter *deciduate.* The only other alternative is for the embryo to leave its share of the placenta (allantois) behind at birth. This occurs (*Perameles*) and the remains of the allantois are absorbed by the maternal tissues. This type has been termed *contra-deciduate.*

Fig. 330.—An Embryo Horse of Six Weeks in its Membranes.
(After Ewart.)



Note the reduced yolk-sac (*y.s.*), the enormously distended allantois (*all.*) forming a diffuse placenta, the prokalymma (*a.c.*), and the villi of the serosa (*t.g.*). The amnion (*am.*) is black.

Fig. 331.—Six Different Types of Placenta.



A, Discoidal. B, Dome-shaped. C, Zonary. D, Diffuse. E, Cotyledonary.
F, Metadiscoidal.

It must be remembered that these types of placenta, depending for distinction upon the degree of quantitative or qualitative production of the villi, are gradational.

The amnion remains as a thin membrane enveloping the embryo and containing the *liquor amnii*, a colourless indifferent fluid. Its walls are said to contract rhythmically and rock the embryo. At birth the amnion is ruptured and its remains are thrown off with the placenta.

The yolk-sac, as before stated, never contains yolk and, after the prokalymma has ceased to be functional, it either shrivels and folds up at the lower pole or its outer wall, the prokalymma, is shed, and the inner wall remains as a vascular membrane.

In this general account there are a series of striking differences from the lower types (the *Sauropsida*), and yet at the same time there is a great degree of similitude. Here are the same four fœtal organs, the serosa, the amnion, the allantois and the yolk-sac (or umbilical vesicle), but their origin and function are different. The actual development of the embryo and its organs is very similar, although it commences much later.

The main differences are as follows:—

| MAMMAL. | SAUROPSIDA. |
|---|---|
| 1. The egg is minute ($\frac{1}{260}$ in. diam. in rabbit) with little or no yolk and segmentation is total and equal. | 1. The egg is large (about 1 inch diam. in chick), has a mass of yolk and segmentation is partial. |
| 2. The development of the embryo is very slow, but that of the membranes is rapid, hence the serosa, amnion and yolk-sac are formed at first without their mesoblastic sheaths. | 2. The development of embryo commences first and that of membranes is slower, hence the membranes have their mesoblastic sheaths from their inception. |
| 3. The serosa early becomes an attaching organ, possibly also nutritive, and the yolk-sac never contains yolk, but it becomes an organ for interchange of blood, hence a nutritive, excretory and respiratory organ, to be replaced in the *Eutheria* by the allantois similarly modified. | 3. The serosa remains simple but is covered by a porous shell, the yolk-sac contains plentiful yolk, and the allantois is a respiratory organ, its cavity forming an excretory reservoir. |

How are we to explain these important differences? The lowest mammals or *Monotremata* have large eggs, with shells and yolk; and the structure of the fœtal membranes, so far as is known, does not essentially differ from that in *Sauropsida*. This fact and others appear to justify zoologists in assuming that the present-day mammals are descended from ancestors which in these respects resemble the monotremes. In other words, the change from an oviparous to a viviparous habit is supposed to account for the differences in structure and function. We must assume that gradually the egg was retained for a longer period before being laid. The serosa then became an organ of attachment to retain the egg, the shell having become superfluous. The embryo was thus nourished by albumen from the uterine glands.

Thus was instituted a habit of ovoviviparity in which the young was hatched inside the mother. The interchange of blood-elements between the blood-vessels of the widely distended yolk-sac and the enveloping maternal tissue was inevitable, and the yolk being no longer required it commenced to atrophy. Thus the metatherian condition is reached in which the yolk-sac placenta is functional and the allantois becomes vestigial.

If, however, the allantoic arteries and veins, as well as the vitelline, become connected with the uterus, the same atrophy of yolk results, and the allantois eventually replaces the yolk sac as a placental organ. To its former function of respiration is therefore added that of nutrition.

The removal of the yolk explains the reversion to a total equal segmentation and the formation of a "metagastrula," whereas the enormous increase in size of the egg on entry into the uterus may be explained as being due to the necessity for the egg being of the same large size as it originally was when there was much yolk, the large surface being required both for absorption and mechanical attachment.

We may briefly summarise the development of a mammal as follows:—

1. Discharge of ovum from Graafian follicle of ovary and passage into Fallopian tube.

2. Maturation and fertilisation in Fallopian tube, followed by total equal segmentation and invagination of hypoblast to form metagastrula.

3. Closure of blastopore and entry of ovum into uterus, accompanied by rapid increase of embryo to form blastocyst.

4. Division of epiblast into embryonic disc and extra-embryonic part, which afterwards forms amnion and serosa; and growth of hypoblast round inside of serosa, the disc forming embryonic hypoblast, the vesicular wall the yolk-sac.

5. Attachment of serosa by villi to the uterine wall.

6. Addition of mesoblastic covering to yolk-sac, growth of allantois and growth of yolk-sac villi to form yolk-sac placenta.

7. Growth of allantoic villi into the uterine tissues and attendant changes, producing the true allantoic placenta. Atrophy of yolk-sac.

8. Birth of embryo by rupture of serosa and amnion, followed by shedding of after-birth or placenta. Termination of uterine gestation.

9. Commencement of mammary gestation.

## CLASSIFICATION OF MAMMALIA.

*Mammalia* have, as we believe, been descended from amphibio-reptiles in the past, so those mammals which still present us with reptilian characters must take the lowest place. Of these we find that two small mammals, the duck-mole and the porcupine anteater, differ from all other mammals in having an oviparous habit, so we are constrained to emphasise this fact by putting them into a sub-order by themselves, called *Prototheria* (first quadrupeds) or *Ornithodelphia.* This distinction is further corroborated by numerous anatomical characters. The extant sub-class *Prototheria* have but one order, the *Monotremata.* All the other mammals are viviparous, but almost the whole of the indigenous mammals of Australia and a few allies in America show a simpler condition of the reproductive organs and along with this a much less pronounced viviparous habit. The young are born at a very early stage and there is, in all but a single exception, no true allantoic placenta. These and other features enable us to divide the "marsupial" animals from the rest into the sub-class *Metatheria,* all the higher forms being known as *Eutheria.*

We thus divide the class *Mammalia* into three sub-classes :—(1) *Prototheria*, (2) *Metatheria* and (3) *Eutheria*. The three sub-classes are divided into orders and sub-orders. The extinct forms are in *italics* :—

| | *ORDERS.* | *SUB-ORDERS.* | |
|---|---|---|---|
| PROTOTHERIA. | 1. Monotremata. | | Duckmole, Echidna. |
| | 2. *Allotheria.* | | *Microlestes, Plagiaulax.* |
| METATHERIA. | 3. Polyprotodontia | | Banded anteater, bandicoot. Tasmanian wolf, opossum. |
| | 4. Diprotodontia. | | Kangaroo, phalanger, wombat. |
| EUTHERIA. | 5. Edentata. | 1. Xenarthra. | Anteater, sloth, armadillo. |
| | | 2. Nomarthra. | Aard-vark, pangolin. |
| | 6. Sirenia. | | Manatee, dugong. |
| | 7. Rodentia. | 1. Duplicidentata. | Rabbits, hares, and picas |
| | | 2. Simplicidentata. | Porcupine, guinea-pig, chinchilla, squirrel, beaver, rat, mouse, pouched-rat. |
| | 8. *Tillodontia.* | | *Tillotherium.* |
| | 9. Ungulata. | 1. Hyracoidea. | Hyrax. |
| | | 2. *Amblypoda.* | *Coryphodon.* |
| | | 3. Proboscidea. | Elephant. |
| | | 4. *Condylarthra.* | *Phenacodus.* |
| | | 5. Perissodactyla. | Tapir, rhinoceros, horse. |
| | | 6. Artiodactyla. | Pig, hippopotamus, camel, ox, sheep, deer. |
| | 10. Cetacea. | 1. Odontoceti. | Porpoise, dolphin, killer. |
| | | 2. Mystacoceti. | Whale. |
| | 11. Carnivora. | 1. Fissipedia. | Bear, badger, weasel, dog, hyæna, civet, lion, cat. |
| | | 2. Pinnipedia. | Seal, sea-lion, walrus. |
| | 12. Insectivora. | 1. Insectivora Vera. | Mole, hedgehog, shrew. |
| | | 2. Dermoptera. | "Flying Lemur." |
| | 13. Chiroptera. | 1. Microchiroptera. | Bats. |
| | | 2. Macrochiroptera. | Fruit-bats. |
| | 14. Primates. | Lemuroidea. | Lemurs. |
| | | Anthropoidea. | Monkeys and man |

# CHAPTER XXVII.

## THE MAMMALIA.

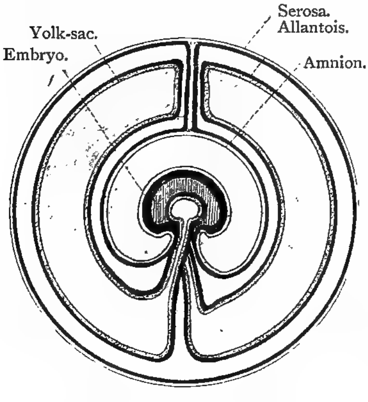
### Sub-Class I.—Prototheria.

The *Prototheria* have only one living order, though there are reasons for believing that certain extinct forms of mammals may belong to this sub-class. They constitute the order *Allotheria,* whilst the living types comprise the order *Monotremata.*

Their great importance consists in the fact that they are the lowest types of mammals and in many respects they form a transition in structure to the reptiles. Like most lowly and primitive forms, they also have a number of very specialised features superposed upon their generalised organisation.

We have already seen that the division into sub-classes is based upon the mode of reproduction and on the comparative structure of the reproductive organs. The features of the sub-class are therefore as follows:—

Fig. 332.—Diagram of the Fœtal Membranes of Echidna as seen in Cross-section.

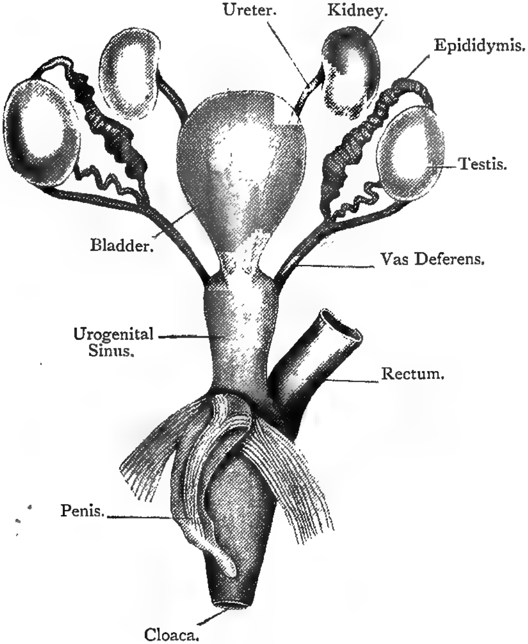


The yolk-sac is on the embryo's left and the allantois on the right.

1. Reproduction.—It was not till 1884 that the egg-laying propensities of these mammals were definitely discovered. The eggs are much larger than

those of other mammals, have a tough flexible shell and a large quantity of yolk. The segmentation is meroblastic, like that of reptiles, and the fœtal membranes are well developed, as in *Sauropsida*, the yolk-sac functions for store of nourishment and the allantois for respiration. The amnion does not appear to completely separate from the serosa, hence the yolk-sac takes up the left and the allantois the right half of the egg-cavity, instead of ventral and dorsal, respectively, as in the chick.

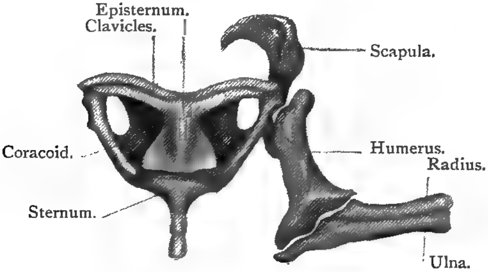
Fig. 333.—Ventral View of Male Urogenital Organs of Ornithorhynchus. (*Ad nat.*)



2. Urogenital Organs.—The base of the oviducts is swollen into a so-called "uterine" part which probably

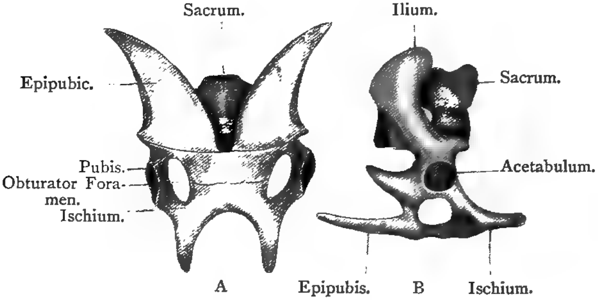
secretes the shell. They have no distinction into Fallopian tube, uterus and vagina, and they open separately into the urogenital sinus.

Fig. 334.—Ventral View of Pectoral Girdle and Fore-Limb of Ornithorhynchus. (*Ad nat.*)



3. Cloaca.—The urogenital canal and the alimentary canal have a common passage called the cloaca which opens by a single aperture to the exterior, the cloacal aperture (hence *Monotremata*).

Fig. 335.—Pelvis of Ornithorhynchus × ½. (*Ad nat.*)

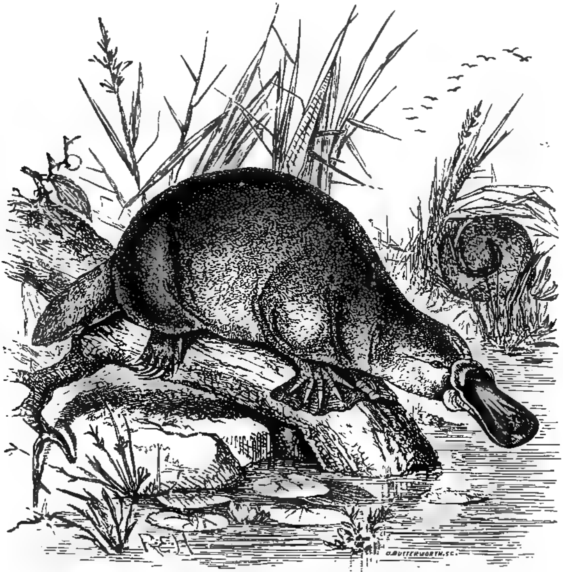


A, Ventral view. B, Lateral view.

4. Skeleton. — Shoulder-girdle has complete precoracoids, coracoids and episternum. The scapula is bent forward and the spine is at the anterior border, not down the middle.

Other skeletal peculiarities must be noted. The pelvis bears a pair of *epipubic bones* similar to those of the *Metatheria*, and at least in *Echidna* the acetabulum is incompletely ossified. The cervical ribs are incompletely fused on to the cervical vertebræ, and the dorso-lumbar vertebræ have no epiphyses, or only traces of them. The cranial bones ankylose early, obliterating all sutures,* and the rami of the mandible are free. There is an entepicondylar foramen in the humerus.

Fig. 336—DUCKMOLE (*Ornithorhynchus anatinus*).



(From GOULD's Mammals of Australia.)

The temperature of the body is low and inconstant. In all these features the *Prototheria* show a low grade of structure approximating to the reptilian type.

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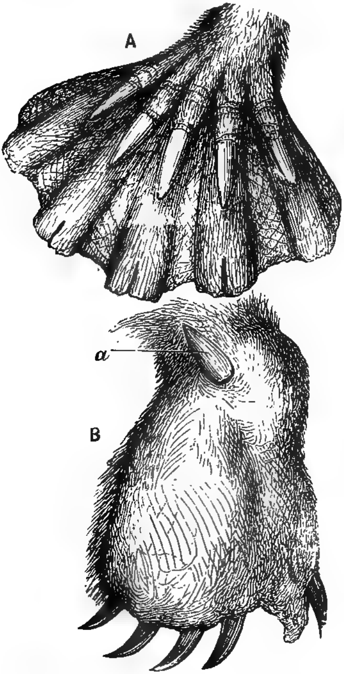
* The young *Ornithorhynchus* is said to possess *pre-* and *post-frontal* bones.

## ORDER I.—*Monotremata.*

There are two families in this order—(1) Ornithorhynchidæ and (2) Echidnidæ, closely allied in many ways. *Ornithorhynchus anatinus*, or the duckmole, is found in the Australian region. Its general appearance may be seen from the figure. The body, usually about 18 inches long, is covered with dense, soft, brownish hair, and the head has a remarkable pair of horny "beaks." The eyes are small and, as in most aquatic forms, there is no external ear. Both pairs of limbs have five digits with claws and a "web" or membrane is present in the front limb, none in the hind. The tail is flat, and in old specimens the hair is absent from its lower surface. In habits the duckmole is "fossorial" and "aquatic." It swims freely and lives in deep burrows in river-banks. At the end of its burrow it constructs a nest in which it lays its eggs. There are no teats and the mammary glands are modified sudorific glands. The teeth are only present in the young and adolescent forms and appear to be worn away early, when they are replaced by the familiar horny pads or "cornules" found in most skulls. The teeth are only molars and few in number, eight

Fig. 337.—FORE (A) AND HIND (B) FOOT OF THE DUCKMOLE.

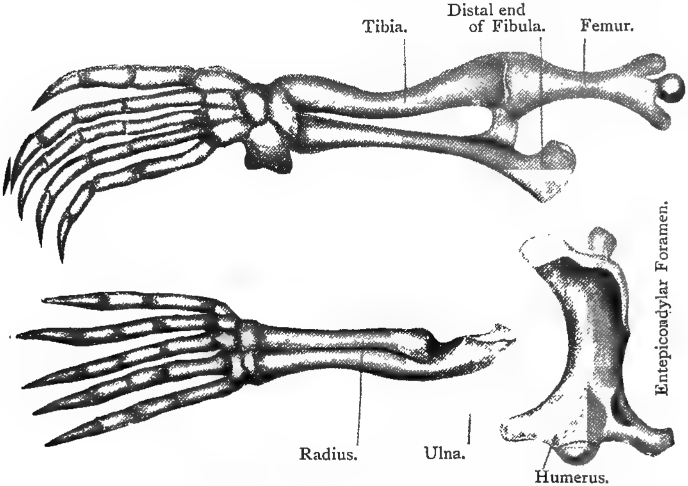


Note the webbed fore-foot and the poison-spur (*a*) on the hind-foot.

to ten in all. They appear to have two main cusps and smaller "crenulations," the cusps lying externally in the lower jaw and internally in the upper. The beaks are borne upon bony processes of the premaxilla and the skull of the duckmole is at once recognised by the peculiar "beak-shape" of the facial region together with the hard cornules.

The male *Ornithorhynchus* has a "spur" on the inside of the hind-foot which is traversed by a canal continuous with the duct of a gland situated over the thigh. It is probably a poison-apparatus and is supposed to be functional early in the breeding season. It is rudimentary in the young female. The skeleton of the limbs shows powerful ridges and crests on humerus and femur, and the fibula has a projecting process beyond the knee-joint which gives it a deceptive resemblance to an ulna.

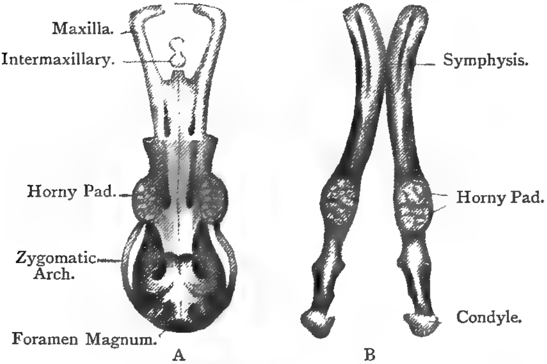
Fig. 338.—Bones of Limbs of Ornithorhynchus. (*Ad nat.*)



Hind-limb above. Fore-limb below.

*Echidna* and the allied genus *Proechidna*, the "Porcupine anteaters," are, like *Ornithorhynchus*, confined to the Australian region, *Proechidna* to New Guinea. *Echidna* may be about 16 to 18 inches long, with a fat compact body, covered not only with thick fur but with strong pointed spines scattered amongst the hair. The general colour is brownish and the spines are usually yellowish. The facial part of the head is produced into a long tubular rostrum. The eyes are small. The limbs each have five toes and in the typical species all are clawed. The tongue is long and protrusible. There is a small poison-spur on the hind-limb. The tail is almost absent. The animal is fossorial and anteating in its habits and can burrow rapidly. It is said not to make a nest but to carry its egg, which has a thin horny shell, in a temporary pouch. The mammary glands are like those of *Ornithorhynchus.* The skull of *Echidna*, in its modifications for ant-diet, is rather like that of the true anteaters. We may note (1) the absence of teeth; (2) the great elongation of the facial region; (3) the degeneration of the lower jaw or mandible. The functions of teeth and lower jaw have largely been usurped by a long adhesive tongue.

Fig. 339.—SKULL OF ORNITHORHYNCHUS × ½.



A, Ventral view of skull. B, The mandibles from above.

## ORDER II.—*Allotheria.*

These consist of a series of small extinct mammals (*Plagiaulax*, *Microlestes*), chiefly known to us by their mandibles or lower jaws and their teeth. They occur in the mesozoic period from the Trias onwards and have doubtful claims to be regarded as *Prototheria*. These claims rest chiefly upon the resemblance of their molar teeth to those of *Ornithorhynchus*. They have, however, large incisors, one pair being much larger than the rest. The heterodont condition is therefore already present. Still more doubtful are the supposed vestiges of a coracoid and episternum. It is obvious that nothing is known of the soft parts, but if their skeleton were shown to agree closely with that of the *Monotremata* there would be reasons for assuming that they probably also possessed the three first features of the *Prototheria*.

## Sub-Class II.—Metatheria.

The *Metatheria* have two living orders, the *Diprotodontia* and the *Polyprotodontia*. They may be said to present at least five important sub-class characters:—

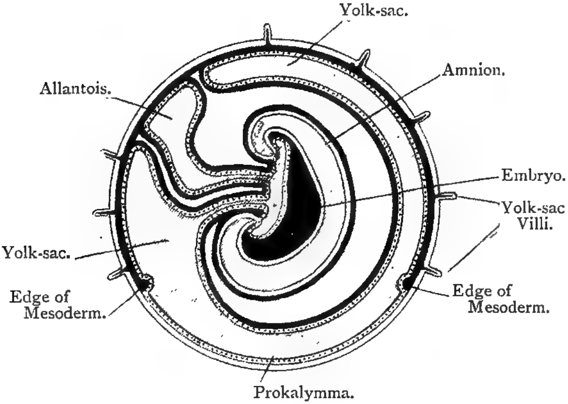
1. They are viviparous but have a very short period of uterine gestation, during which a yolk-sac placenta is present and an allantoic placenta only exceptionally.
2. The oviducts are divided into three parts—(1) Fallopian tube, (2) uterus, (3) vagina, and there is no fusion between the oviducts except at the lower part of the vagina.
3. Urogenital sinus and rectum open separately to the exterior, though surrounded by the same sphincter muscle.
4. Amongst numerous skeletal peculiarities we may note the presence of epipubic bones and of only one deciduous tooth on each side of each jaw.
5. The temperature is more constant than in *Prototheria*, but is lower than in *Eutheria*.

The condition of the placenta has been described. The allantois is obviously in a degenerate condition in the majority of *Metatheria* (*cf. Hypsoprymnus*), but in forms like *Phascolarctos* it is normal and possibly performs its primary function of respiration.

Recently, however, the discovery of an allantoic placenta in *Perameles* has shown us that at least one metatherian has advanced to the fœtal condition of the *Eutheria*. The structure of this placenta would seem to have certain

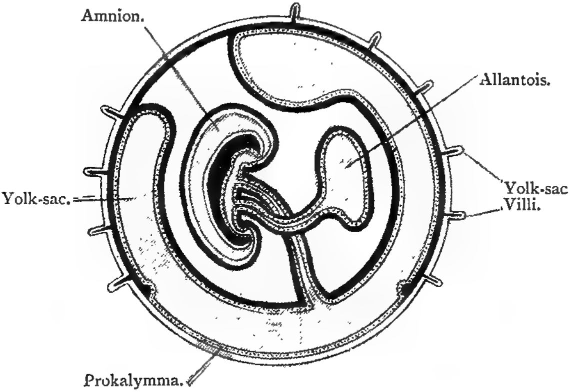
Fig. 340.—DIAGRAM OF PHASCOLARCTOS (*Koala*) EMBRYO AND ITS FŒTAL MEMBRANES.

(Modified from SEMON).



Note the yolk-sac villi, but none to the allantois.

Fig. 341.—DIAGRAM OF HYPSOPRYMNUS (A KANGAROO) EMBRYO IN ITS FŒTAL MEMBRANES. (Modified from SEMON.)



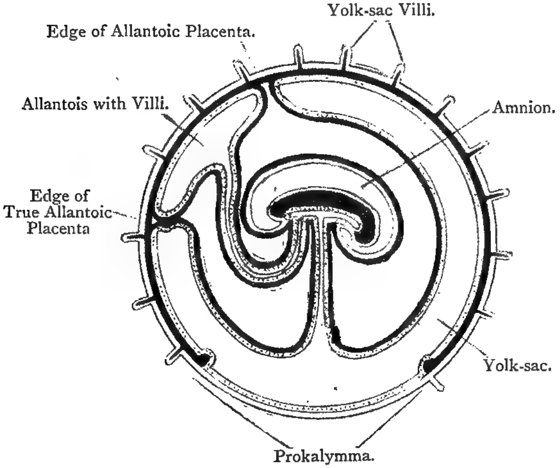
Note the degenerate allantois lying freely.

features which might indicate an independent evolution of the allantoic placenta within the group.

The epipubic bones have the same relations as those of the *Prototheria*, and the exact significance of the tooth-succession is not yet decided. The known facts are as follows :—

The majority of the *Metatheria* retain the one set of teeth throughout life, with the single exception of the third upper and lower tooth on each side behind the canine, hence termed the third premolar. This tooth usually resembles the teeth behind it rather than those in front, and at some time (earlier or later according to the species) it falls out and is replaced by a permanent tooth.

Fig. 342.—Diagram of Embryo of Perameles with Fœtal Membranes.
(After Hill.)



Note the allantoic villi.

The next fact to note is the later discovery of a series of tooth-germs in the front of the jaw, which never cut the gum but are absorbed after reaching a certain stage. The deciduous premolar is said to rise in connection with these, and the most reasonable view seems to be to regard these germs and the deciduous premolar together as the lacteal or deciduous series and the replacing premolar, together with the other functional teeth, as the permanent series. The difference between the *Metatheria* and *Eutheria* in their dentition would then resolve itself into one of degree only, the former having reduced their lacteal dentition till only vestiges of all but the last remain. This reduction might be correlated with the great development of the lacteal nutrition involving a sucking mouth and loss of function for teeth till a later period in life.

Other structural features of the *Metatheria* are as follows :—

There is a prolonged period of mammary gestation, during the early part of which the young are fed by the contraction of muscles over the mammary glands, the milk being injected down the throat of the young. In a large number of the *Metatheria* a fold of the abdominal integument envelops the young, forming a pouch or marsupium. The teats are long and are always abdominal in position.

The brain is small in proportional size and has a large anterior commissure but a small corpus callosum, as in *Prototheria*. The skull of a metatherian may be known by the following peculiarities, of which the majority are usually present :—

1. The angle of the mandible is inflected. (See Fig. 349.)
2. The lacrymal foramen is outside the orbit.
3. The malar extends backwards to the glenoid cavity.
4. The bony palate is incomplete.

The inflected mandibular angle is probably a trace of the modification by which the quadrate bone has become the tympanic, the malar probably in early types extending back behind the squamosal to the quadrate (see ear-ossicles). The lacrymal foramen was probably primitively outside the orbit, and the complete bony palate is a mammalian character, its incompleteness hence indicating an early type.

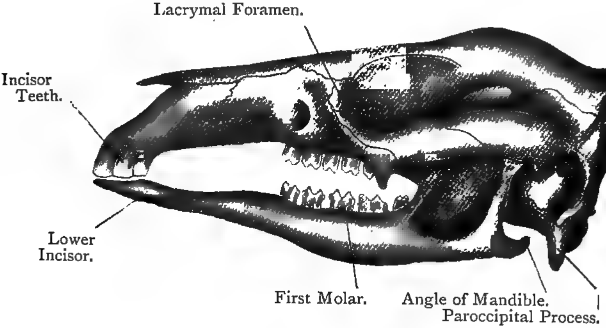
These skeletal features may be illustrated by taking the kangaroo as a type of the *Metatheria*.

## THE KANGAROO (*Macropus*).

The kangaroo belongs to the order *Diprotodontia* or herbivorous section of the *Metatheria*.

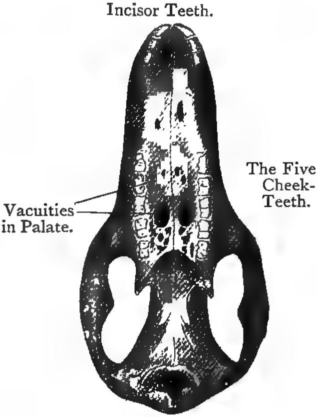
The skull is seen in side view in Fig. 343. Notice specially the continuation of the malar to the glenoid cavity, and the situation of the lacrymal foramen outside the orbit, the incomplete ossification of the palate and the inflected angle of the lower jaw.

Fig. 343.—LATERAL VIEW OF SKULL OF A YOUNG KANGAROO. (*Ad nat.*)



Note the dentition with only two lower incisors, no canines and five cheek-teeth. Also the Metatherian characters.

Fig. 344.—VENTRAL VIEW OF SKULL OF KANGAROO × ¼. (*Ad nat.*)



The dentition is peculiar. There are three upper incisors, flat and chisel-shaped, then a space or diastema in which there are no teeth. The canines are absent, though occasionally present in some kangaroos, and there are five cheek-teeth. But the true dental formula of a kangaroo is 3.0.2.4, so that there should be *six* cheek-teeth in all. The reason for the discrepancy is that the first premolar drops out at the same time that the second or last premolar replaces its antecedent "milk" tooth, so that only one premolar persists.

Another peculiar feature is that a younger kangaroo with the milk premolar not yet replaced also has only five teeth in all, because the last molar does not appear till the first premolar has dropped out.

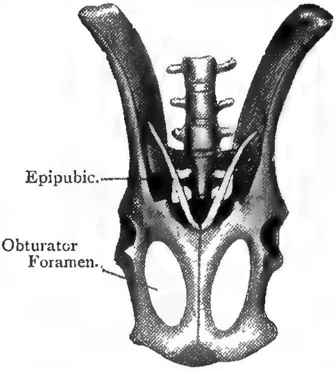
Thus, although the old kangaroo has only five back teeth, of which the first is the *second premolar* and the other four are the molars, the dental formula of the species is 3.0.2.4, because another premolar has been lost during life in front of the remaining teeth. The lower jaw has one long incisor on each side which has a cutting edge down each side. The two rami of the mandible are bound by ligament only, which permits a movement of one ramus upon the other. When the two posterior ends of the rami are approximated the incisor teeth diverge and cut any substances between them and the upper incisors of each side. On divergence of the two posterior ends the two incisors come together like the blades of a pair of scissors and sever any substances lying between them. Hence the kangaroo differs from the sheep and horse in *cutting* its forage rather than breaking it. There are no canines and the premolars and molars resemble those of the upper jaw. The inflected angle is another metatherian character.

In the vertebræ the chief feature to notice is the presence of chevron-bones in the tail. These hang down under the vertebræ and are usually present only in those mammals which have a highly-developed tail. The fore-limb is small and has five complete digits with claws. The shoulder-girdle is closely similar to that of the *Eutheria*, the coracoid and precoracoid elements being only represented by vestiges. The hind-limb usually has only four digits, the hallux or big toe being lost. Of the remainder, the fourth is very large and strong, with a powerful claw; the fifth is smaller and the second and third are reduced to attenuated remnants. These two are united together in one flap of skin from which the two little claws protrude. This very peculiar condition is known as *syndactylism.* It is not a true metatherian character, as it is only found in the *Diprotodontia* and one family of the *Polyprotodontia*

(*Peramelidæ*). It is, however, confined to these and not found in the *Eutheria*.

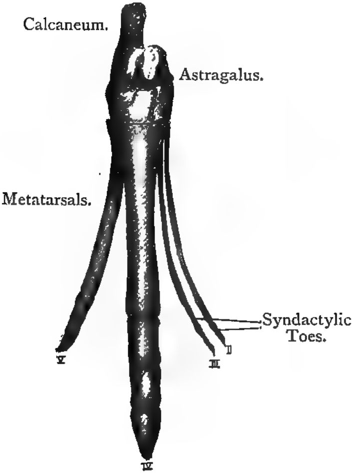
The tibia and fibula are very long and the femur is short but powerful. The pelvis shows well the large epipubic bones, found not only in *Metatheria* but in *Prototheria*.

Fig. 345.—PELVIC GIRDLE OF THE KANGAROO × ¼. (*Ad nat.*)



The foot of the kangaroo is modified for rapid locomotion, mainly by jumping, and the toes are correspondingly reduced. In some respects it is not unlike that of the two-toed ostrich. The vestigial second and third toes take no part in locomotion but may be useful for scratching the fur.

Fig. 346.—HIND-FOOT OF KANGAROO × ¼. (*Ad nat.*)



Note the absence of the hallux, the large fourth toe and the syndactylic second and third.

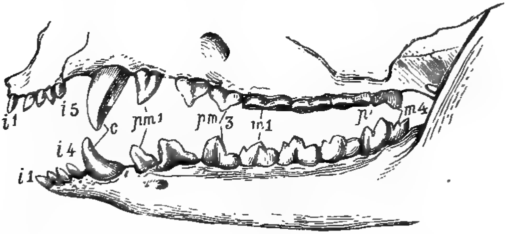
## ORDER I.

### *Polyprotodontia.*

The *Polyprotodontia* are so-called because they have a large number of front or incisor teeth. There are always more than three pairs of incisors in the upper jaw, usually four or five; hence the skull of a polyprotodont can, apart from other metatherian characters, be recognised at once by the presence of more than three pairs of upper incisors. The canines are large and prominent and the molars are cusped. In other words, the *Polyprotodontia* have a typical carnivorous dentition, and all are flesh- or insect-eaters. They are aquatic, cursorial, fossorial, or arboreal.

Family I.—**Didelphidæ** comprise the *Opossums*, found in the warmer regions of America. They are usually "true arboreal" and hence have an opposable hallux or big toe, the other four toes being nearly equal and each bearing a claw. The Yapock, however, is aquatic and has webbed feet. The opossums vary in size and coloration and there is a large number of species.

Fig. 347.—JAWS AND TEETH OF THE OPPOSUM (*Didelphys*).



Note the five upper and four lower incisors, long canines, sharp cusped molars with four true molars $\left(\frac{5134}{4134}\right)$. An essentially carnivorous dentition.

Family II.—**Dasyuridæ** comprise a number of carnivorous and insectivorous animals found in the Australian region. They vary in size from the Tasmanian wolf *(Thylacinus)* to the little mouse-like *Phascogale*. The Tasmanian "devil" *(Sarcophilus)* has the fossorial habits of the badger, and the Dasyures *(Dasyurus)* are much like small civets. The Banded Anteater *(Myrmecobius)* has a great number of small teeth and it has no pouch.

Family III.—**Peramelidæ** comprise a number of small animals, the Bandicoots, found only in the Australian region. They are "small-flesh" eaters (worms, insects and occasionally vegetable diet).

They are interesting for two structural features, viz., the presence of an allantoic placenta and the syndactylic condition of the hind-foot (see Diprotodontia). The "Native Rabbit" *(Peragale)* is fossorial.

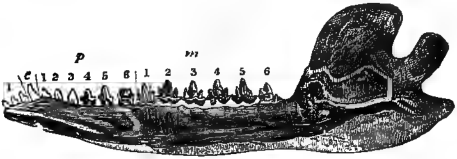
Family IV.—**Notoryctidæ** is made for the curious metatherian mole *(Notoryctes)*. A true fossorial type found in the sandy districts of central Australia. Its structure is adapted for rapid burrowing and in this respect shows a likeness to the fossorial armadillos and to the mole.

Distribution.—The Family of the Opossums is found extending throughout the American continent, except the extreme north. The other three families are found in Australia or the Australian district, including Tasmania and New Guinea.

This present-day distribution of *Polyprotodontia* differs from that of the past. There are a large number of mesozoic mammals found widely scattered in Britain, Europe, United States and elsewhere, which, mainly in their dental character, seem to resemble the modern *Polyprotodontia* (especially *Myrmecobius*). These appear to indicate that the distribution of the *Polyprotodontia* was in these early times much wider than at present (*cf.* *Diprotodontia*).

Fig. 348.—Inner View of Left Ramus of Lower Jaw of Amphilestes Broderipi.

(From Flower and Lyddeker, after Owen.)



From the Stonesfield Slate.

## Order II.—*Diprotodontia.*

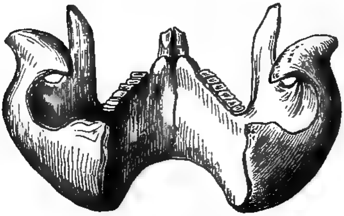
The *Diprotodontia* are essentially herbivorous, and hence they have few chisel-shaped incisors, never exceeding $\frac{3}{1}$ and in some cases being reduced to $\frac{1}{1}$. The incisors of the lower jaw never exceed one pair, hence the name of the order. The lower canines are always lost, and often the upper molars have not the sharp cusps of the *Polyprotodontia* but have blunt tubercles more suited for crushing vegetable food. The limbs vary in character, but they always have the syndactylic hind-foot described in the kangaroo. (This feature is also found in the *Peramelidæ.*)

Family I.—**Macropodidæ.**—A large family of kangaroos and their allies. The kangaroo has been used as a type of metatherian skeleton. The hind-limbs and tail are enormously developed for jumping. At rest the kangaroo places the whole foot on the ground. All are strictly herbivorous and the stomach is complex, the front part being sacculated and containing the œsophageal and cardiac glands. The true kangaroos and wallabies are cursorial, playing the part of antelopes or deer in the districts they frequent. The rat-kangaroos are smaller, nocturnal and partially fossorial. Others, the tree-kangaroos, are arboreal.

Family II.—**Phalangeridæ.**—A family containing a great number of small arboreal animals. They are usually woolly and often have a prehensile tail. In addition, a number of them have a flap of skin or patagium which enables them to "sail" from tree to tree (incidental ærial). From these habits it is not surprising to find five toes all present on each limb and the hallux opposable to the other four. These phalangers approach more nearly the *Polyprotodontia*, especially as they have additional small functionless incisors in the lower jaw, and their diet is by no means strictly herbivorous. The common koala (*Phascolarctos*) and the flying squirrels (*Petaurus*) should be noted.

Family III.—**Phascolomyidæ.**—A very small family, consisting of about three species of wombats. The wombat (*Phascolomys*) is a small bear-like terrestrial or partially fossorial animal. All five digits are retained on both limbs and the syndactylism is not very pronounced. But the peculiar dentition is the great feature of this form. Just as similar external conditions cause a resemblance of the Tasmanian wolf (*Thylacinus*) to the dog, or *Notoryctes* to a mole, so here we have a metatherian repetition of the eutherian rodent. There is one pair of incisors in each jaw; they grow from persistent pulps and have enamel only on the front surface. There are no canines and there is a large space or diastema between the incisors and the "cheek-teeth." These are five in number, one premolar and four molars; $\frac{1014}{1014}$ is the formula.

Fig. 349.—Posterior View of Lower Jaw of Wombat.



Showing inflected angle.

Family IV.—**Epanorthidæ.**—Another small family which contains a remarkable little animal, the selva or opossum-rat (*Cœnolestes*). The selvas have recently been found alive in S. America though they were supposed to be extinct. They are diprotodont in their lower jaw, but the teeth of the upper jaw more nearly resemble certain of the *Polyprotodontia.* They differ from the rest of the *Diprotodontia* in not having a syndactylous foot, though doubtful traces of syndactylism in some of their fossil allies have been stated to exist.

Distribution of Diprotodontia.—The families of the kangaroos, phalangers and wombats, in fact nearly all the

*Diprotodontia*, are confined to the Australian region; but the selvas, occurring as they do in South America, form a remarkable exception. We have already seen that the *Polyprotodontia* have three families in the Australian region and one in America, and the same is now known to be the case in the *Diprotodontia.* The possible explanations of this distribution will be given in the chapter on Geographical Distribution. We may here note that syndactylism, or the curious union of the second and third hind-toes, occurs in one family of the *Polyprotodontia* and in three families of the *Diprotodontia*, but that all these families are found in the Australian region.

The *Diprotodontia* do not appear in the past to have had a much wider distribution than at present, though there are one or two extinct forms which are found in the same regions as their modern relatives.

*Diprotodon* was a large rhinoceros-like animal of Pleistocene times. It is intermediate in structural characters between the kangaroos and the phalangers. *Thylacoleo* was another large phalangeroid type, and *Phascolonus* from Queensland was a large tapir-like form of wombat. These types would lead us to suppose that the *Diprotodontia* of Australia attained considerable dimensions in the past, and the absence of diprotodont remains outside the Australian area seems to point to an evolution of these herbivorous animals from polyprotodonts within that area, especially as the Australian remains do not date further back than the Pleistocene. In South America, however, the selvas and the fossil *Epanorthus* extend back to the mid-tertiary epoch, perhaps indicating that the diprotodont type was evolved in this region at an earlier period than in Australia, but was never so successful for want of isolation from eutherian types.

# CHAPTER XXVIII.

## *MAMMALIA*—(*Continued.*)

## Sub-Class III.—Eutheria.

TYPES 2 AND 3, HORSE AND OX; 4 AND 5, DOG AND CAT.

The *Eutheria* mark the culminating point in mammalian structure and, as might be supposed, the members of this sub-class show the greatest diversity of adaptive modifications. As a general rule we may say that the hæmal form of embryonic nutrition is highly developed, the chief organ forming the hæmal placenta being the allantois. The yolk-sac placenta, when formed at all, is merely a transitory structure of little functional significance. Further advances upon the metatherian type are found in the reproductive organs. The urogenital and anal openings are, as a rule, quite distinct, the perinæum separating the two orifices: this is especially evident in the male. The lowest part of the oviducts, the vaginæ, are always fused together and with few exceptions the second or uterine portion shows also varying grades of fusion, such as the bicornuate and bipartite uterus: this fusion of the uteri probably has partly to do with a reduction in the fecundity. Correlated with the high development of a hæmal gestation there is a tendency to a reduction in the period of lacteal gestation, though the mammary glands are still well developed and the mammæ are permanent.

In the skeleton there are important features. The teeth are typically diphyodont and heterodont, and it is usual to derive the very numerous modifications from the typical dentition of $\frac{3\,1\,4\,3}{3\,1\,4\,3}$. This typical dentition is, indeed, only found in very few types. of which perhaps the pig is the best known; but the assumption of loss of certain teeth in some, and of multiplication of molars in others by secondary division, makes it possible to derive the more aberrant types. Of these we may instance the *Edentata* and *Cetacea* as differing widely from the type. The typical dentition indicates two very important differences from the *Metatheria*. Firstly, the incisors are never more than three on each side and, secondly, the molars are not more than three. We have seen that four incisors and four molars are the rule in the *Polyprotodontia* and that four molars are usual in the *Diprotodontia*. Lastly, we may call to mind the peculiar condition of the deciduous or milk-dentition in the *Metatheria*. A complete milk series (diphyodont) is the rule in *Eutheria*.

Turning to the rest of the skeleton we find that, as in *Metatheria*, the coracoid element of the shoulder-girdle is reduced to a mere vestige; the coracoid process of the scapula, and the episternum is absent as a separate bone. In the pelvic girdle there are no epipubic bones.

The temperature of *Eutheria* is higher than that of either *Metatheria* or *Prototheria* and is also more constant; that is to say, the temperature of the body varies only within narrow limits whatever the temperature of the surroundings. This is only another instance of the higher type having its internal economy adjusted in such a way as to be independent of the immediate surroundings. The individual variations within the sub-class are from about 35° C. to 40° C.

Modern *Eutheria* have not only an important structural distinction in their brain from that of the other sub-classes, such as the great development of the corpus callosum and a corresponding reduction in the anterior commissure, but also an advance in the type of brain. It usually forms a greater proportion of the bulk of the body, the cerebrum gradually assuming more and more comparative importance as the higher orders are reached. Thus the cerebrum comes to completely overlie not only the optic lobes but the cerebellum as well, and its surface becomes folded into numerous convolutions. Apparently the earlier fossil forms (*e.g.*, Eocene) had far smaller brains in proportion, and a gradual increase in size and complexity of the brain therefore appears to be one of the most important lines along which mammals have progressed. The exact significance of this fact is not quite clear, but as the brain is the special centre regulating interaction between the organism and its environment, it is probably the structural expression of the increasing "complexity" of life now followed by higher organisms. (See page 462).

At the present day the *Eutheria* are tolerably sharply differentiated into orders, but the energy of palæontologists has in recent times unearthed a number of transition forms which, whilst adding enormously to the difficulties in the way of a "natural" classification, enable us to trace the descent of the greater number of our modern types.

Adaptive modification is very conspicuous in the *Eutheria*, and, as elsewhere, it has taken place to a large extent independently of genetic connection. At the same time we find in several cases that the two are parallel. Thus the orders *Sirenia* and *Cetacea* are entirely aquatic or natatorial, the *Chiroptera* are entirely ærial, and as a rule the *Primates* are arboreal, though only of the "transition" group, whilst the true cursorial are mainly in the *Ungulata*.

Again, we find as a general rule that the lower or more primitive types affect the primitive terrestrial, arboreal, or fossorial habitats usually with nocturnal proclivities. Instances of this may be seen in the *Edentata*, *Insectivora*, a number of *Rodentia* and the most generalised of the *Carnivora*.

We may illustrate the structure of the **Eutheria** by a short study of the following types :—

| | | |
|---|---|---|
| 1. | Rabbit, | Primitive terrestrial. |
| 2–3. | Horse and Ox, | Cursorial. |
| 4–5. | Dog and Cat, | Transition cursorial. |
| 6. | Sloth,. | Arboreal. |
| 7. | Mole, | Fossorial. |
| 8. | Porpoise, | Natatorial. |
| 9. | Bat, | Ærial. |

1. The Rabbit has already been described.

1. The **Primitive Terrestrial** Types. — Hedgehog, Shrew and Bear.—We must suppose that the first mammals were small generalised terrestrial mammals, with tubercular teeth and omnivorous diet, inclining to insects and "small-flesh." They merge into the incidental arboreal, fossorial and cursorial forms: some of the *Insectivora* of the present day probably give us an approximate semblance of them. They were

possibly able on occasion to scratch or burrow, to run and climb. From this it will be seen that the later mammals have become specialised in varying degrees for special habitats, the five principal of which we will notice.

A study of man will show that he does not agree with the true or specialised group of any of these types, but that he would really fall into the incidental, if not the transition, group of all but the ærial. To this adaptability to all environments without a corresponding modification involving loss of organs and specialisation, man probably owes his position at the head of the mammalian world. In other words, as the environment is ever inconstant and specialisation means a modification for one particular temporary form of environment, it also means certain extinction of the type, sooner or later. True evolutionary progress is effected by an acquired reactivity to a *variety* of environmental surroundings and not by an adaptation to a "special" environment, which checks further progress and culminates in extinction of the type.

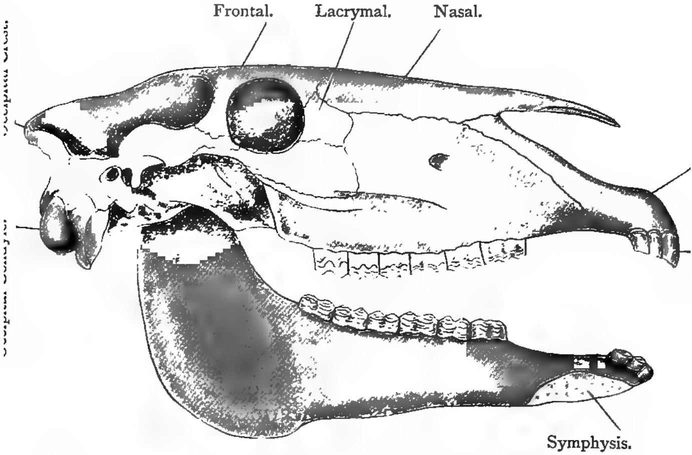
## 2 and 3.—THE HORSE (*Equus caballus*) AND OX (*Bos taurus*).—CURSORIAL.

The horse and ox represent two culminating points in the evolution of the large herbivorous cursorial type, the former belonging to the sub-order *Perissodactyla* and the latter to the *Artiodactyla*, which together comprise the order *Ungulata* or hoofed animals.

Both the horse and ox stand high on their four legs and walk only on their toes (*digitigrade*). In each case the legs and neck are long. As they obtain their food from the level of the ground, or graze, the elongation of the neck and head must keep pace with that of the limbs. They are surrounded in natural conditions by the carnivorous types, the large "cats" and the "dogs," and they are endowed with keen senses. The sense of hearing is assisted by the large external ear or pinna which can be turned in any direction to catch the sound. That of sight is mainly assisted by the long neck which adds considerably to the field of vision. The sense of smell is also highly developed. The effects of these developments in the *Ungulata* will be seen in corresponding modifications of the carnivorous types (see Dog and Cat).

Both types are covered with dense hair which is particularly long upon the tail. This organ is mainly used for protection against the attacks of certain flies. The horses and their close allies, the zebras and asses (*Equidæ*), frequent high, open, grassy plains, their limbs being adapted for fleet movements over hard ground. Even in a domestic state the horse shows a peculiar aversion to trusting itself to soft or boggy ground. On the other hand, the ox family (*Bovidæ*) is at home upon any grassy pasture, whether in forest glades or in rocky districts. The food is in each type much the same and the long soft lips assist greatly in obtaining it. We shall see below, however, that the method of feeding or dealing with the food is different, involving certain differences in the structure of the stomach.

Fig. 350.—Lateral View of Horse's Skull.
The right mandible has been removed. (*Ad nat.*)

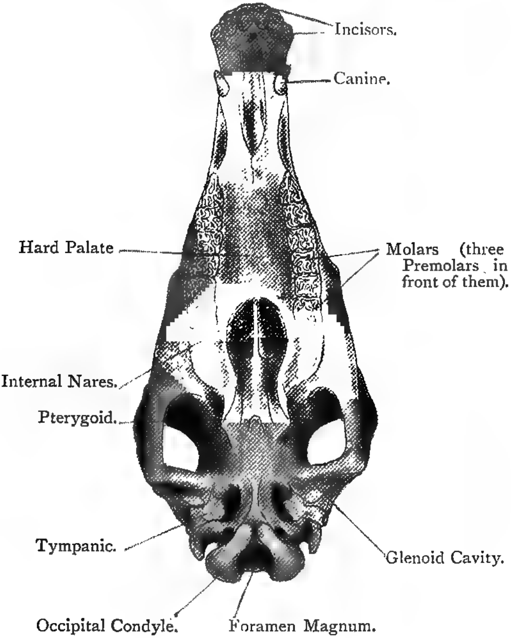


Note complete orbit, large nasals and lacrymals, and predominant facial regions.

In habits both families are, as a rule, gregarious, congregating in herds. This habit conduces to mutual protection, and is made possible by the wide expanses of pasture at present existent on the earth's surface, though it involves more or less extensive periodic migrations from place to place.

Bearing in mind both the points of similarity and of difference in the habits of the two types, we can pass to the skeleton. Let us first glance at the skulls of the two types. Notice in both the large development of the facial region in comparison with the cranial. This is due not only to the large maxilla, but also to the part taken by the jugal and the lacrymal in the formation of this region.

Fig. 351.—VENTRAL VIEW OF SKULL OF HORSE (*Equus Caballus* × $\frac{1}{8}$). (*Ad nat.*)



Hence the small size of the orbit, which is also completely bounded by bone,* a postorbital process of the frontal descending to meet the zygomatic arch below.

In both types the mandibles are large and heavy, expanded behind into broad strong plates, evidently built

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* This complete closure of the orbit is not effected in the lower *Perissodactyla* (*e.g.*, Rhinoceros and Tapir), nor in the more primitive *Artiodactyla* (*e.g.*, Pig).

for long-continued and powerful masticatory movements. In the same way the molar teeth in both are ridged or tuberculated, the ridges being worn down very early in life, exposing the dentine. The parts between the enamel crests are filled up with *cement.* The enamel being harder than either dentine or cement, it always forms rough ridges with complex outline, on the inner side of which rests the dentine, on the outer the cement. In both the horse and the ox the crowns of the molar teeth are much elongated, forming the type called *hypsodont.* This condition, like the bony orbit, has been developed within the two sub-orders, many of the less specialised members of each order having short crowned or *brachydont* molars.

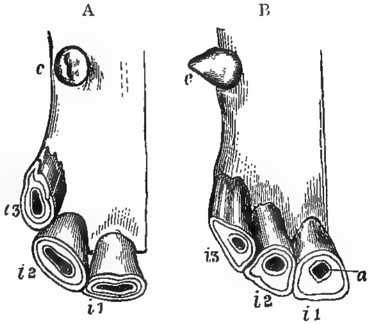
In this way the row of molars forms a crushing mill which is capable of reducing to a pulp the most siliceous of grasses, and the size of which largely accounts for the prominent facial region. The molar series is separated by a more or less prominent space or diastema from the front teeth, indicating a separation in function between the two series. The condyle of the mandible is transversely cylindrical, and allows of some lateral but little backward motion, owing to the presence of a postglenoid process of the squamosal.

Apart from these general resemblances, the differences are sufficiently striking. Firstly, we notice that the skull of the ox bears a pair of large bony processes or cores upon the frontal bones, which form the basis of support for the long hollow horns in which they are encased in the living animal. These horns, assisted usually by the speed of the animal, form the organs of defence, or even offence, of the large family to which the ox belongs (*Bovidæ*), whilst frontal organs of one kind or another (antlers, &c.) are largely found in the *Artiodactyla ;* there is no trace of them in the horse, which trusts to its speed, or on occasion to its kicking powers, for defence.

Less conspicuous distinctions in the skulls are the much larger nasals and the presence of an *alisphenoid canal* (through which runs the main branch of the external carotid artery) in the horse. These two features are small and may appear unimportant, but they serve to distinguish the two large sub-orders of the *Artiodactyla* and *Perissodactyla.*

Turning to the dentition there are sufficiently obvious differences. In the ox there are no incisors nor canines in the upper jaw, their place being taken by a horny pad. In the mandible there are three pairs of chisel-shaped incisors and a pair of canines which resemble incisors in shape and size. In the horse, on the other hand, there are three pairs of incisors in both upper and lower jaw which are of a peculiar shape. They have their terminal surface pushed in as a deep pit, partially filled with cement. On being worn flat the surface of the tooth presents two concentric circles of enamel, the inner circle becoming narrower with age. The canines are small and pointed and are only rarely present in the female.

Fig. 352.—Upper Jaw (left-half) of Young (A) and Old Horse (B).



As regards the molar series we have seen that there are considerable resemblances in the two types, and in each there are six functional teeth on each side, of which three are premolars and three are molars. Here the resemblances end. In most horses there is, at least in the adolescent stage, a very small first premolar in each upper jaw, which usually falls out at maturity. Thus the full dentition of a young horse may be given as $\frac{3143}{3133}$, but that of a mature mare is $\frac{3033}{3033}$. The dentition of the ox is $\frac{0033}{3133}$.

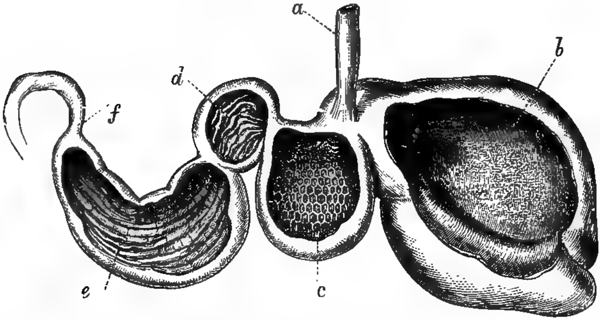
Though the patterns of the enamel in the molars have a general resemblance, a little study shows that they are derived from different types. The horse starts from the simple bilophodont type, found in the tapir, consisting of a pair of transverse ridges: this is further complicated, as in the rhinoceros, by a junction of the two ridges and by their bending into a crescentic outline: in the horse these ridges are still further twisted, the multiplication of enamel ridges being the end in view.

The ox, on the other hand, starts from the bunodont type found in the pig, with four principal crowns. These do not unite transversely, but each independently becomes crescentic, producing the *selenodont* or crescentic type of molar. The crescents may unite longitudinally but not transversely.

The study of the teeth of these two types shows that in this respect the ox is more specialised than the horse, a conclusion which agrees with the comparative structure of the stomach. The stomach of the horse is fairly simple; it is at most constricted into cardiac and pyloric portions, whereas that of the ox has four distinct parts or chambers.

Fig. 353.—Stomach of a Ruminant, Showing Internal Structure.

(Flower and Lyddeker.)



*a*, Œsophagus; *b*, Rumen (paunch); *c*, Reticulum (honeycomb); *d*, Psalterium (many-plies); *e*, Abomasum (reed); *f*, Duodenum.

The *rumen* (or paunch) is a large and capacious sac for storage of food; the *reticulum* (or honeycomb bag) is a small globose sac with reticulate walls: following this is the *psalterium* (or many-plies) with folded walls, succeeded by the *abomasum* (or reed) which is the true digestive stomach. The food is cropped and swallowed, passing down to the paunch, in which it is stored. After feeding, the animal retires to a secure retreat or at least comes to rest, and the food is passed by the reticulum up the œsophagus into the mouth. Here the process of mastication or rumination is effected by the molar teeth. The chewed food is then passed down to the psalterium and the abomasum where digestion commences. The horse, on the other hand, masticates his food at the time of feeding, and there is in this case no rumination or "chewing the cud." The rest of the alimentary canal is very similar in both types, the cæcum being large and the intestine long, characters usually found in herbivorous animals.

Returning to the rest of the skeleton we find that the vertebral column is of the same general type, the cervical vertebræ especially being markedly *opisthocœlous.* The axis vertebra has a crescentic odontoid process, another feature in which the horse and the ox converge, though the more primitive forms of each sub-order differ in having simple conical odontoid processes.

The dorso-lumbar vertebræ are *nineteen* in number in the ox, but *twenty-three* in the horse. In a similar manner the ox has usually twelve to fifteen pairs of ribs, whilst the horse has from eighteen to nineteen pairs. The ribs of the ox are usually flatter and broader. In both types the front dorsal vertebræ bear very long neural spines, to which is attached the elastic ligament (*ligamentum nuchæ*) running forward along the cervical vertebræ to the skull and supporting the weight of the head.

The difference in the number of dorso-lumbar vertebræ is probably due to the shifting of the pelvis further forward in the ox than in the horse, in its turn connected with the greater proportionate "pushing" power of the ox.

Now let us turn to the limbs and limb-girdles. In both the same plan prevails. The scapula is elongated and narrow, of the cursorial type, and the clavicle is absent; it is not required in animals in which the limbs are not moved inwards to the middle line and would indeed be a source of danger when, as in jumping, the weight of the body is thrown on to the fore-limb. The pelvis is of the same general type in each, with large ilia fusing not only with the primitive sacral vertebræ, but with three or four others in addition. The limbs have in the cursorial type to perform a great uniformity of movement, and by reduction and fusion from the pentadactyle type they approximate to the condition of a simple jointed lever. Thus in each case the ulna and fibula tend to disappear, their remains or vestiges being seen along the border of the radius and tibia respectively. The carpal bones are reduced to six in each case, and the tarsals to five or six in the horse and to four in the ox. In addition, the two rows are firmly interlocked

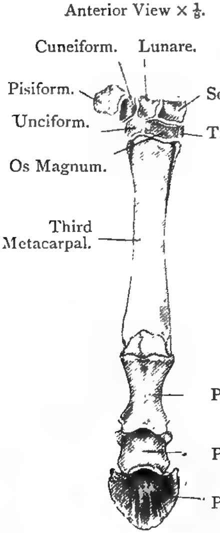


Fig. 354.—The Right Manus of a Horse. (*Ad nat.*)

Anterior View × ⅛.

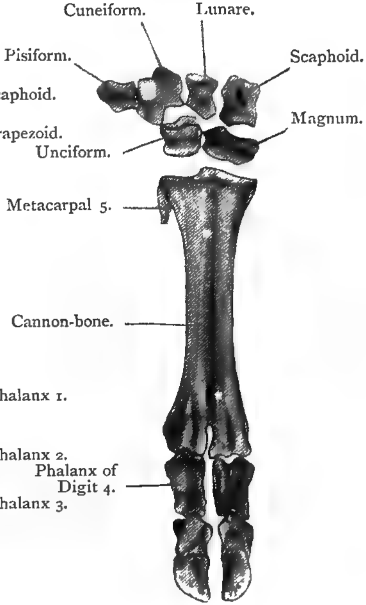


Fig. 355.—The Right Manus of an Ox × ¼. (*Ad nat.*)

and lie alternately with each other (*diplarthrous*) to prevent all lateral twisting. The mode of locomotion is digitigrade, the toes alone touching the ground, and the metacarpals and metatarsals are reduced in number and elongated. The terminal phalanx or phalanges bear horny hoofs.

With all these general resemblances we can note such important differences that it is an easy matter to distinguish all the limb bones of the two types. The humerus of the ox has a very prominent *great tuberosity* which bends over the condyle as a hook-shaped process and the bicipital groove is single; in the horse there is a double bicipital groove and the great tuberosity is simple. The ulna of the ox extends down the side of the radius for the whole distance, whereas that of the horse has fused on to the radius more completely, and can be traced only at most about half-way down. In the carpus the suture separating the os magnum and the unciform is in the middle line, whereas in the horse the magnum is much larger than the unciform and the dividing suture is towards the outer side. This is directly connected with the important difference in the manus. Both have been evolved from a pentadactyle type, but the ox has lost the first digit or pollex, followed

Fig. 356.—Tibiofibula of a Horse × 1/8. (*Ad nat.*)

A, Anterior View.
B, View of Distal Extremity.

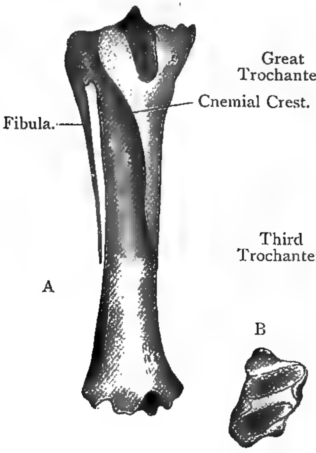
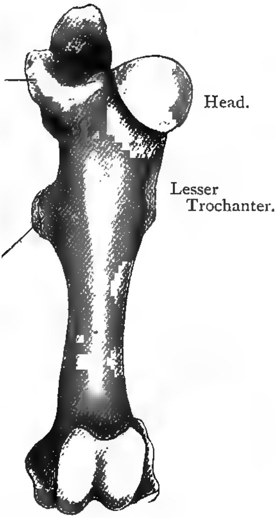


Fig. 357.—Right Femur of a Horse. (*Ad nat.*)

Anterior View × 1/8.



by a great and equal reduction of the second and fifth digits, leaving the third and fourth of equal size. Metacarpals three and four fuse together to form the so-called "cannon-bone," which still, however, bears distally the two functional digits (three and four) and two small vestigial digits (two and five). The former carry the two paired hoofs, which appear superficially like a "cloven" hoof, and the latter also bear small hoofs or horny nodules. In the horse the same derivation from the pentadactyle type can be traced, but the weight is borne predominantly on the third digit. Thus the first and fifth disappear altogether, the

Fig. 358.—The Left Pes of an Ox × $\frac{1}{4}$.

(*Ad nat.*)

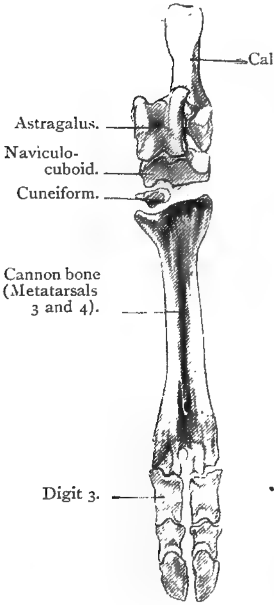
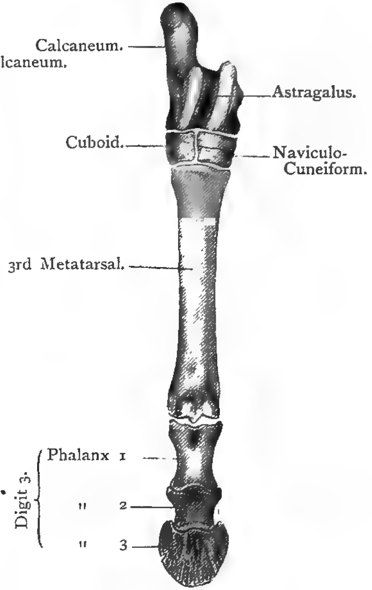


Fig. 359.—Right Pes of Horse (*Equus Caballus* × $\frac{1}{6}$).

(*Ad nat.*)



second and fourth digits also go, though their metacarpals remain as the two splint-bones down the hinder borders of the large and elongated third metacarpal or "cannon-bone," which bears the third digit and the single hoof. Just as in origin the cannon-bone of the ox is formed of two metacarpals and that of the horse is one, so they can be immediately distinguished by the double hinge-joint at the distal extremity of the former and the single hinge-joint on that of the latter.

In the hind-limb the femur is recognised by the presence in the horse of a *third trochanter* on its outer border, and the tibiofibula or tibia, carrying the fused remnant of the fibula, will be seen in the ox to have three articular facets at its distal extremity. The two larger articulate with the astragalus, as in the horse, but the small outer one articulates with a small condyle on the calcaneum. The astragalus in the horse has a flat facet for the navicular below it, but that of the ox has a hinge-joint with the naviculo-cuboid bone below it, which gives it a double appearance, a hinge-condyle at each end. In other words, the horse has only a crurotarsal joint, as in most mammals, but the ox has a certain amount of intertarsal movement as well as the crurotarsal. Of the distal tarsals the navicular and cuboid fuse *across* in the ox to form a *naviculo-cuboid*, whereas in the horse the navicular commonly fuses with the ecto-cuneiform below it, or remains distinct, but never fuses with the cuboid. There is usually a small middle cuneiform in the horse over the inner splint bone (digit two). The digits of the hind-foot are modified in a closely similar way to those of the fore-foot.

The metacarpal "cannon-bone" of the ox is distinguished from the metatarsal by the much shallower median groove in the former, and the metacarpal "cannon-bone" of the horse is flattened from the front behind, whereas the metatarsal is round in cross section.

If it be remembered that the horse's limb is formed from hypertrophy of one digit and the bones in the main axis above it, whereas that of the ox is really bilateral or formed from two digits and the bones above them, which are only in later geological times fusing together to form one, it is easy to account satisfactorily for the persistent calcaneo-fibular joint, for the fusion across the middle line of navicular and cuboid, for the "double" astragalus, and for the fused third and fourth metapodials.

The numerous structural resemblances and differences in the horse and the ox we may sum up as follows:—

1. Resemblances of the two types which are due to descent from a common mammalian ungulate ancestor. These are characters of ordinal rank or the distinctive characters of the order *Ungulata*. The most important are the presence of a dentition adapted for a vegetable diet, heterodont and diphyodont; the commencing adaptation of the limbs for terrestrial locomotion with claws tending to assume the condition of hoofs; little or no clavicle.

2. Resemblances due to evolution on similar lines since the divergence from a common stock. Of these we may instance (1) The assumption of a digitigrade locomotion and reduction in number of toes. (2) The interlocking of carpal and tarsal bones (diplarthrous) connected with the increasing size and rapidity of movement on harder ground. (3) The expansion of the facial region, correlated with the increased size of molar teeth, and the completion of bony orbit. (4) The conversion of brachydont teeth into hypsodont, the increased complexity of the enamel ridges and the addition of cement.

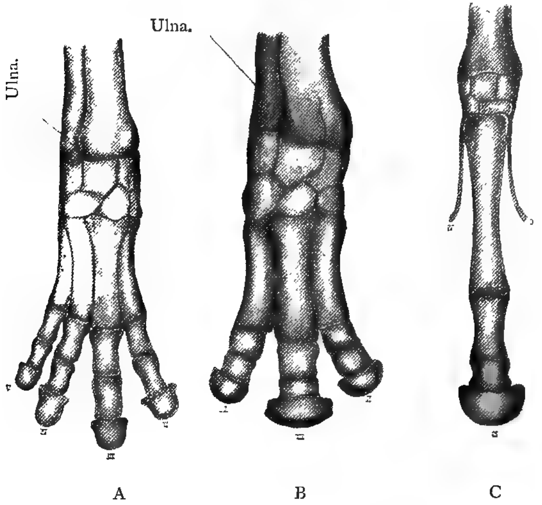
3. Differences due to evolution on somewhat distinct lines since divergence from the common ancestor. The principal of these are (1) The modelling of the limbs in the horse, on the one-toe principle, the main axis passing down the third toe, and in the ox, on the two-toe principle, the main axis passing down between the third and fourth toe. (2) The formation in the ox of bony frontal organs (horns and horn-cores) for defence and their absence in the horse. (3) The different method of feeding involving a more complex stomach and loss of upper incisors in the ox. (4) The different principle upon which the complex molars are evolved. (5) Other peculiarities, such as the presence of alisphenoid canal, of twenty-three dorso-lumbar vertebræ, and of broad nasals in the horse. (1), (4) and (5) are characters of subordinal value, as they are distinctive of the *Artiodactyla* and *Perissodactyla*.

Before leaving these two important types we may inquire—How do we know that they have been descended in the past from a common ancestor which had five toes, was plantigrade, and had other primitive characters? The proofs are several.

Firstly, we note that the horse has splint bones or vestiges of metapodials, 2 and 4, and that the ox has two complete though small vestigial digits, the second and fifth, making four in all. As the pentadactyle limb is the only type from which all mammalian limbs can be derived by a supposition of fusions and reductions having taken place in the course of evolution, it is legitimate to infer that these forms have degraded from this type and lost four and three functional toes respectively.

Fig. 360.—THE MANUS OF (A) THE TAPIR; (B), THE RHINOCEROS AND (C) THE HORSE

(After FLOWER.)



Note the alternate carpal bones and the predominant third digit in each, but the gradual reduction in the other digits.

Secondly, the types which are most kindred in structure to the horse and the ox, *i.e.*, the other *Perissodactyla* and *Artiodactyla* respectively, arrange themselves in two series, thus:—

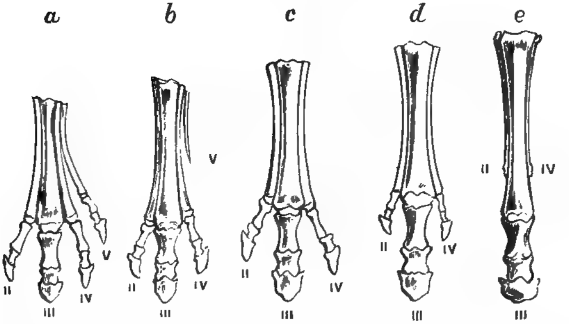
| *Perissodactyla*— | *Artiodactyla*— |
|---|---|
| Tapir. | Pig. |
| Rhinoceros. | Chevrotain. |
| Horse. | Ox. |

In all three of the first series the third toe is the largest and strongest, but whilst the tapir has four toes touching the ground (in the fore limbs), the rhinoceros has three and the horse has one. Hence the conclusion is irresistible that the tapir, haunting the soft ground of forests, has remained at the four-toed stage; the rhinoceros has progressed slightly further and given up its fifth toe; and the horse, frequenting drier, harder ground and moving more rapidly, has lost all but the third or middle toe. The same lesson is taught by the other series in which the third and fourth toes are of equal size. Here the pig has four toes, all touching the ground, though the second and fifth are smaller and shorter than the others. The chevrotain and ox show a further reduction of these two toes, and the camel (in this respect the last of the series) has lost all trace of them and has only the third and fourth. (See Fig. 391, page 577.)

We have seen that the same series can be traced in the teeth, the simple bilophodont teeth and nearly complete dentition ($\frac{3143}{3133}$) of the tapir leading through the rhinoceros to the horse, whilst the simple bunodont molars of the pig, with its full dentition of $\frac{3143}{3143}$, leads through the chevrotains, with no upper incisors but still with canines, to the very specialised condition of the ox. A similar gradation can be made out in other structural features, such as the loss of fibula and ulna and fusion of tarsal bones.

Fig. 361.—The Foot Skeleton of the Horse and Four of its Ancestors.

(From Marsh.)



Showing Gradual Reduction of Outer Toes and Increase of the Middle Toe.

a, *Pachynolophus* (Eocene); b, *Anchitherium* (Early Miocene); c, *Anchitherium* (Late Miocene); d, *Hipparion* (Pliocene); e, *Equus* (Pleistocene).

Thirdly, there is the direct evidence furnished by fossil forms. In the case of the horse and the ox the series is practically complete. We cannot do more here than merely enumerate the known ancestors of the horse. Fossil remains of the horse itself are found no further back than the Pliocene in Europe, or possibly the Miocene in India. *Hipparion*, as large as a donkey, and with three toes, is found in the

Pliocene and Upper Miocene; *Anchitherium*, an animal about the size of a sheep, with three functional toes (like the rhinoceros), is found in the late Miocene; whilst a similar form in the early Miocene shows the vestige of the fifth toe as a small metapodial splint-bone. *Pachynolophus* of the Upper Eocene and *Hyracotherium* of the Lower Eocene were still smaller (about the size of a hare), and in the front-limb they had four toes (2, 3, 4 and 5) and three on the hind—in fact, resembling in this feature the tapirs; one species of *Pachynolophus* shows a vestige of the first digit in the presence of a splint-like metacarpal. These types also show the changes in other structural features, such as the teeth. (See Fig. 361.)

In the New World the same series has been made out and carried back even further to the little *Phenacodus* of the Eocene, with five perfect plantigrade digits and a complete dentition, which, with its allies, forms a meeting point of the modern *Ungulata.*

A very interesting point is the separate series of the New and Old World, and it has been maintained with much reason that the horse was independently evolved in the two hemispheres.

In the case of the ox a similar series can be made out, true *Bovidæ* dating back to the Upper Miocene, whilst forms allied to the pigs and chevrotains go back to the Eocene. On this point we may quote Flower and Lyddeker:—"The primitive Artiodactyles, with the typical number (44) of incisor, canine and molar teeth, brachydont molars, conical odontoid process, four distinct toes on each foot, with metapodial and all carpal bones distinct, no frontal appendages, and (in all probability) simple stomach and diffused placenta, were separated at a very early period into Bunodonts and Selenodonts, although there is evidence of intermediate forms showing a complete transition from the one modification to the other. These and other fossil forms so completely connect the four groups—Suina, Tylopoda, Tragulina and Pecora—into which the existing members of the sub-order have become divided, that in a general classification embracing both living and extinct forms these divisions cannot be maintained."

## 4 and 5.—THE DOG (*Canis familiaris*) AND CAT (*Felis domesticus*).—TRANSITION CURSORIAL TYPES.

The dog and cat are examples of mammals which, whilst having fully adopted the quadrupedal terrestrial mode of life, have retained the varied use of their limbs in other directions to such an extent that these limbs do not show complete adaptation to a cursorial habit.

Both belong to the large and important order of *Carnivora*, which, in the most typical representatives, feed upon the flesh of other mammals. This is usually the case with both the dog and cat, but the latter, like the whole family of *Felidæ*, is in this respect the most typical of all the *Carnivora.* It is a commonplace observation that a dog may be fed indefinitely upon vegetable food and not suffer in health, a diet hardly suitable for a cat.

The habits of the two animals, in a state of nature and when domesticated, are full of interest. The dog tribe, as a rule, hunts in packs (though the fox and a few others are exceptions). He also hunts by scent and sight and relies upon dogged persistent pursuit to catch his prey. When run down the victim is torn to pieces by combined action. Hence a dog will bark when on the trail, as the advantage this gives in assisting his companions more than compensates for warning the prey. Again, the dog is typically a "long-winded," enduring animal, and his fore-paws are fully engaged with running, so that he attacks with the mouth alone.

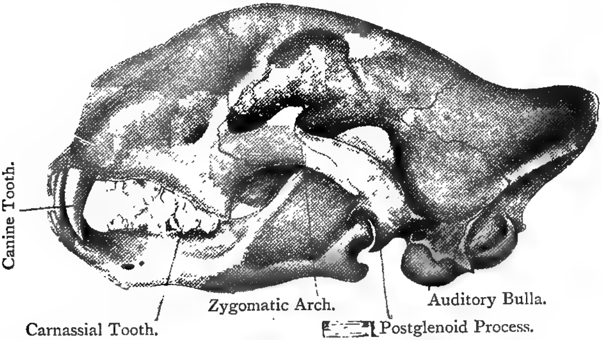
On the other hand, the cat is, as a family, solitary, or hunts in pairs, and obtains his prey by stealth and surprise. Lurking in the regions frequented by the victims he seizes them unawares. If a fleet-footed animal be attacked and missed it is usually not pursued for any distance. Thus the "cats" are quiet, are proverbially soft-footed and hunt in silence. The structure of their foot is described below, but we may point out here that the "pads" are usually softer than those of the dog, and the claws are in walking withdrawn over the tops of the toes, partly for preserving their sharpness and partly, no doubt, to prevent noise. Though powerfully built, the cats are mostly "short-winded" and incapable of sustained exertion. When caught, the prey is killed not only by the teeth but by the claws, which are then protruded. Thus the fore-paws of a cat are not nearly so exclusively cursorial organs as those of a dog.

Other habits necessarily follow from these. A "cat" frequenting the haunt of victims with a high sense of smell must be scrupulously clean—the fæces have to be buried and the fur must be periodically cleaned. With a dog there is no such necessity, and, indeed, presence of uncleanly habits has probably proved of use in nature as a means of communication for keeping the packs together. Many of these habits are retained in our domestic friends, though apparently of little use to them now.

Keeping these points in mind, we may glance at the anatomy of the two types.

Placing the two skulls before us, we note their features in common as follows:—In each the incisor teeth are small and pointed and are never more than $\frac{3}{3}$, a distinction from *Polyprotodontia;* the canines are long, powerful and pointed; and the premolars and molars have sharp-edged cusps, with an absence of the flat grinding surfaces seen in the herbivorous types. In both there is a specially large cusped tooth in upper and lower jaw which is called the "carnassial" tooth, usually said to be used for breaking slippery bones. The glenoid cavity of the squamosal is a transverse groove, and into this there fits the cylindrical condyle of the mandible. Owing to this arrangement the mandible can only move in a perpendicular plane. Immediately behind the glenoid cavity is a wide process of the squamosal, called the postglenoid process, which prevents all backward horizontal motion of the mandible.

Fig. 362.—Lateral View of Lion's Skull × $\frac{1}{4}$. (*Ad nat.*)

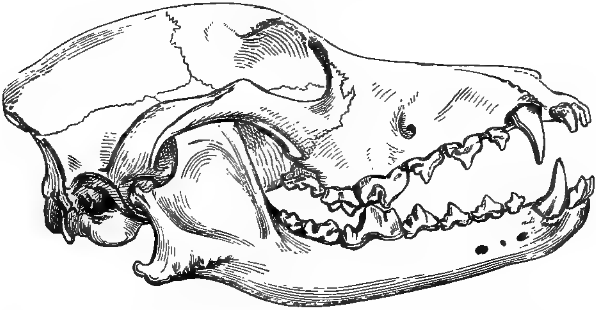


On the cranial surface there are at least two large bony crests—the sagittal crest along the middle dorsal line and the occipital crest from side to side at the junction of parietals and occipitals. These form the surfaces of origin for the large jaw-muscles (*temporalis*) which pass down in the temporal fossa to be inserted in the mandible, the coronoid process of which is large. In this region we also observe the strong and widely protruding zygomatic arch. The tympanic bone is expanded into a large bulbous swelling or tympanic bulla. If the inside of the cranium be viewed through the foramen magnum, a bony septum or tentorium will be seen which protrudes between cerebrum and cerebellum.

Compared with the horse and ox the cranial part of the skull is larger and longer in comparison with the facial portion, the orbits face forwards and, in dried skulls, are confluent with the temporal fossæ.

Fig. 363.—The Skull of the Dog from the right side.

(From Flower and Lyddeker.)



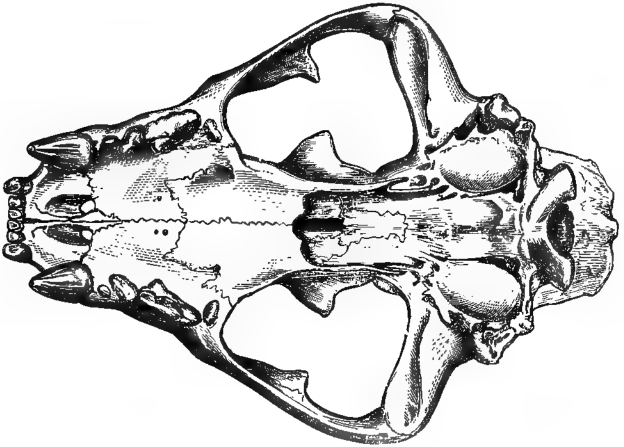
We saw that the facial portion of the *Ungulata* (Horse and Ox) was long, partly at least to provide room for the long row of grinding molars. In the dog and cat the proportion between cranial and facial part is altered from at least two causes. Firstly, the brain is proportionately larger and more highly developed, hunting being a more intellectual pursuit than grazing; and, secondly, the mechanical necessities for a powerful "bite" demand a shortened jaw. (See below.)

The features given above are typical of the skull of the higher *Carnivora*, and they are mostly referable, directly or indirectly, to the carnivorous habit.

The skull of the dog has a dental formula of $\frac{3142}{3143}$, and it has thus two molars (one on each side) short of the full typical Eutherian dentition. In this and in many other respects the dog is the more generalised type of the two (*cf.* diet).

The cat has a dentition of $\frac{3131}{3121}$, hence there has been a great reduction in the number of teeth, especially as the upper molar is also merely a vestige. In this case, however, as in the dog, the last premolar of the upper jaw and first molar of the lower jaw are the carnassial, hence it is easy to observe which teeth have disappeared. Correlated with the reduction in number of the teeth is the shortening up of the jaws, involving a still further reduction of the facial region. If the mandible be regarded as a lever (of the third order), the "weight" will act at the level of the canines, the fulcrum is at the glenoid cavity and the "power" at the insertion of the jaw-muscles, a little in front of the glenoid cavity. Hence the simplest way of increasing the "power" is to move the "weight" nearer the "fulcrum," or, in other

Fig. 364.—Ventral View of Lion's Skull × ¼.

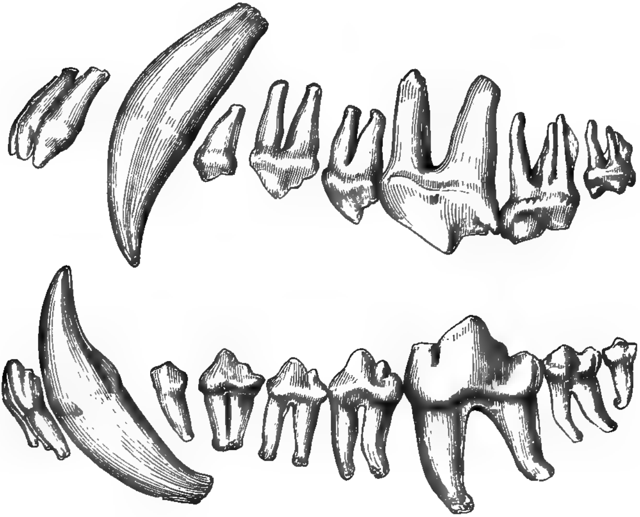


Note the large round tympanic bullæ, the wide zygomatic arch, the shortened facial region and small number of cheek-teeth. Dental formula—3.1.3.1.

words, to shorten the whole mandible. This shortening is carried to an extreme in the cat and gives the face of the animal its peculiar "round" appearance.

As smaller anatomical differences which are valuable in classification, note the alisphenoid canal in the dog but none in the cat, and the larger auditory bulla in the latter, inside which there is a more complete bony septum.

Fig. 365.—The Permanent Teeth of the Wolf. (Nat. size.)



Note small pointed incisors, large canines and cusped molars. The large fourth upper premolar bites on the large first lower molar and both are the carnassial teeth.

The vertebral column of the dog and cat call for little mention. Both have the same number of vertebræ, cervical 7, dorsal 13, lumbar 7, sacral 3, caudal 18–22. The dorso-lumbar are 20, compared with 19 in the ox and 23 in the horse. They have very little, if any, tendency to the opisthocœlous condition of the horse and ox. The tail is usually long and flexible and is put to a variety of purposes.

The ribs in the cat and dog form a compact thorax which, however, is remarkably narrow from side to side. The explanation of this peculiarity will be found in Chapter XXVI. (Sternum and Ribs).

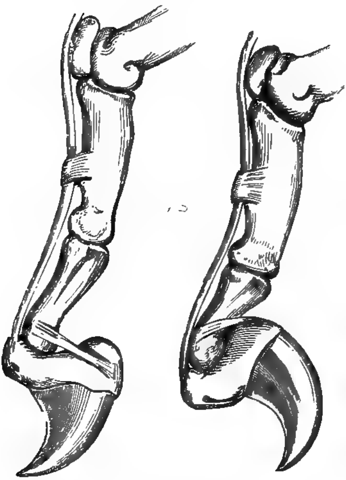
The limbs are fairly long and about equally developed. They resemble each other (dog and cat) far more closely than do those of the horse and ox. Both types are digitigrade and unguiculate (little claws or unguiculæ on each toe). There are five toes in the front-limb and four in the hind, the hallux being the only aborted toe. In each the under-surface of the toes has a series of "pads" or callosities, consisting of a large middle one and a row of smaller ones.

Coming to details, the scapula of the dog is slightly elongated, but broad, with about equal prescapular and postscapular fossæ. It is distinctly a "transition" type. There is no clavicle, except for an occasional minute trace. The humerus is curved and there is a large supratrochlear foramen. The radius and ulna are both developed but immovably fixed together. The carpus has the scaphoid and lunare united to form one bone, the scapholunar (a carnivore feature), hence there are, with the pisiform, only seven carpal bones. The pollex is shorter than the other four toes and does not reach the ground. Hence the animal really walks on four toes in fore- and hind-limb. The last phalanges bear small blunt claws which are not retractile.

In the hind-limb and girdle the pelvis is not unlike the ungulate type, but the ilium has not two "angles" or processes, as in the horse and ox, as the "angle of the croup" is very small. The femur is long and curved, the tibia and fibula are also proportionately long, and the latter is complete though thin. There is no reduction of the tarsal bones, and, as stated above, there are four functional toes. The hallux is often represented by a metatarsal bone, and may, as in the "dew-claw" of domestic dogs, be present as a small digit. The claws resemble those of the front-limb. In the cat there is a clavicle which is reduced in part and connected only by cartilage to the scapula and the sternum. The scapula has a metacromion barely present in the dog. The humerus is similar to that of the dog but proportionately longer. There is no supratrochlear foramen, but there is an entepicondylar foramen on the inner side. The radius and ulna are like those of the dog but proportionately longer. The carpal bones and manus are very similar, but the terminal phalanges of the digits can be withdrawn, with their sharp claws, over the penultimate phalanx.

Fig. 366.—A Side View of a Cat's Toe with Retractile Claw.

(After T. J. Parker.)



On left the claw is retracted by the ligament behind it; on the right the tendon is retracted and the claw exserted.

In the hind-limb and girdle we may note again the greater length of limb but a general similarity to the dog. There are the same retractile claws as in the fore-limb. As in the dog, the hallux is represented by a vestigial metatarsal.

The stomach of these carnivorous types is always simple and there is a small cæcum. In the cat the tongue is armed with rasping horny papillæ which assist the teeth in "stripping" bones. The intestine is always very short. The brain is well convoluted and the senses are highly developed. The external pinnæ of the ear are large and triangular-shaped. Most of the "cats" have long and sensitive hairs or vibrissæ on each side of the snout, useful in nocturnal prowls, as fine organs of touch.

We may trace the same three series of features as were pointed out in the horse and ox, *i.e.*, (1) Resemblances due to descent from a common ancestral species; (2) Resemblances due to similar modifications since that time; (3) Differences due to divergent modifications since that time.

1. The *Carnivora* appear to be descended from very generalised mammals which combined many of the

characters of the earliest *Ungulata* and *Insectivora.* The dog has very nearly the typical Eutherian dentition, and the bears, show the primitive plantigrade mode of progression. The extinct *Creodonta* have more generalised characters. The scaphoid and lunare were not fused, the feet were plantigrade and pentadactyle, the femur had a third trochanter, and some of them appear to have had $\frac{3}{3}$ molars, thus completing the typical dentition. The formation of the teeth was, however, distinctly carnivorous; with large canines and cutting-molars, though "carnassials" were not so distinctly defined. Hence we may with some certainty suppose that the earliest carnivore was plantigrade, pentadactyle, teeth "carnivorous" and diphyodont, formula $\frac{3\,1\,4\,3}{3\,1\,4\,3}$, probably scaphoid and lunare fused.

2. Since the divergence from a common ancestor, each has changed by the adoption of a digitigrade progression, loss of hallux, and reduction of pollex, development of cranial crests and temporal fossa, loss of last upper molar.

3. At the same time the two have diverged into separate families by the greater "carnivorous" progress of the cat, involving shorter jaws, less teeth, retractile claws and other differences noticed above.

The differences between dog and cat are of the family grade, or little beyond, but those between horse and ox are subordinal and therefore greater.

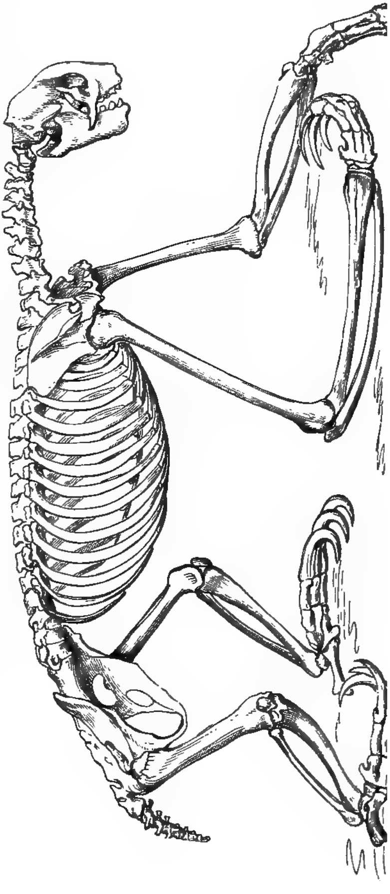
The carnivorous diet largely releases a mammal from distributional limits of temperature, as its food is cosmopolitan; hence the *Canidæ* are universally distributed (except in oceanic islands), whilst the *Felidæ* are found everywhere, except in Madagascar, Notogæa and oceanic islands.

The *Felidæ*, representing the culminating point of the *Carnivora*, must be regarded as one of the most successful types of the *Mammalia.* They are pre-eminent for physical and intellectual strength, great "slimness" and alertness, for an absolute disregard of the feelings, and the power and will to profit by the toil and mishaps, of others. Such traits carry all the elements of success.

## Cursorial Adaptation.

This is not so strongly marked as some of the others, as it mer into the primitive terrestrial. As examples, we may take marsu dog, dog, pig, ox, sheep, rhinoceros, horse, and other *Ungulata*.

1. Incidental group: *ursidæ* or bears, *mustelidæ* or weasel fam *viverridæ* or civets. They are not well marked off from the primit terrestrial, but can on occasion move rapidly on hard ground. They show an incipient raising of the body upon the toes, a leading feature of the cursorial type.



2. Transition group: dog, *felidæ* (or cat family), pig, rhinoceros, tapir, kangaroo. This shows an increasing acquirement of the ability to move fast over hard ground either to catch or to escape. The digitigrade mode of locomotion is acquired and the claws in many cases commence to form hoofs. Here also commences a reduction in the number of the toes to four or three.

3. True cursorial: horse, sheep, ox, deer, &c. These types show the ultimate cursorial modification. The toes are reduced to two, paired, or one unpaired, and bear hoofs. The clavicles tend to disappear. The carpus and tarsus are reduced and many of the elements fuse. The proximal elements become dovetailed into the distal (diplarthrous) as a palliative against the torsion due to rapid locomotion on hard ground. All these three cursoria types are herbivorous.

# CHAPTER XXIX.

6. SLOTH. 7. MOLE. 8. PORPOISE. 9. BAT.

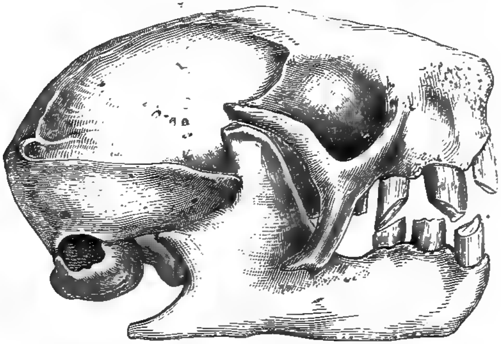
## VI.—THE SLOTH (*Bradypus tridactylus*)—Arboreal.

The sloths are truly arboreal mammals, being very completely adapted to a tree life. The hair is shaggy and its neutral tint is much in harmony with its surroundings, the more so in those species which cultivate the growth of a green alga upon the hair. The external ears are reduced, probably for easy passage through boughs, and the tail is vestigial. The fore-limbs are longer than the hind, as one tendency of the arboreal habit is the greater use of the fore-limbs. The sloths are herbivorous, feeding solely upon the leaves of trees, and they belong to one of the lowest orders of the *Eutheria*, namely, the *Edentata*. We shall therefore expect to find in them certain "edentate" characters, others due to a herbivorous diet, and yet others correlated with the arboreal habit.

The skull has several peculiarities. The zygomatic arch is not complete, as the jugal does not reach back to the squamosal, and the premaxillæ are nearly absent, which assists in reducing the facial part of the skull in proportion to the cranial. The incisor teeth (on premaxilla and opposite it) are absent, and so most probably are the canines (though in the two-toed sloth the first tooth is long and pointed like a canine). There are five stump-like homodont teeth in the upper jaw and four in the lower jaw. These grow from persistent pulps, as they are worn away and have no enamel. An outer layer of cement envelops the hard thin coat of dentine, which in its turn encloses a softer vasodentine. In use the same principle is involved as in other herbivorous types, the hard dentine here playing the part of enamel and forming the slowly-wearing ridges between cement and vasodentine. So far as is known there is no milk dentition. It is difficult to say how far these peculiar dental characters are due to degeneration from a higher Eutherian type, or how far they are due to a primitive condition.

The cervical vertebræ are nine in number, an exception to the very general rule of seven in mammals. On the other hand, the two two-toed species have seven and six respectively. This anomaly may be probably connected with the low organisation of the *Edentata.* The same variation is seen in the dorso-lumbar vertebræ. Our species has usually nineteen to twenty, with fifteen to seventeen pairs of ribs, but the two-toed species may have twenty-seven, with twenty-four pairs of ribs. The neural spines all slope backwards and are not arranged about a centre of motion as in the cursorial types. The pelvis fuses with at least six vertebræ and the caudal vertebræ are vestigial.

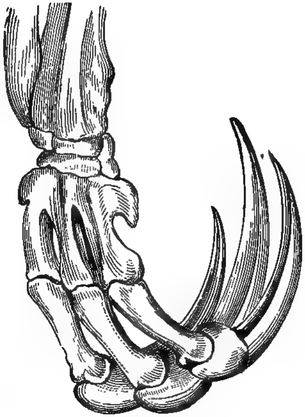
Fig. 368.—Lateral View of Skull of Three-Toed Sloth. (*Bradypus tridactylus.*)



Note the peg-like molar teeth, the short muzzle and the forked malar bone.

It is in the limbs and limb-girdles that the arboreal adaptation is most marked. The scapula is triangular, of the climbing type. The coracoid process sometimes forms a distinct bone, but is always large, and the clavicle is attached to it. The arm-bones are very long and slender and the radius and ulna are both present, the radius being capable of rotation over the ulna (in supination and pronation). This movement is usually developed in arboreal or even transition arboreal types, as the variety of movement involved in such a habitat demands it. In the cursorial types we have seen that this movement is given up, the bones being permanently crossed or even fused. On the other hand, the arboreal habit, like the cursorial, does not entail differential use of the digits, and there is a corresponding reduction in their number and complexity. As in the cursorial types, it is the digits near the central axis that alone remain. Our type has lost the first and fifth digits, and the other three are long and curved, each being armed with a long curved claw. The digits are incapable of independent motion and are largely enveloped in one fold of skin. In fact, the hand is reduced to the condition of a triple hook, fit only for the function of suspension from the boughs of trees. [The two-toed sloth has, in addition, lost its fourth digit, and the tree anteater (*Cycloturus*) has gone a stage further, the third digit (*cf.* horse) having a very large claw and the second a smaller one, the other digits being lost.] The metacarpals and the proximal phalanges are fused together into one bone, and with them are joined the vestigial metacarpals of digits one and five. The carpal bones are quite immovable, and the scaphoid is fused with the trapezium, as also is the os magnum with the trapezoid.

Fig. 369.—Manus of Three-Toed Sloth (*Bradypus tridactylus*).

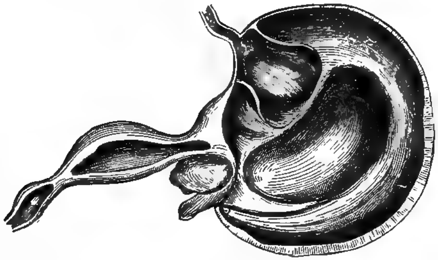


Note the three long recurved claws, the fusion of the first phalanges and the metacarpals into one bone, the fusion of scaphoid and trapezium and of trapezoid and os magnun. The unciform is round the corner, making six carpal bones instead of the usual eight.

This modification allows the sloth to hang from the boughs of trees without any muscular effort, and, indeed, it is said so to hang after death. At the same time, it renders the animal quite unfit for terrestrial locomotion (*cf.* bat and whale), the horse being equally unfitted for climbing or burrowing.

The pelvis is much smaller than in the terrestrial types, the comparison in this respect with its near ally, the ground sloth (*Megatherium*), being very striking. The hind-limb is similar in general characters to the fore-limb. The femur is long and slender; the tibia and fibula are of about equal size and allow the foot to face inwards. The foot, like the hand, is elongated and has the same condition of the digits, the second, third and fourth alone remaining. The tarsus shows the same fusion and reduction of elements as the carpus, all the bones but the astragalus becoming fused together in many individuals. As in the case of the metacarpals, so here the three metatarsals are fused together into one bone. The fibula has lost its connection with the calcaneum, but articulates with the astragalus.

Fig. 370.—STOMACH OF SLOTH.



Note the complex folds and the two-chambered condition.

At the base of the limbs the brachial arteries break up into networks of vessels, known as *retia mirabilia*, an adaptation apparently serving to overcome the effects of gravity upon the circulation of the limbs (see page 464). The mammæ are pectoral, a position common amongst arboreal and ærial types.

The stomach of the sloth, as in most herbivorous animals, is complex, consisting of at least two chambers, each of which has an appendix or cæcum.

### ARBOREAL TYPE.

These all dwell typically in trees. As examples we may cite—the marten, polecat, lemur, monkey, pangolin, opossum, tree-shrew, squirrel, tree hyrax, tree anteater, phalangers, sloths.

1. The "incidental" group: marten, polecat, pangolin, squirrels. In these types a terrestrial life in forests is indulged in and the animals can walk with ease on the earth, but resort to the trees for food or shelter. The limbs usually commence to show a "climbing" form, the claws are sharp and the animal "hangs on" to the tree by this means.

2. The "transition" group: monkeys, lemurs, opossums. Here the "tree" and "ground" habit are both indulged in, but the arboreal adaptations are marked. The first digit becomes opposable to the other four to form a climbing "grip." The limb-bones are all retained and partake of the "climbing" characters.

3. The true arboreal type: sloth, tree anteater. In these the arboreal habit is predominant. The claws are permanently curved for hanging to the boughs and the number of digits tends to be reduced to three or two. Retia mirabilia are usually present to allow of free circulation in the vertically placed limbs. Both insectivorous and herbivorous diets are found.

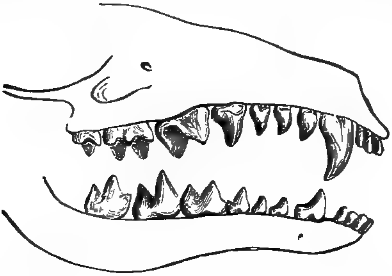
Like the cursorial type, the arboreal is evidently derived from the primitive terrestrial and its incidental group has given rise to the ærial.

## VII.—MOLE (*Talpa europæa*).—FOSSORIAL TYPE.

The mole is the commonest and best known of the true fossorial or burrowing types and its anatomy is an object-lesson in adaptation. Externally we note the elongated cylindrical body, clothed in fine short fur which will lie with equal facility in either direction. There are no external ears, and the eyes are extremely minute, lying deep in the fur. The snout is pointed and the tail is small and stump-like. The skull is long and tapers to the front end, which is strengthened by the forward projection of the mesethmoid. The teeth are numerous and in many cases they are forty-four in number, corresponding to the typical eutherian dentition of $\frac{3\ 1\ 4\ 3}{3\ 1\ 4\ 3}$. The mole belongs to the *Insectivora*, an order the members of which typically prey upon small invertebrate animals, such as insects and worms. This is naturally a more primitive mammalian diet than mammalian flesh or even grass or fruits, so it is not surprising to find that the *Insectivora* illustrate in their dentition a type usually regarded as of early origin, the mole being no exception. The incisors are small and chisel-shaped, the canines somewhat prominent in the upper jaw, but more like incisors in the lower, in which the first premolar resembles a canine. The premolars as a whole are simple and conical, and the molars are tuberculate, having sharp conical cusps adapted for tearing and crushing rather than grinding. These teeth are preceded by a complete milk-dentition.

The vertebral column is a strong axis, and the constituent vertebræ are articulated together by very "strong surfaces." The dorso-lumbar vertebræ are usually nineteen, a common mammalian number. The pelvis is attached to six vertebræ.

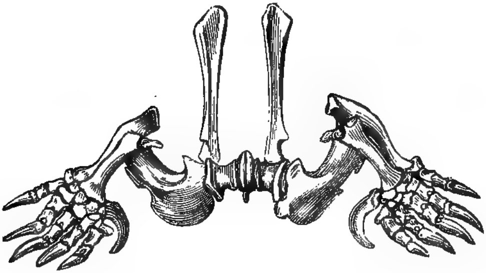
Fig. 371.—JAWS OF TEETH OF THE MOLE × 3.



Note the tubercular molars and the incisor-like lower canine followed by a caniniform premolar. Dental formula $\frac{3\,1\,4\,3}{3\,1\,4\,3}$.

Between the dorso-lumbar vertebræ are small extra bones, sometimes called "intercentra," represented in most mammals by mere discs of cartilage (intervertebral discs). The ribs are well formed and taper off rapidly forwards. At the front end of the sternum there is a large and conspicuous "presternum," which in great part appears to represent the episternum as found in *Monotremata*. The first pair of ribs are strong and short and support the base of the episternum. At the front end just under the throat the episternum forks, and to it is attached on each side a short strong cylinder of bone. This bone is usually termed the clavicle, but as it is ossified partly from membrane (clavicle) and partly from cartilage, it probably represents the clavicle and precoracoid joined in one. Its distal end forms an attachment for the humerus and it is also joined by a ligament to the scapula. The scapula is long and narrow and assists, as usual, in bearing the humerus. The bony connection of "clavicle," episternum, ribs and vertebral column, assisted by the scapula, forms a solid fulcrum for the fore-limb. The humerus is quite unique. Short and stout, it is expanded into lateral crests and processes. The radius and ulna are also short and stout and the olecranon is long, increasing the mechanical advantage of the extensor muscles.

Fig. 372.—Anterior View of Pectoral Girdle and Limb of the Mole.

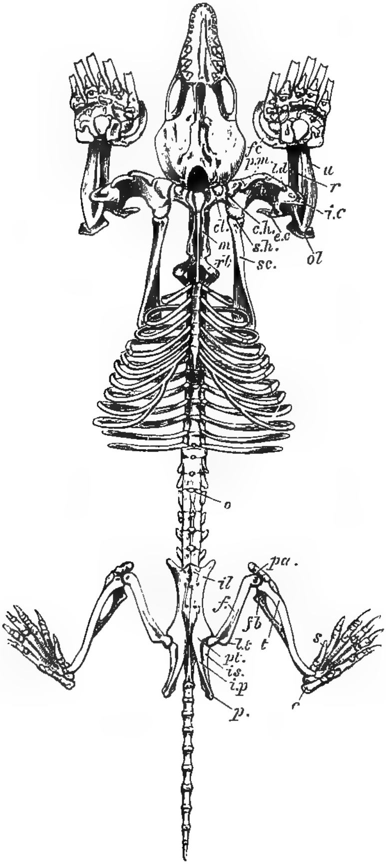


Note the shortened limb, powerful clavicle and humerus and broad scoop-like manus.

The carpal bones are compact and the whole manus is broad and flat. There are five short digits with strong claws. Inside the first digit is a falciform bone which some authorities regard as a prepollex or sixth digit. Whatever its homology, it assists greatly in adding to the "expanse" of the hand. The movement of digging, like those of swimming and flying, involves a great development of the pectoral muscles; and in correlation with this there is a median keel or ridge on the sternum at their point of origin (*cf.* bat and bird). All the above structural features point to the burrowing function of the fore-limbs. With regard to the forward extension of the episternum, and with it

Fig. 373.—Ventral View of Skeleton of Mole × ⅔.

(From Flower and Lyddeker.)



*c.h.*, Articulation of humerus with *cl.*, clavicle; *s.h.*, ditto with scapula; *e.c.*, external condyle of humerus; *f.*, femur; *fb.*, fibula; *fc.*, falciform bone; *h*, humerus; *il.*, left ilium; *i.p.*, ramus of ilium and pubes; *l.d.*, ridge of latissimus dorsi muscle; *l.t.*, lesser trochanter; *m.*, manubrium terni; *p.m.*, ridge of pectoralis major muscle; *pt.*, pectineal ridge; *rb.*, first rib; *s.*, plantar sesamoid of hind-limb; *t.*, tibia.

of the fore-limb, Flower and Lyddeker remark : "The fore-limbs are thus brought opposite the sides of the neck, and from this position a three-fold advantage is derived : in the first place, as this is the narrowest part of the body, they add but little to the general width, which, if increased, would lessen the power of movement in a confined space ; secondly, this position allows of a longer fore-limb than would otherwise be possible and so increases its power ; and, thirdly, although the entire limb is relatively very short, its anterior position enables the animal, when burrowing, to thrust the claws so far forward as to be in a line with the end of the muzzle, the importance of which is evident. Posteriorly the hind-limbs are similarly removed out of the way by approximation of the hip-joints to the centre of the body." The pelvis is bent inwards towards the middle line in the acetabular region and there is no pelvic symphysis.

The hind-limbs are not so abnormal as the fore-limbs, burrowing being effected only by the latter. The lower half of the fibula is fused with the tibia. There are five clawed toes and the animal is plantigrade.

We may notice that the mole is a type not only extremely specialised for one habitat, but, like the sloth, it has certain primitive characters which have persisted from early times. We already mentioned that the more primitive types have, as a rule, survived in arboreal or fossorial habitats : in the mole we recognise primitive characters in the form and number of the teeth, in the "intercentra," the episternum and possibly the prepollex.

## FOSSORIAL ADAPTATION.

The fossorial type is to be derived directly from the primitive terrestrial and like the others is found in varying degrees. We may take the following as examples :—*Echidna*, badger, anteater, armadillo, aard-vark, rabbit, bandicoot, marmot, prairie-dog, mole.

As in the other types, we may take three groups :—

1. Incidental group : *Echidna*, anteater, *Proteles*, banded anteater (*Myrmecobius*). This consists of animals which prey upon earth-loving insects, such as ants. The limbs show strong claws on each digit, and in most cases the tongue and salivary gland are modified for ingestion of ants, or at least the teeth show an approximation to the insectivorous type or a degeneration from a carnivorous type (*Proteles*). They are really little modified from the primitive terrestrial group.

2. Transition group: armadillo, aark-vark, bandicoot, rabbit, marmot, prairie-dog, &c., show a well-developed burrowing habit and a domicile underground, although their food is still in most cases obtained terrestrially. The claws are well developed, and in many cases the fore-limbs are shortened and the ridges or crests for the limb-muscles are prominent. The terrestrial habit is still well in evidence, however, and the necessity for speed above ground limits the limb-modification.

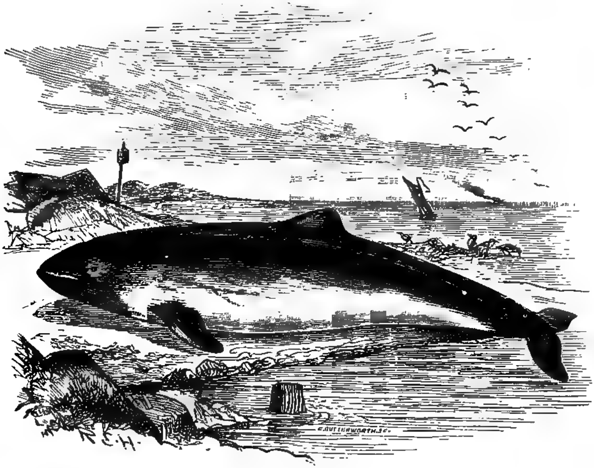
3. True fossorial: *mole*, golden mole, *Notoryctes.* In this type the food is subterranean and the habit is completely fossorial. The sense of sight is vestigial, hearing and smell being hypertrophied; the fur is reversible, lying evenly either forwards or backwards, and the limbs are essentially fossorial. The body is cylindrical, and the fore-limbs are shortened up with powerful keeled sternum and tuberosities, digits strong and spreading, with strong claws. In some respects the structure resembles that of the swimmers, the motion being somewhat similar. Insects and other "small flesh" form the diet, a truly herbivorous fossorial mammal being unknown.

## VIII.—The Porpoise (*Phocæna communis*).—Natatorial or Aquatic.

The porpoise belongs to the order *Cetacea* (see page 578) and the sub-order *Odontoceti* (or toothed whales). Its general appearance is familiar. It may be anything up to five feet in length and is fish-like in shape, *i.e.*, the body is more or less circular in cross-section and is thickest just a little anterior to the middle, from which it tapers gradually to the tail, more abruptly to the head. It is dark greyish-green on the upper half of the body and head, on the tail and fins, and a pearly-white on the under surface. The surface of the body is smooth and oily and there is no hair. The mouth, with wide gape, is at the front end of the head, the eyes are lateral and small with no lacrymal glands, whilst the external ears are absent. A minute pin-hole leads from the exterior to the tympanum on each side, and at the top of the head is a single crescentic nostril which is open or closed as required. About a quarter of its length from the head the paired fins are seen protruding ventro-laterally, formed from much modified fore-limbs. Behind the middle line here is a median dorsal fin, and the tail is modified into a bilateral or symmetrical tail-fin, the "flukes" of which lie horizontally. Thus we find that externally in form, colour, reduction of ears and loss of hair, the porpoise is perfectly adapted for its marine life. It is essentially gregarious, living in herds or "schools," and haunts the pelagic water, *i.e.*, at or near the surface of the open sea, though not usually found far from land. Along with the rest of the *Cetacea*, it was for long regarded as a fish till the researches of Cuvier revealed its true relationships.

The diet of the porpoise is fish, the pelagic species, such as mackerel, herrings and pilchards, being the usual victims.

Fig. 374.—The Common Porpoise (*Phocæna communis*).
(From Flower and Lyddeker.)

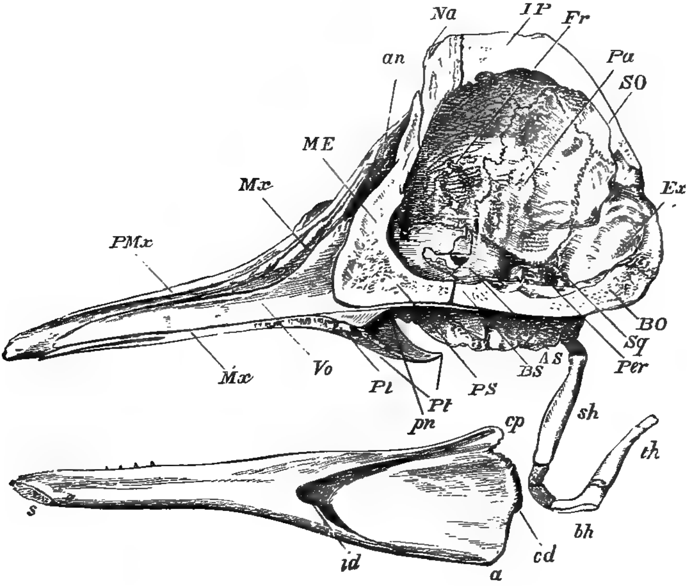


Passing to the internal characters we note the absence, or practical absence, of salivary glands. The primary function of lacrymal glands is to supply moisture for the surface of the eye, that of the salivary glands to supply moisture to the food : hence the absence of both in aquatic animals. Under the tough skin we find a very dense thick layer of fatty tissue or "blubber," which is really the enormously hypertrophied panniculus adiposus. The porpoise has dispensed with its outer coating of hair to produce less friction and consequently greater speed, hence the warmth of the body is retained by "blubber."

The skull is of very peculiar shape and construction. The cranial part is almost globose in shape, and the facial is long, flat and tapering, forming the so-called "rostrum." It is not difficult to get at least some insight into the reasons underlying these peculiarities. If we recall the facial part of any of our terrestrial animals we find that it subserves two functions. The under-surface and lower part of it, forming the buccal chamber, is connected with the alimentary function; it bears the teeth and forms the palate. The upper part contains the large and complex nasal chambers, access to which is obtained by the

Fig. 375.—SECTION OF SKULL OF YOUNG DOLPHIN (*Globiocephalus mela.*

(After FLOWER.)



*Pl*, Palatine. *Per*, Internal nares. *Pt*, Pterygoid. *PS*, Presphenoid. *BS*, Basisph
id. *AS*, Alisphenoid. *Vo*, Vomer. *Mx*, Maxilla. *PMx*, Premaxilla. *ME*, Mesethmo
*n*, External nares. *Na*, Nasal. *IP*, Interparietal. *Fr*, Frontal. *Pa*, Parietal. *S*
upraoccipital. *ExO*, Exoccipital. *BO*, Basioccipital. *Sq*, Squamosal. *Per*, Periot
*h*, Hyoid. *cd*, Condyle. *a*, angle. *s*, Symphysis.

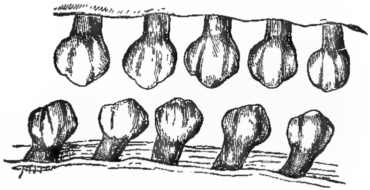
anterior nares at the front end of the facial region. The nasal chambers serve the dual functions of smell and of respiration. The length of the nasal chambers and the distance between the anterior and posterior nares, combined with the great exposed surface of the turbinals, ensure the activity of the olfactory sense.

In the *Cetacea* the ærial olfactory sense is of little or no use, whilst a rapid and easy passage of air to the lungs is essential. Hence the anterior nares have progressed backwards till they come to lie vertically over the internal nares, and the nasal "chamber" of terrestrial types, with its complex turbinals, has been converted into a simple pair of short passages, with no turbinals, leading directly downwards to the glottis. In terrestrial types the roof of the nasal chamber is formed by the nasals and partly the frontals. Here the nasals and frontals are pushed backwards before the retiring nostrils. The frontals squeeze the parietals to the sides and meet the supraoccipital, whilst the nasals are pressed against the front wall of the cranial cavity. Hence the "rostrum" represents only the ventral or alimentary part of the mammalian facial region, consisting solely of the premaxillæ—which follow the nostrils backwards and become very elongated—the maxillæ, mesethmoid and the vomer.

The maxillæ, premaxillæ and mandibles bear a single row of small teeth, very numerous and all of the same size (homodont). Each tooth has a single root, and in the porpoise is scoop-shaped and raised on a short base. (In the dolphin each is a simple conical point.) There are usually about twenty-five on each side, upper and lower jaws, and as they are homodont we can use no dental formula but $\frac{25}{25}$ (dolphin $\frac{40}{40}$ to $\frac{60}{60}$). There is no succession (monophyodont), but there are said to be traces of a second or permanent dentition which is only transitory and

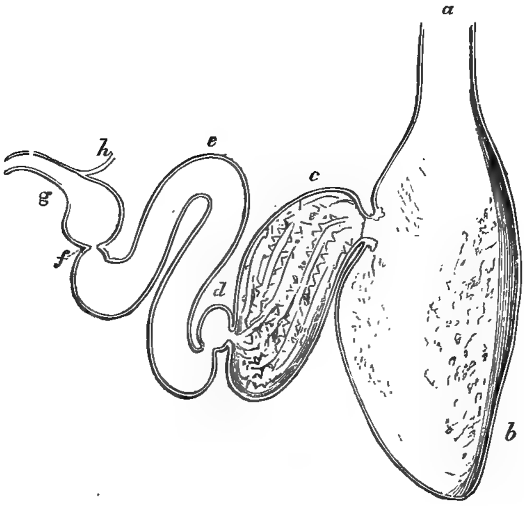
Fig. 376.—TEETH OF PORPOISE × 2.

(From FLOWER and LYDDEKER.)



never replaces the functional teeth; hence these latter are often regarded as the milk-teeth (*cf. Metatheria*). The homodont condition is correlated with the function of seizing and retaining small slippery fish which are not masticated but "bolted" entire, as in the case of sharks and other fish. The immense number of teeth is a great morphological difficulty, especially if we assume that the *Cetacea* are descended from terrestrial *Eutheria*, with teeth approximating in number to the typical dentition of $\frac{3143}{3143}$. It has been suggested that the tritubercular or multitubercular carnivorous type of tooth of these ancestors, losing its tearing and crushing function, became split up into three or more single-cusped elements which would give at least $\frac{3 \cdot 1 \cdot 12 \cdot 9}{3 \cdot 1 \cdot 12 \cdot 9}$ or $\frac{25}{25}$. The rudimentary molar teeth of the *Mystacoceti* or toothless whales are said to break up in this way into simple elements.

Fig. 377.—Diagrammatic Section of Stomach of Porpoise.
(After Flower and Lyddeker.)



*h*, Bile-duct. *g*, Duodenum. *f*, Pylorus. *e*, Pyloric Portion. *c*, Middle Portion. *b*, Cardiac Part. *a*, Œsophagus.

The molar teeth of elephants consist of many (up to twenty-four) successive ridges, each with its roots. Hence it is possible, by an appeal to the principle of cusp-multiplication followed by separation, to suggest an origin for the great number, as well as the simple structure of the cetaceous teeth.

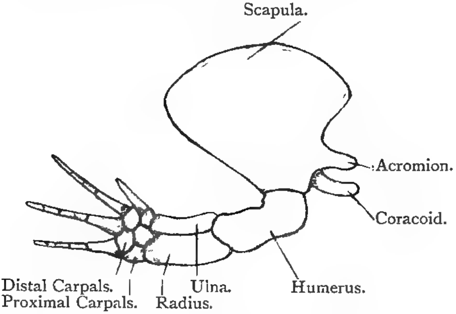
Behind the mouth the larynx and glottis are produced from the ventral wall of the œsophagus upwards as a long cylinder into the base of the internal nostrils, a striking adaptation which enables the porpoise to open its mouth under water and even to swallow whilst breathing. A similar modification is found in young *Metatheria*, in this case enabling them to breathe and swallow milk at the same time.

Returning to the porpoise we find that it possesses a complex stomach, a rare possession for a flesh-eater. The first and largest chamber is a storage sac with no glands, probably a mere dilatation of the œsophagus: this is followed by a smaller receptacle with fundus (tubular) glands and folded walls: a very small globular third compartment passes into a long vermiform fourth part which has pyloric glands and leads into the duodenum.

Reverting to the skeleton, we find the cervical vertebræ, seven in number, are short and fused together. A flexible neck, far from being a necessity, is rather a drawback to an aquatic animal, rigidity of the anterior end being imperative for rapid locomotion. The dorso-lumbar vertebræ are hard to define for there is no sacrum, but between the first caudal and the last cervical there are about twenty-seven in number, the first thirteen, as in most mammals, bearing ribs. The transverse processes are prominent, as also are the neural spines. The former arise from the side of the centrum in the last lumbar, but higher and higher up on the neural arch as one proceeds forwards. The round disc-shaped epiphyses are very conspicuous. The hindermost of these dorso-lumbar are probably the former sacral vertebræ, but as the ilia have atrophied there is no certainty.

The caudal vertebræ are numerous (30-31) and, as in the kangaroo, bear paired chevron bones on their under surface. It is usually assumed that the caudals commence with the chevron bones. The fore-limb and girdle are unique. Clavicles are absent, but the scapula is large, flat and broadened into a fan-shape. The prescapular fossa is very small, the spine being bent forwards (aquatic type). The humerus moves freely on the scapula, but this is the only possible movement of the limb. The humerus is very short and stout and bears two equally short flattened bones, the radius and ulna. Six small carpal bones follow carrying five digits. The digits are peculiar in having a greater number of phalanges than is usual for mammals (2.3.3.3.3.). This feature has formed a puzzle to morphologists; a possible explanation of their multiplication is the formation of supplementary phalanges from the epiphyses of the others to meet the demand for increased surface. Some of the phalanges present the anomalous feature of an epiphyses at each end. The whole limb is firmly welded together by fibrous tissue and little or no motion is possible at elbow or wrist: indeed, in old specimens, the limb-bones are ankylosed together. The shortening of the limb is due to the same cause as in the mole, *i.e.*, the need for a short, quick, powerful stroke.

Fig. 378.—Lateral View of Pectoral Girdle and Fin of a Porpoise × ¼. (*Ad nat.*)



The hind-limbs have entirely disappeared, leaving no trace, and the pelvis is represented only by a pair of small bones which represent the ischia. In terrestrial mammals the ischia form a support for the cavernous bodies of the penis and these small ischia of the porpoise perform a like function; it is probably to this subsidiary function that they owe their preservation.

The dorsal fin and the tail, except for its central vertebral axis, have no osseous support like that of the paired fin, but are stiffened by strong dense fibrous tissue.

The heart in *Cetacea* is large, and there are underlying the vertebral column a number of fine vessels, or retia mirabilia, which may assist the animal in keeping under water for long periods (see page 464).

It is sometimes asked, How do we know the porpoise (*Cetacea*) to be a mammal? And again, How is a porpoise adapted for an aquatic habit? If we divide the structural facts of the porpoise into (1) resemblances to other mammals and into (2) adaptive characters, the questions will be answered. Of the first category we have only to refer to Table on page 431 and it will be found that the porpoise agrees with all the twelve mammalian characters there enumerated with the reservations of no hair, no hind-limbs and homodont teeth. Again, it conforms to no one character of the second class (fishes).

Of adaptations to an aquatic habitat we may specially note:—

1. Fish-like shape, with dorso-ventral coloration.
2. Loss of hair and external ears and formation of "blubber."
3. Fore-limbs formed into fins, hind-limbs lost and tail forming a fin.
4. Homodont dentition (fish diet).
5. Modification of nostrils to form vertical blow-hole and prolongation of larynx.
6. Retia mirabilia.
7. Loss of salivary and lacrymal glands.

## AQUATIC ADAPTATION.

A large number of *Mammalia* frequent the water either temporarily or permanently, and the degree of aquatic habit marks the degree of adaptation. We may cite the following—hippopotamus, water-voles, the yapock (*Chironectes*), river-shrew (*Potamogale*), otter, sea-otter, walrus, sea-lions and seals, manatee and dugong, whales, porpoises and dolphins. These may be studied from this point of view in the following order:—

1. The incidental group.—Leaving out of consideration the hippopotamus, water-vole, musquash and other mammals which frequent water but do not show marked adaptations thereto, we have the duckmole, coypu, yapock, desman, river-shrew, otter and beaver. These all swim actively in the water and the toes are often united with a web of skin which enables the limbs to act as paddles. In addition, the tail is usually modified. In many cases its hair is lost and it is scaly and flat (*cf.* duckmole, beaver, river-shrew). They are all freshwater river animals, and the majority are also fossorial, living in holes, so that the claws remain long and powerful. They are fairly at home on land and retain their hair.

2. The transition group.—The sea otter (*lutra*) carries us on to the second group of the walrus, sea-lion and seals. Here the body is fish-like and the limbs are modified into true paddles, the front-limbs forming the steering paddles and the hind-limbs the motor paddles. The terrestrial habit is more and more forsaken. The walrus and sea-lion can still place the sole of their hind-limb on the ground and can walk clumsily. They come ashore to breed. The seal has progressed further. The hind-limbs are permanently bent backwards for swimming and the external ears have disappeared. In all this group, however, the hair remains as fur all over the body.

3. The true aquatic.—The *Sirenia* or manatee and dugong and the *Cetacea* remain. They are fish-like in shape, the fore-limbs are formed into paddles and the hind-limbs have disappeared altogether as the motor paddle is formed by the tail. In this respect they carry on the adaptation of group 1 rather than group 2, which form their motor paddle from the hind-limbs. The hair is almost entirely lost and the pinna of the ear is lost. The claws, reduced in group 2, are lost here. The blood-system has networks of blood-vessels, called *retia mirabilia*, to allow of "holding the breath" under water.

The *Cetacea* are further adapted than the *Sirenia*. They become so fish-like in form that they were for a long time supposed to be fish. Many have the dark upper-surface and light under-surface characteristic of fish (dolphin, porpoise). The front-limbs are very shortened for a sharp quick stroke, and the phalanges are increased in number from the normal mammalian type. The nostrils open on the top of the head and in many there is a dorsal fin. A flexible neck is no longer required and the cervical vertebræ fuse into one mass. Salivary glands for moistening food tend to disappear. There are special adaptations to a fish diet (homodont dentition), as in *Odontoceti*, and to a plankton diet (pelagic animals), as in *Mystacoceti.*

We may trace the evolution of aquatic forms from the resort of fossorial types to the soft ground in the neighbourhood of rivers, then to the acquirement of aquatic food, either fish or water-weeds. The river leads to the river mouth (*Sirenia*) and this to the open sea. The *Pinnipedia*, however, may have taken to the sea direct from a polar-bear-like habit.

In all, the mammalian type has its teeth modified for the fish diet and the limbs and tail modified for the fish mode of locomotion, sharp short strokes with a large surface being the end to be attained.

## IX.—THE BAT (*Pteropus edulis*). The Ærial type.

The Fox-bat belongs to the order *Chiroptera* and to the sub-order *Megachiroptera*. The other sub-order of the *Microchiroptera* includes the small British bats. As a rule, the *Megachiroptera* are fruit-eating and the *Microchiroptera* feed upon insects. As shown below, this is correlated with the greater adaptation to flight in the latter. However, the fox-bat is here taken as a type because its greater size facilitates an examination of its anatomy.

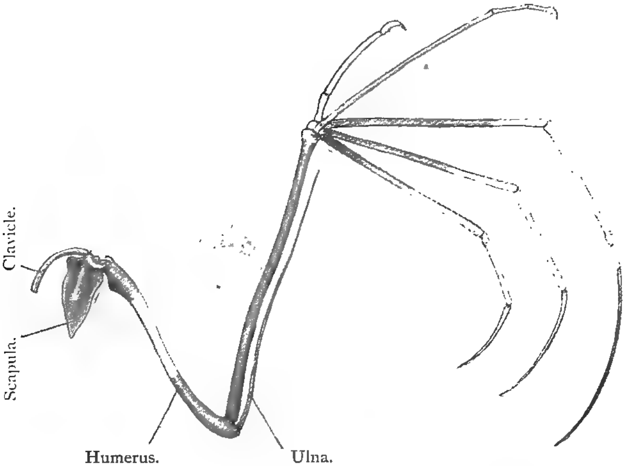
Fig. 379.—FEMALE AND YOUNG OF A FOX-BAT (*Xantharpyia collaris*).

(From SCLATER, Proc. Zool. Soc., 1870.)

The fox-bat may have an expanse of five feet across the wings. The head is not unlike that of a small fox, with a sharp intelligent look about the eyes. The external ears are large and the sense of hearing is acute. The body is covered with fine thick hair which is woolly round the neck. The whole appearance of the animal is totally unlike that of any other mammals outside the order, owing to the presence of an enormous pair of membranous wings (though an approximation to this condition is found in the colugo). The wing, as is clearly seen in the skeleton, is formed by the fore-limb, upon which is stretched the membrane. The concavity of the elbow is filled with a small antebrachial membrane. The hind-limbs are very small and armed with claws. The patagium extends from the fore-limb down to the ankles, being attached to the sides of the body, and a slight interfemoral membrane stretches across between the hind-limbs. These three membranes form the patagium, consisting

Fig. 380.—The Pectoral Girdle and Fore-Limb of Pteropus.

(*Ad nat.*)



throughout of a double fold of skin. There is no external tail. In the *Microchiroptera* the tail is well developed and forms an axial support for the interfemoral membrane. By this means the latter group are able to turn rapidly in the air in pursuit of insects.

The sense of touch is remarkably developed in bats, some families having a pair of peculiar organs, the "nose leaf," on the snout. It consists of an irregular cutaneous expansion, supplied by the fifth nerve, and apparently enables the animal to be cognisant of variations in vibrations of the air caused by objects in close proximity. In a great number of bats the ear-pinna is also enormously developed, though not excessively so in our type.

The bat has lost almost all power of terrestrial locomotion and at best can shuffle clumsily along the ground. This is due to the great reduction of the hind-limbs and especially to the fact that the knees, in connection with the support of the patagium, are bent backwards like the elbows, making them unfit for walking. The "wings" are also quite unsuited for the same purpose. The hind-limbs are used for grasping boughs, and the bat thus hangs suspended head downwards, often enveloped in its patagia. We have already noticed that the ærial types have been evolved from the arboreal, and in this respect the *Megachiroptera* are less specialised than the *Microchiroptera*, as their food and resting-place are arboreal.

The bats were for a long time regarded as birds, or at least not recognised as true mammals. There is, however, if possible, less difficulty in noting their mammalian affinities than in the case of the porpoise. A reference to the two columns of Aves and Mammalia in Table, page 431, will make this quite clear. The generally accepted view regards them as modified *Insectivora*.

The skull is very variable in general form and structure throughout the group. The fox-bat has a fairly even set of teeth, well defined into incisors, canines and molars, the canines being slightly the longest. There are only two incisors in each jaw, a common condition in bats, though the lower jaw may have as many as three. The molars and premolars have blunt crowns and are $\frac{5}{6}$. No bats have more than $\frac{6}{6}$ or $\frac{3 \cdot 3}{3 \cdot 3}$.

Thus the fox-bat has a dental formula of $\frac{2}{2}\frac{1}{1}\frac{3}{3}\frac{2}{3}$, a considerable reduction in number from that of the typical eutherian. The number agrees closely with the fruit-eating or frugivorous *Primates*, the marmosets having $\frac{2}{2}\frac{1}{1}\frac{3}{3}\frac{2}{2}$.

The cervical vertebræ are small and compressed and carry very small neural spines. The thoraco-lumbar vertebræ, bearing fourteen pairs of ribs, are seventeen in number. They are all set in one curve, have few processes, very little motion on each other, and are not infrequently, as in birds, largely ankylosed or fused together. In each case rigidity of the central axis is a necessity.

The caudal and sacral vertebræ are fused together.

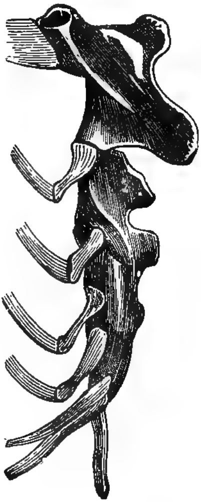
The thoracic cavity is spacious and the ribs are compact. The sternum has a prominent median keel, which is largest on the presternum but is continued as a series of smaller keels on each sternebra. The scapula is large and triangular and is firmly connected with the presternum by the clavicles. These are stout and curved though not shortened, as in the mole. The fore-limb is enormously long and the bones are slender. The ulna is vestigial, like that of the horse, but the radius is very long. It bears six small carpal bones and five digits. The pollex is short and free from the wing; it bears a claw. The other four digits are enormously elongated and serve when separated to extend the wing-membrane. The second digit terminates in a claw, but the others end in tapering phalanges.

It is instructive to compare this wing with that of the bird. We see at once that the same ends are attained by a different method. The main axis of support is the fore-limb in each case, supplemented in the birds by the reduced digits. The lateral axes are formed in the bird by the shafts of true feathers and in the bat by the digits. Lastly, the vanes of the feathers serve the same mechanical purpose as the patagium of the bat. The sternal carina is found in each, as an attachment for the pectoral or "flight" muscles, but whereas the fulcrum of the fore-limb is attached to the sternum mainly by the coracoid, supplemented by the clavicle in the bird—the bat having, as a mammal, practically lost its coracoid in early times, has to rely upon the clavicle alone.

We may recollect that the mole has a keeled sternum and a strong bony junction of scapula to presternum. These are alike due to hypertrophy of the pectoral muscles, in its turn connected with excessive use of the fore-limb, but in the mole the fore-limb is shortened, not lengthened, as the medium upon which the work is done is solid earth, not air.

The pelvis of the bat is produced backwards and there is usually no pelvic symphysis. The hind-limbs are small. The fibula is a small splint-like bone down the side of the tibia. There are five toes, of which the first is slightly the smallest: they bear curved claws. As in the mole and porpoise, the adaptation has resulted in increase of the fore-limb and reduction of the hind-limb.

Fig. 381. — Lateral View of the Sternum of a Fox-Bat (*Pteropus*).



Note discontinuous keel.

The stomach of the fox-bat is simple, though the pyloric portion is produced into a process.

The mammæ of the bat are pectoral and paired. The fecundity is low, as is natural when the parent has to carry the family about with her, clinging to her under-surface. Such a position of the young may account for the pectoral mammæ.

The adaptation of the bat to an ærial habit may be summarised as follows:—(1) Fore-limbs and four digits elongated, supporting "wing membrane." (2) Hind-limbs bent backwards and assisting to support "wing membrane" and "interfemoral membrane." (3) Keeled sternum, connected by large clavicle to scapula. (4) Partial ankylosis of dorso-lumbar vertebræ. (5) Great development of hearing and of "motion-sense." (6) Small fecundity and pectoral mammæ.*

## ÆRIAL ADAPTATION.

The ærial types are modified from the arboreal, a short step only intervening between the two. As examples we may instance the flying "squirrels" and phalangers of Australia (*Cuscus*, *Petaurus*), the true

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* Probably connected with arboreal habit which preceded that of flight (*cf.* Primates).

flying squirrels (*Pteromys*), *Anomalurus*, the colugo or flying lemur (*Galeopithecus*) and, lastly, the bats. We may divide these into three groups :—

1. The incidental group. —The phalangers, marsupial squirrels and true flying squirrels. All are arboreal and still adapted thereto. "Flying" is to them merely incidental, as is swimming to the first aquatic group. They have a thin fold of skin or *patagium* which stretches from fore-limbs to hind-limbs and acts as a parachute. In all, the tail is bushy and not only acts as a balancing organ in jumping but as a steering organ in flight. The spreading of this patagium is an easy addition to the long jumps from bough to bough performed by their "non-flying" allies.

2. Transition type.—The colugo or flying lemur. In this the patagium extends further between the tail and the hind-limbs. The animal appears to have more direct means of steering itself, and flight is less "incidental" and more evenly balanced in the life of the animal with the arboreal habit. The limb-bones are long and slender to allow of a larger patagial surface.

3. True ærial.—The bats. These are the culminating group of the ærial types. Here the ærial habit becomes predominant. The patagial surface becomes further extended, especially that part of it which can be voluntarily moved in the neighbourhood of the fore-limb. The fore-limb and the digits are greatly elongated, forming axes for support of the patagium, the pectoral muscles are employed for movement and a keel on the sternum is the result. In one group of bats (Pteropodidæ) two digits retain their claws and in the rest only one, the thumb. In the former the diet is still arboreal (fruits), but in the latter it is strictly ærial (insects). As, however, insects are not confined to the air we do not find a specially marked peculiarity in the teeth. The adaptations to flight are, therefore, mainly to be found in the locomotor organs.

# CHAPTER XXX.

## *MAMMALIA—(Continued).*

## **Sub-Class III.—Eutheria.**

### Order V.—*Edentata.*

The general anatomical characters of the sloth have been already described, the animal being taken as a completely arboreal type (page 533). The order appears to occupy the lowest place in the sub-class and its members have great diversity of habits. They are either arboreal and herbivorous or semi-fossorial and insect-eating. The body is clothed in hair, in one family supplemented by bony plates. Both pairs of limbs are well developed and armed with claws. The digits may vary from 2 to 5. The teeth are always either simple and homodont, with persistent pulps, and with few exceptions monophyodont or they are absent altogether. They are usually also deficient in enamel and the incisors and canines always are absent. The order shows remarkable diversity in the structure of the placenta and in specialisations of teeth, limbs and body-covering. It is divided into two sub-orders which are widely separated, both structurally and geographically.

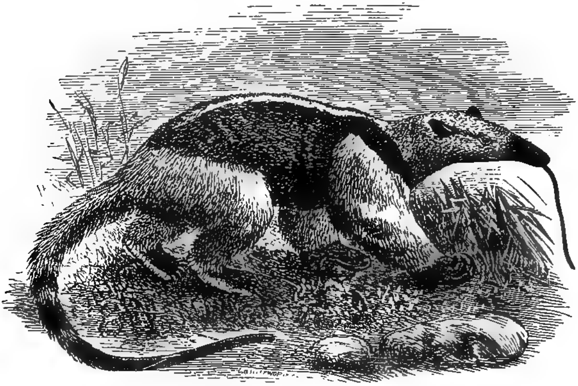
### SUB-ORDER I.—XENARTHRA.

In this sub-order are contained at least four families. In them the uterus is simple and the placenta is discoidal or dome-shaped and deciduate. Mammæ are usually two and pectoral. The vertebræ usually have extra articular processes. The sub-order is entirely restricted to the Neogæan realm (South America).

Family I.—**Bradypodidæ** or Sloths.—Purely arboreal, leaf-eating animals; *Bradypus* has been described. We may recall (1) the adaptation to arboreal habit; (2) the low eutherian characters shown in a bipartite uterus, occasional presence of a complete coracoid and varying number of cervical vertebræ. They are found only in forests of South America.

Family II.—**Megatheriidæ** or ground sloths.—Extinct terrestial forms, occurring backwards from the Pleistocene. They are closely allied to the sloths, but show certain resemblances to the anteaters. They were apparently huge hairy monsters, that fed upon leaves of trees. *Megatherium* walked upon the outer side of the feet, on pads covering the fifth digit of the front-limb and the fourth and fifth of the hind-limb. The second, third and fourth digits of the front-limb and the third of the hind-limb were armed with huge claws. *Mylodon* was another well-known form which may possibly still survive in parts of South America.

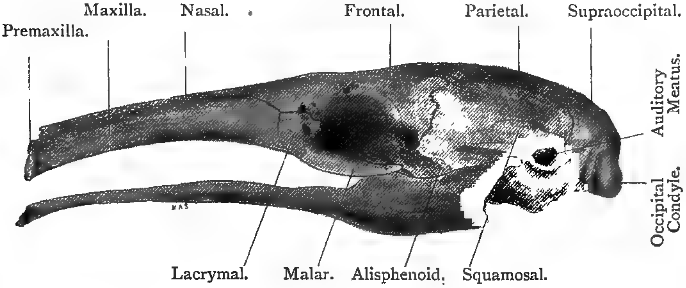
Fig. 382.—TAMANDUA ANTEATER (*Tamandua tetradactyla.*)



(FROM PROC. SOC., 1871., PL. XLIII.)

Family III.—**Myrmecophagidæ** or Anteaters.—These show a similar adaptation to anteating to that already noticed in *Echidna*. There are no teeth, the mandible is rudimentary, facial region tapering and terminating in a small round mouth. The tongue is very long and copiously supplied with saliva from the large submaxillary glands. The tail is usually long and in the tree-anteaters is prehensile. The third toe of the manus is always large and bears a large claw. The great anteater is purely terrestrial; the Tamandua and Two-toed anteater (*Cycloturus*) are arboreal.

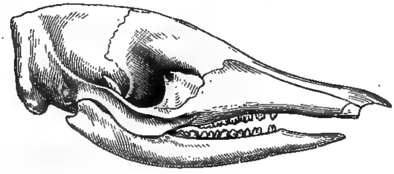
Fig. 383.—LATERAL VIEW OF SKULL OF ANT-EATER. (*Ad nat.*)



Note the absence of teeth, the elongated jaws and incomplete zygomatic arch.

Family IV.—**Dasypodidæ** or Armadillos.—They are unique amongst mammals in having the head and body enveloped in bony dermal scutes covered with horny epidermis. In the typical forms there can be distinguished a cephalic plate over the head, a large pectoral and pelvic, covering respectively the fore and hind part of the body, and a number of rings between them. The tail is also enveloped in a series of rings. The ventral surface is usually soft and hairy and the habit of rolling-up in a ball is common. Armadillos are largely insectivorous and have a long sticky tongue with large submaxillary glands. On the other hand, they have a large number of simple teeth which in many cases are diphyodont. They are mostly fossorial and the toes are armed with strong claws. The genus *Tolypeutes*, in which the rolling-up is best perfected, is said not to burrow. They vary in size from the little Pichiciago of 6 inches to the great Armadillo of three feet. The largest

Fig. 384.—LATERAL VIEW OF SKULL OF ARMADILLO.



Note the absence of incisors and canines, the numerous cheek-teeth, the long snout with small premaxillæ.

and most specialised of the Armadillos, known as the Glyptodonts, are extinct forms found in the Pleistocene. The body was enveloped in one huge shield into which the head could be retracted. The vertebral column is ankylosed together, the shield preventing free movement (*cf.* tortoise).

From this brief description of the *Xenarthra*, it will be seen that the present forms are only the remains of an extensive group of mammals which once held a dominant position in the Neogæan realm. Why such powerful creatures as *Megatherium* and *Glyptodon* have disappeared is a question that has puzzled many. All we can say is that a type, like an individual, has a limited part to play on the stage of organic evolution, determined by the relationship of an organism to its environment.

## SUB-ORDER II.—NOMARTHRA.

This small sub-order contains two families which are doubtfully related to each other. They are terrestrial or arboreal and feed on "ants" or termites. Hence in them is found the same elongated snout, small mouth, long mobile tongue and large salivary glands, as in the anteaters and *Echidna.* The uterus is bicornuate, or there are two uteri, and the placenta is non-deciduate and diffuse (or zonary, modified from the diffuse). There are no extra articular processes on the vertebræ.

Family I.—**Orycteropodidæ.**—Aard-varks or earth pigs. The aard-vark of South Africa is a nocturnal and partially fossorial animal. Its body is sparsely covered with hairs. It is plantigrade with four and five toes all armed with strong claws. The teeth are unique in structure amongst mammals. They grow from persistent pulps, gradually pushing forward in a manner similar to that found in the elephant and the kangaroo. There are usually five on each side in use at the same time and about ten in all. All but the three last are preceded by a milk set, which are absorbed before cutting the gum. This appears to indicate premolars and molars and a possible degeneration from a higher type of heterodont dentition.

Family II.—**Manidæ** or Pangolins.—The pangolins are elongated, terrestrial, fossorial animals: many can climb trees. They have the body clothed in a series of large overlapping scales of horny epidermic origin. On the under-surface there is usually hair only. The tail is long and protected in a similar manner to the body. Like the Armadillos, they can usually roll themselves into a ball. The skull, especially in the jaw region, is modified for the "termite-eating" habit, as in the anteaters:

thus there are no teeth, the mandible is much reduced, the jaws are long and tapering, the mouth small and the tongue long and mobile. The limbs are short and the claws long and powerful. The Pangolins are found in East Africa and in the Oriental region (India), and comprise one genus.

Like the *Xenarthra*, the *Nomarthra* are very low types of *Eutheria*, which affect an arboreal or fossorial habit. They are confined to Arctogœa, just as the *Xenarthra* are confined to Neogœa.

## ORDER VI.—*Sirenia*.

The *Sirenia* are aquatic herbivorous animals known as the Manatees and Dugongs, or sometimes collectively as the Sea-cows. They live either in rivers or at the river-mouth, and, although well adapted for aquatic habit, they do not quite reach the same stage in this direction as the *Cetacea*. As in the latter, the body is more or less fish-like with tapering tail ending in a horizontal "fluke," there is little or no hair and no pinna to the ear, the fore-limbs are in the form of flippers and the hind-limbs are absent. The valvular external nares open far back towards the top of the head, resulting in the formation of a rostrum, and there are retia mirabilia in parts of the body. In all these anatomical features the *Sirenia* are like the *Cetacea*, but here the resemblance ends. The cervical vertebræ are never fused together, the teeth are neither absent nor homodont and the food consists of aquatic weeds. The flippers usually have no more than the normal number of phalanges* (2.3.3.3.3.) and the joints of the fore-limb are largely functional, as the flipper is used not only for swimming but for assisting food to the mouth, and in some cases possibly in holding the young. In comparing these characters with the porpoise, it will clearly be seen that the *Sirenia* have not progressed quite so far in adaptation as the *Cetacea*. Other special points in the anatomy show that there is no true genetic connection between the two orders.

In *Sirenia* there is the same tendency to disappearance of the front teeth as we have noticed in the *Edentata*. The manatees have no functional incisors nor canines

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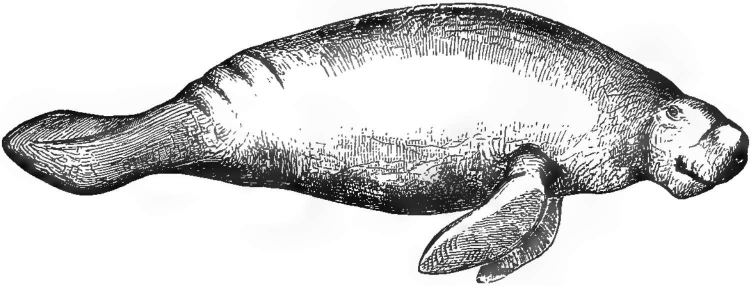
* Rarely four.

and the male dugongs have a single pair of tusk-like upper incisors. The place of front teeth is taken by hard horny pads upon the rostrum and mandible. The molar teeth have a pair of transverse ridges, like those of the tapir, and they succeed each other in series, as in the elephant, armadillos and kangaroo. The extant forms are apparently monophyodont. The stomach is fairly complex, with at least two chambers, and the intestine is long. The placental characters are not fully known, but the dugongs have a zonary placenta which is non-deciduate. The mammæ are paired and pectoral in position. At the present day the order is limited to a zone between 30° N. and 30° S. of the equator.

Fig. 385.—AMERICAN MANATEE (*Manatus Americanus*) from life.
(From FLOWER and LYDDEKER.)



Family I.—**Manatidæ** or Manatees.—Three species found in the rivers falling into the Atlantic basin. They are peculiar in having only six cervical vertebræ. Beneath the horny pads of the jaws are vestigial incisor teeth $\frac{2}{2}$ and the molars may be as many as $\frac{11}{11}$.

Family II.—**Halicoridæ.**—The Dugongs are larger and are found in the Red Sea, Indian Ocean and Northern Australia. The males have incisor tusks which are vestigial in the female. The molars do not exceed $\frac{6}{6}$. They are more marine than the Manatees.

Family III.—**Rhytinidæ.**—The Rhytina or Steller's sea-cow was a large sirenian (25 feet) formerly found in the district of Behring Island. It was finally exterminated at the hand of man in 1768. This species had no teeth, their places being supplied by horny pads.

Certain fossil forms, such as *Halitherium* (Miocene), show us that the sirenians were abundant at that epoch and even to the Eocene. *Halitherium* also had a diphyodont dentition and the pelvic-girdle and hind-limb were not so reduced as in present-day species. The *Sirenia* are usually regarded as having been derived from very generalised terrestrial herbivores, approximating to the lowest *Ungulata*, but there is little direct evidence at present for such a view. They are a primitive and much modified order, in these respects resembling the two preceding orders, and though there is no question that they are descended from terrestrial eutherian mammals, little more can be said.

## ORDER VII.—*Rodentia.*

The rabbit has already been described as a typical mammal, and, except in respect to their peculiar dentition, the *Rodentia,* as a whole, are a group with habits and structure which apparently approximate to those of the primitive Eutherian *Mammalia.* Thus they are all of small size, mainly terrestrial, though some are arboreal, usually plantigrade, with little or no reduction in the number of toes, each of which carries a scratching claw. The orbit is never completely encircled by bone, the clavicles are always present though often reduced, and there is often a third trochanter.

But the most distinctive character of the order is the dentition. The canines are always absent and the incisors are reduced in the majority of cases to two in each jaw. These grow perpetually from persistent pulps, and as the enamel or hardest portion of the tooth is only present on the outer surface, the wear of upper and lower teeth on each other produces a sharp chisel-like edge. These teeth are used, in the majority of cases, for other purposes in addition to that of obtaining food. The teeth are succeeded by a large space or *diastema* and a number of premolars and molars, which are often reduced from the $\frac{3}{2}\frac{3}{3}$ of the rabbit to $\frac{1}{1}\frac{3}{3}$, or even, in exceptional cases, to $\frac{0}{0}\frac{2}{2}$.

The molars vary much in character, but are always flat and worn on the surface, exposing complex enamel-ridges. In order that the incisors may have free play, the condyle is freely movable in the glenoid cavity and there is no post-glenoid process.

This peculiar dentition is not confined to the *Rodentia;* two persistent permanently-sharp incisors of a large size, with corresponding reduction or loss of the others, appear to have been evolved in several independent series of *Mammalia.* In present-day forms, the wombat (Fig. 349) amongst *Diprotodontia*, the aye-aye (Fig. 394) amongst the lemurs, and *Hyrax* (*Hyracoidea*) of the *Ungulata* (Fig. 386), all have essentially the same adaptation, whilst the single pair of persistent incisors of the elephants may also be recalled.

In extinct types, the important orders of *Tillodontia* and *Typotheria* have a somewhat similar arrangement, the former being often regarded as transition types between *Rodentia*, *Carnivora* and *Ungulata.*

All *Rodentia* are herbivorous and usually have a long intestine and large cæcum.

The brain is of a low type, proportionately small; the cerebrum is little convoluted and too small to reach backwards over the cerebellum.

The uterus is often double, as in the rabbit, or is widely bicornuate, and there is usually a high fecundity. The placenta is discoidal and deciduate.

From these and other characters the *Rodentia* occupy a low place amongst *Eutheria*, but apparently their adapted dentition has enabled them to become the most widely distributed and abundant mammalian order. Their present day headquarters appear to be the Neogœan realm (South America) in which there occur enormous numbers, including the Capybara or largest existing rodent.

The order can be traced back to the Upper Eocene, below which it is more or less merged into the earliest *Ungulata.*

The hares, rabbits (*Leporidæ*) and the picas (*Lagomyidæ*) are placed in a sub-order, *Duplicidentata*, characterised by more or less enamel on the inner surface of the incisors, the presence of a small inner pair of incisors in the upper jaw, a tendency to a larger number of molars and the descent of the testes into a scrotal sac. They are confined to the Arctogœan realm.

The rest of the *Rodentia* form the large sub-order *Simplicidentata*, with only one pair of upper incisors, having enamel only on their outer surfaces; the molar teeth tend to become reduced in number and the testes are mainly abdominal. They are of world-wide distribution and include the *Hystricomorpha* or porcupine-like forms (porcupines, guinea-pigs and capybara); the *Myomorpha* or mouse-like forms (rats, mice, and voles); and the *Sciuromorpha* or squirrel-like forms (squirrels, marmots and beavers).

The beavers are confined to Arctogœa and the *Hystricomorpha* are most abundant in Neogœa.

## ORDER VIII.—*Ungulata.*

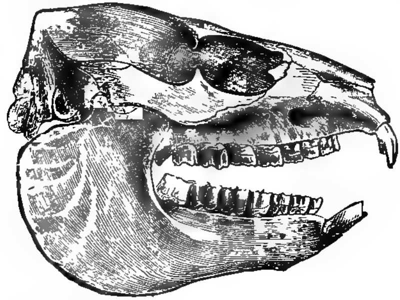
The order *Ungulata* has four living sub-orders which are sharply distinguished from each other and from other orders. The labours of palæontologists have brought to light a number of extinct forms which are evidently allied to the living *Ungulata*, though in most cases they show, as is to be expected, a number of characters in common with the more primitive members of other orders. Hence the order has been gradually widened till it now contains such a variety of types that they have few special features in common. In a general way they are all herbivorous and adapted for walking upon land on all four limbs. The teeth are heterodont and the canines are, as a rule, not longer than the incisors or molars, in many cases resembling in appearance either of these latter, or they may be altogether absent. The premolars and molars are large and flat, adapted for grinding and crushing rather than cutting. The dentition is diphyodont and the first or milk-series remains functional for a long time, largely assisting the permanent series in their long and arduous duties. The lower types have the typical eutherian dentition of $\frac{3\,1\,4\,3}{3\,1\,4\,3}$, but this is considerably changed in the more specialised forms.

The limbs are devoted in this order solely to terrestrial locomotion, with its single series of motions. Hence the clavicles are nearly always absent and the ulna and fibula reduced in the higher types. The carpal and tarsal bones remain serial only in the lower types, becoming alternately interlocked in the higher. There is a tendency throughout the order for a reduction in the number of toes, the third alone or third and fourth persisting in the higher forms. The typical mammalian claws at the end of the digits usually become converted into unguæ, or hoofs, presenting a flat surface to the ground. There can, along with these progressive changes, be noticed the gradual assumption of a digitigrade method of walking from the primitive plantigrade. Special allusion has been made to most of these points in dealing with the horse and ox. The intestine is always long, the uterus is usually of the bicornuate type and the placenta is non-deciduate and either zonary, diffuse, or cotyledonary.

### SUB-ORDER I.—CONDYLARTHRA.

The members of this sub-order are all extinct and they represent the very lowest point of the ungulate stock. They have the typical eutherian dentition of $\frac{3\,1\,4\,3}{3\,1\,4\,3}$ and the molars were of simple brachydont structure. The limbs were plantigrade, with five toes, and the carpal and tarsal bones were serial. The fibula and ulna were not reduced, though the latter had already lost its connection with the calcaneum. The femur had a third trochanter, as in modern *Perissodactyla.* The tail was long. The humerus, contrary to that of other *Ungulata*, had an entepicondylar foramen, resembling that of *Carnivora.* The toes appear to have borne blunt claws rather than hoofs. *Phenacodus* is the best known genus to which the modern horse, and hence *Perissodactyla*, can

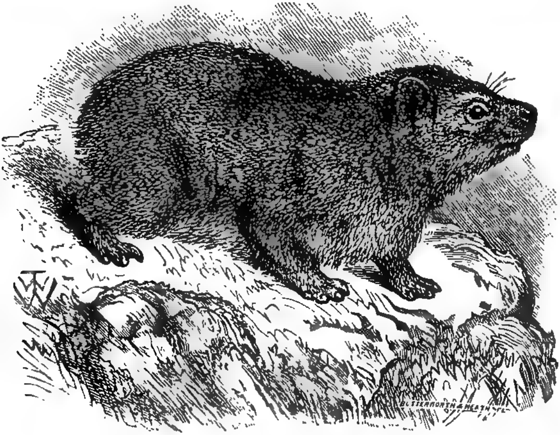
Fig. 386.—Lateral View of Skull of Daman (*Hyrax syriacus*).



Note the rodent-like incisors, absence of canines and long row of seven grinding premolars and molars. The malar bone is seen to extend back to the glenoid cavity.

be traced by a continuous series of forms. *Periptychus* is also regarded by many as being at or near the point of origin of modern *Artiodactyla.* On the other hand, many of the *Condylarthra* show structural resemblances to the *Hyracoidea* especially in the serial carpal bones. Thus they form the point of convergence for at least three of the four modern sub-orders. They are all rather small animals and are found in the Lower Pliocene of Europe and North America.

Fig. 387.—The Dasse *(Hyrax capensis).*
(From Flower and Lyddeker.)



### SUB-ORDER II.—HYRACOIDEA.

This is a small modern sub-order, comprising a few furry rodent-like animals of the genus *Hyrax* (*Procavia* and *Dendrohyrax*) and a third extinct genus, *Pliohyrax.* The first pair of upper incisors grow from persistent pulps as in rodents, and the others are absent (the second pair being rudimentary in the young). There are two pairs of incisors in the lower jaw. Canines are absent, but the molars and premolars are complete, all tending to resemble each other. The enamel of the molars is folded, the pattern most nearly resembling that found in the rhinoceros.

The feet are plantigrade, but the toes have become reduced in number: there are four on the front foot and three behind, the third (middle) being the largest. The carpals and tarsals are serial, as in *Condylarthra*. The fibula is complete and has acquired an articulation with the astragalus.

The stomach is slightly constricted into two chambers and there is a fairly large cæcum. There are also two, peculiar, paired, conical cæca attached to the large intestine, which are not known to occur in any other mammals. The placenta is said to be zonary and deciduate. *Hyrax* inhabits rocky grounds and extends from Syria to Cape Colony; in the latter place it is known as the "dasse," or "klip das," in the former as the daman. *Dendrohyrax* is arboreal and is found in East Africa.

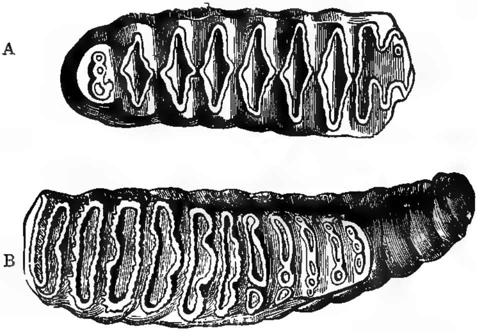
The recent discovery of *Pliohyrax* in the Lower Pliocene of Europe (Samos) has added yet more interest to these extraordinary little animals. *Pliohyrax*, known only by the skull, was larger than *Hyrax* and more generalised. Thus, in addition to the large median incisors there were also two smaller ones and a canine the latter in shape resembling a premolar. Hence, in the upper jaw at least, the dentition was 3.1.4.3. The premolars differed somewhat from the molars. Judging by the peculiar position of the anterior and posterior nares and the orbits, *Pliohyrax* was probably amphibious, if not completely aquatic. As already indicated, the *Hyracoidea* are probably an offshoot from a condylarthrous type which have retained many primitive characters.

### SUB-ORDER III.—PROBOSCIDEA.

The elephants differ from the other *Ungulata* so much that they have to be placed at the least in a sub-order apart. The most important anatomical characters are these:—The nose produced into a long proboscis or trunk; one pair of upper incisors forming long tusks; molar and premolar teeth large and polylophodont, showing horizontal succession; fibula and ulna complete; the carpals and tarsals serial and five toes present; placenta zonary and non-deciduate and mammæ pectoral.

The proboscis forms a "limb" capable of almost any diversity of movement and function. Its presence and use involves a shortening of the neck and a raising of the occipital crest of the skull: This is effected by the growth of a mass of bone, lightened by a number of enclosed air sinuses. In this manner the muscles for raising the head, inserted in the occipital region of the skull, obtain sufficient leverage to support the weight of the trunk and tusks. These latter are true incisors, though during development they move from the premaxillary to the maxillary region.

Fig. 388.—Surface Views of a Single Molar Tooth of (A) the African and (B) the Indian Elephant.



Note the polylophodont enamel ridges in each, worn by attrition into flat crests.

They have a tip of enamel which is soon worn off and the tusk then consists of dense ivory or dentine.

The molar teeth consist of a vestigial first premolar, only found occasionally, and six others, or making a normal dentition of $\frac{1033}{0033}$, but each tooth is of enormous size and they succeed each other in horizontal succession, only two being generally in use at the same time. There appears to be no milk-series, hence the *Proboscidea* are monophyodont. Each tooth is polylophodont, *i.e.*, with many transverse ridges. If we start with the multitubercular tooth and gradually form a number of transverse ridges by union across the tooth, we produce a molar not unlike that of some fossil *Mastodons.* The ridges are then filled up by the addition of cement, and further deepening of the valleys and multiplication of the ridges would produce the tooth of the elephant. The worn surface presents crests of enamel, between which are alternate layers of dentine and cement.

It should be specially noted that the elephant's molar is produced from the simple brachydont multitubercular type by a similar and parallel series of processes to those in the ox and horse, consisting of (1) multiplication of enamel crests; (2) heightening of the tooth to allow for wear; (3) addition of cement.

The limbs in elephants show primitive characters. Although the clavicles are lost and the femur has no third trochanter, the radius and ulna are quite distinct and permanently crossed and the fibula is well formed, articulating with the calcaneum. The animal is practically plantigrade and moves slowly; the carpus and tarsus are not twisted nor interlocked to form alternate rows, but are serial. Each toe has a small broad hoof, the weight of the body being borne on the sole or pad of the foot. Elephants are strictly herbivorous, feeding principally on the leaves of trees, such as the mimosa. Their stomach is simple and there is a large cæcum.

Family I.—**Elephantidæ.**—The modern elephants are found in the Oriental and Ethiopian regions. The molars of the African Elephant have diamond-shaped ridges, the ears are larger and both sexes have tusks. The Mammoth (*Elephas primigenius*) flourished in recent times in Europe, N. Asia and parts of America. It had a woolly coat, enormous curved tusks and broad deep molars. Other fossil elephants of the Pliocene and Pleistocene connect modern elephants with the mastodons. These had large straight tusks and in some the molars were tubercular. In many there was a small pair of lower incisors. Mastodons first occur in the middle Miocene and extend throughout Pliocene in Europe and into the Pleistocene in N. America. They are important, as they clearly show us the lines along which the elephants have been evolved from a primitive ungulate stock.

Family II.—**Dinotheridæ.**—In *Dinotherium*, an elephant-like animal of the Miocene and Pliocene, the *lower* incisors hung downwards below the chin as a pair of long tusks. The molars were bilophodont or trilophodont and had no horizontal, but a regular vertical, succession.

### SUB-ORDER IV.—PERISSODACTYLA.

A good deal has already been said concerning the *Perissodactyla* in the chapter upon the Horse and Ox, in which this sub-order is contrasted with that of the *Artiodactyla* (page 509).

The main structural features of the sub-order are as follows:—(1) The molar teeth are bilophodont, or with complex crowns derived from the bilophodont condition. (2) Dorso-lumbar vertebræ, usually twenty-three in number. (3) The femur has a third trochanter. (4) In the skull the nasals are large and there is an alisphenoid canal. (5) The carpus and tarsus are alternate and the toes are never more than four, mostly three or one, but in all cases the main axis of support passes through tibia, astragalus, navicular, and third toe. (6) Stomach simple. (7) Diffuse placenta and mammæ inguinal.

The molar teeth pass, in the group, from the simple brachydont bilophodont condition (derived, as shown, page 462, from the tubercular type) to the complex hypsodont type with cement added.

The third trochanter is preserved in this group from the early condylarthrous ancestors, and the disappearance of the toes can be traced upwards within the group. No modern *Perissodactyla* have five toes, but the tapir has four in the fore-foot, the pollex being lost, the rhinoceros has three and the horse merely the one. The main axis passing through tibia, astragalus, navicular and third toe, it naturally follows that the fibula is reduced or at least loses its articulation with the calcaneum, and the astragalus has nearly all its distal articular surface attached to the navicular. In the front-limb the os magnum becomes more and more prominent as the third toe usurps the functions of the others.

In the simplicity of the stomach and the diffuse placenta the *Perissodactyla* appear to present more primitive characters than the *Artiodactyla*. (As has been noticed, there has been a great deal of parallel evolution in these two sub-orders. The common characters thus acquired form a basis for the institution of the group *Ungulata Vera* containing these two sub-orders, in contrast with the three preceding sub-orders as *Sub-Ungulata*. Such a classification, based upon parallel evolution, must, however, be unnatural.)

Family I.—**Tapiridæ.**—These interesting animals, the tapirs, are found in swampy forest districts of Brazil and of Malay. Hence they form an instance of discontinuous distribution of a family. They form the base of the present-day *Perissodactyla* as they have $\frac{4}{3}$ toes and the teeth are bilophodont and brachydont. The upper molars show an external ridge connecting the two transverse ridges, thus approaching the rhinoceroses; the incisors are of average length and the third lower one resembles a canine. The dental formula is $\frac{3}{3}\frac{1}{1}\frac{4}{3}\frac{3}{3}$. There is a very slight proboscis or trunk. They feed upon the leaves and young shoots of trees.

Fig. 389.—THE AMERICAN TAPIR (*Tapirus Americanus*).
(From FLOWER and LYDDEKER.)

Tapirs occur in Europe and Asia in the Miocene strata, thus explaining the discontinuous distribution in this instance by a dying-out of the intermediate portions of a once widely and continuously distributed form.

Family II.—**Rhinocerotidæ.**—The rhinoceroses form a transition family between the tapirs and horses. They are found in forest regions of the Ethiopian and Oriental regions. They can move rapidly on fairly hard ground and have three toes and hoofs on each foot. The teeth are slightly more complex than the typical bilophodont. The two transverse ridges are curved backwards, forming crescentoid ridges, whilst they are connected externally by a longitudinal ridge. The crowns are still low and there is little or no cement. The incisors are few and rudimentary and the upper canines are absent. The nasals bear an unpaired "horn" of purely epidermic origin and having no horn core. In the two-horned species the second and smaller horn is carried on the frontals: this species is African. The upper lip is long and prehensile and the skin is very thick and hard with little hair. The food consists of herbage and leaves of trees.

Family III.—**Equidæ.**—Little need here be said of this family (see Horse). The horses are essentially graminivorous inhabitants of hard upland plains. The teeth are hypsodont and the crowns are extremely complex, though to be derived from the bilophodont type. Cement fills up the spaces between the ridges. The third toe alone remains and bears a hoof, the second and fourth metapodials being represented by two splint bones.

The pedigree of the horse can be traced from *Condylarthra* (*Phenacodus*). (See page 523.) The fossil ancestors of the horse are hard to classify as they are gradational, but the *Palæotheriidæ* is a family often constituted for *Palæotherium*, *Anchitherium* and other forms, which, as a rule, were at about the level of the rhinoceros in the structure of their teeth and toes. The earlier types of the *Eocene*, such as *Pachynolophus* and its allies, form the family *Lophiodontidæ*. They have still more generalised characters and connect the *Perissodactyla* with *Condylarthra*.

Thus this sub-order *Perissodactyla* forms a remarkable field for the study of evolution. One important point we may notice before leaving it. The tapirs and rhinoceroses take in many structural points a lower level than many forms which have perished. For example, *Hipparion* was a horse-like type of the Pliocene, which certainly comes within the range of the *Equidæ*, and the question often arises—How is it that these lower forms (tapir and rhinoceros) have survived and "higher" have become extinct? Put more generally, the question becomes—How is it that primitive animals still survive contemporaneously with the higher types? Leaving out of count special explanations applying to cases like the Australian *Metatheria*, the general explanation is:—(1) Species survive only so long as they are in structural harmony with their environment. (2) Environments change rapidly, but "ancient" environments exist at the present day as well as "modern or up-to-date" environments.

Hence the widely-scattered tapirs of the Miocene are now found only in the low-lying swampy forest land for which their structure is suited; in the regions where now the open grassy plains have become predominant the tapir died out, to be replaced by horse-like types more suited to the changed surroundings. The soft ground and the arboreal diet are complimentary to the numerous toes and the simple teeth of the tapir, whilst the hard level ground and siliceous grass calls forth the limb with single axis and the deep, complex, cemented teeth of the horse.

In response to the environmental factors which have changed, such as the presence of large *Carnivora*, these primitive types have also evolved horns (rhinoceros), or incisor tusks (elephant), or have adopted an arboreal or fossorial habit (*Hyrax*).

Hence we find that gradational adaptive structure in living forms is mainly due to "gradational" environments, and that in fossil forms it is due to gradual change of environment.

## SUB-ORDER V.—ARTIODACTYLA.

The *Artiodactyla* form a large branch or assemblage of *Ungulata*, which in many respects show parallel evolution to the *Perissodactyla*. They follow, however, rather different lines:—(1) The molar teeth are bunodont or selenodont. (2) The dorso-lumbar vertebræ are nineteen. (3) The femur has no third trochanter. (4) No alisphenoid canal and small nasals. (5) The carpus and tarsus are alternate and the toes are four or two; the main axis is between the third and fourth toes. (6) The stomach may be simple or complex and the placenta diffuse or cotyledonary.

One division of the *Artiodactyla* retain the bunodont teeth (*Bunodonta*), only multiplying the number of the tubercles, whilst the other division (*Selenodonta*) have the tubercles twisted into crescents or curves and worn down, thus producing the selenodont type. As in the *Perissodactyla*, there is the addition of cement and the heightening of the crowns.

The femur appears to have lost its third trochanter very early in the history of this sub-order. The toes show the same gradational reduction as in *Perissodactyla*, but on a different plan. The third and fourth toes are always equal and larger than the second and fifth. These latter are hoofed and touch the ground in pigs, but are greatly reduced in sheep and oxen and disappear altogether in the camel. It follows from the main axis passing between the third and fourth toes that the cuboid and ectocuneiform tend to be more or less equally developed, and that the astragalus articulates equally with the cuboid and navicular whilst the fibula, or its distal end, still remains in articulation with the calcaneum. The cuboid often fuses across the middle line with the navicular.

Family I.—**Hippopotamidæ.**—The Hippopotamus is confined to the rivers of Africa. Its canines and incisors are large and grow from persistent roots. The molars are of a slightly modified bunodont type and each tubercle wears into a three-lobed crown. The stomach is complex and the diet herbivorous. All four toes (first is absent) are present, the hoofs are not compressed and there is no fusion of the metapodials. In Pliocene and Pleistocene times the *Hippopotamidæ* were found throughout Eurasia.

Family II.—**Suidæ.**—The pigs have a bunodont dentition with many tubercles which, when worn, form irregular crowns. The canines grow from persistent pulps and form tusks. The dental formula is typical $\frac{3\,1\,4\,3}{3\,1\,4\,3}$. The stomach is simple and the diet omnivorous. All four toes are present, but the second and fifth are shortened up and the hoofs of the third and fourth are compressed into the middle line, forming the "cloven hoof." The metapodials and tarsal bones are, however, not yet fused and the ulna and fibula are still unreduced. The placenta is diffuse. The typical pigs are confined to the old world, but the peccaries *(Dicotyles)* are found in South America; they differ in dentition from the true pigs.

Fig. 390.—THE AFRICAN WATER-CHEVROTAIN (*Dorcatherium aquaticum*).

(From FLOWER and LYDDEKER.)

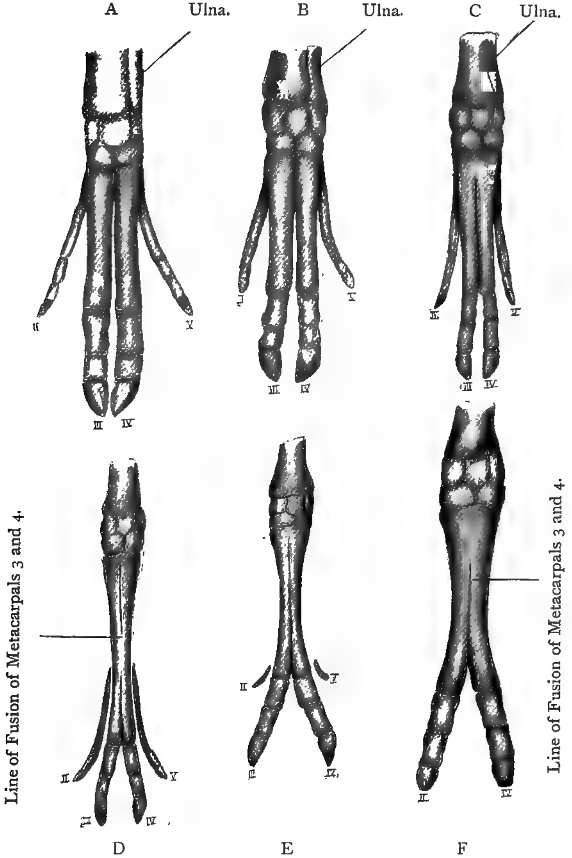
Family III.—**Tragulidæ.**—This is a small family of little *Ungulata* called the chevrotains. In dentition they most nearly resemble the *Pecora* as there are no upper incisors. There is, however, a pair of well-developed upper canines. The molars are selenodont. The stomach is complex, lacking only the manyplies of the *Pecora*. The ecto-cuneiform, navicular and cuboid bones fuse in one, and in most the third and fourth metapodials fuse together. The chevrotains resemble the *Suidæ* in having a diffuse placenta and in the presence of a complete fibula, whilst in one genus, *Dorcatherium*, the third and fourth metapodials are not fused. The chevrotains (*Tragulus*) are found in the forests of the Oriental Region and the water-chevrotain (*Dorcatherium*) is found in West Africa.

They are an interesting family, showing anatomical characters partly resembling the *Suidæ* and partly the *Pecora*. In the complete fusion of distal tarsal bones they go beyond both these families. *Dorcatherium* is found in the Miocene and Pliocene of Europe and India.

Family IV.—**Camelidæ.**—The camels form with the American llamas and their allies a natural family. They have three pairs of upper incisor teeth in the young, but all except the third incisor are lost later. Canines are present and the molars are typically selenodont. The loss of the two pairs of upper incisors foreshadows the condition found in the *Pecora*. The stomach has only two compartments corresponding to the first and fourth of the *Pecora*. The tarsal and carpal bones are distinct and separate, but the third and fourth metapodials are fused to form a "cannon bone." The third and fourth toes are alone present and the weight is borne upon pads under the penultimate phalanges; the small nail-like hoofs do not touch the ground. The placenta is diffuse. The camels are indigenous to Western and Central Asia. In South America are found the closely allied and similarly domesticated llama (*Auchenia*) and the alpaca, with their wild relatives, the guanaco and vicuña. They inhabit mountainous regions and are domesticated for their wool.

Family V.—**Pecora.**—The *Pecora* are the most important family of *Ungulata*, comprising deer, antelopes, sheep, oxen and the giraffe. They have the following characters in common, with isolated exceptions. The upper incisors and canines are lost and replaced by a hard pad. The molar teeth are selenodont and show every gradation from brachydont to hypsodont types. The stomach is complex, with four compartments (see Ox, page 514). The cuboid and navicular bones are fused and the third and fourth metapodials are fused to form the "cannon bone." There are usually only traces of the second and fifth toes. The fibula is completely fused to the tibia and the ulna to the radius. Most early fossil *Pecora* and a few modern types (musk-deer) have no processes of any kind on the head, but the majority of modern forms have paired bony processes attached to the frontal bones. These may be small and permanently covered with hair, as in the giraffe, or they may when complete consist of naked bone and are then known as antlers, as in deer: these antlers are shed annually. Lastly, the bony core may form a central support for a hollow "horn" of epidermic structure. The horn is never (except in the American Prongbuck) shed and grows perpetually from the base. The young deer has no frontal processes,

Fig. 391.—MANUS OF ARTIODACTYLA. *(Ad nat.)*



A, The Pig, third and fourth metacarpals are free and there are four functional toes. B, *Dorcatherium*, closely resembling the pig. C, *Tragulus*, with third and fourth metacarpals fused, second and fifth still entire. D, Deer. E, Sheep, and F, Camel, showing gradual disappearance of second and fifth toes and of ulna.

but these gradually arise as small protuberances covered with hair or "velvet." When the antlers are full-grown the "velvet" is rubbed off by the deer by friction against trees or other objects until the bony antler alone remains. The branches of the antler are called "tynes," and in those species with many tynes the number of these increases every year. Antlers are usually confined to the male sex.

The musk-deer (*Moschus*) and the water-deer (*Hydropotes*) have no antlers in either sex, but, on the other hand, they retain the upper canine teeth as long sharp tusks.

In all the *Pecora* the placenta is cotyledonary, a specialised derivative of the diffuse.

The true deer are not found in the Ethiopian region, their place being taken by the "horned" antelopes. To this region are confined the giraffes. The sheep, oxen and goats are more or less northern forms, the north temperate regions of Eurasia and N. America being their headquarters.

The above five families of *Artiodactyla* are intimately connected by numerous fossil forms.

## ORDER XI.—*Cetacea.*

The porpoise has been described as a typical aquatic mammal and it also serves as a type of the order *Cetacea.*

Under the heading of the porpoise we have noticed the adaptations to an aquatic life which constitute the main peculiarities of the *Cetacea.* These consist of the following:—

1. Fish-like shape, with dorso-ventral coloration.
2. Loss of hair and external ears and formation of "blubber."
3. Fore-limbs formed into fins, hind-limbs lost and tail forming a fin.
4. Homodont dentition (fish diet).
5. Modification of nostrils to form vertical blow-hole and prolongation of larynx.
6. Retia mirabilia.
7. Loss of salivary and lacrymal glands.

In addition, we may note the well-convoluted cerebrum of the brain and the abdominal testes. The stomach is usually somewhat complex, though the whole order is essentially carnivorous—an important distinction from the *Sirenia.* The uterus is bicornuate and the placenta, like that of many *Ungulata*, is diffuse and non-deciduate.

The *Cetacea* are usually gregarious and are widely distributed marine mammals. They are divided into two suborders, the *Odontoceti* and the *Mystacoceti*, which are widely apart.

### SUB-ORDER I.—ODONTOCETI.

The *Odontoceti* (toothed-whales) comprise the families of the sperm-whales *(Physeteridæ)*, the gangetic dolphins *(Platanistidæ)* and the dolphins *(Delphinidæ)*. They have a great number of homodont monophyodont teeth. They are more adapted to aquatic habits than the *Mystacoceti* in one or two respects, such as the entire loss of the olfactory organ and the formation of a single external nas.

The *Physeteridæ* are large predaceous marine forms, such as the sperm-whale. The *Platanistidæ* comprise the estuarine or freshwater river-dolphins, such as the blind-dolphin of the Ganges. The large family of the *Delphinidæ* includes the dolphins and porpoises of European seas, the narwhal (*Monodon*) of Arctic seas, with a single twisted tusk formed of a left upper incisor, and the "killers" (*Orca*).

### SUB-ORDER II.—MYSTACOCETI.

The *Mystacoceti* (baleen-whales) have teeth only in the embryonic young, which never become functional. They are replaced by a row of baleen-plates suspended from the upper-jaws, forming the so-called "whalebone." Their edges are frayed and they act as a sieve for separation of the food from the water. The head, especially the facial portion, is enormously developed, and the rami of the lower jaw are only connected by ligament. The whales feed upon small pelagic organisms, such as pteropods and certain *Crustacea.* The buccal cavity is huge and becomes filled with sea-water containing such pelagic organisms. The former is then driven out between the baleen-plates by elevation of the tongue, the latter being retained and swallowed. In *Mystacoceti* the ribs are attached to the transverse processes of the vertebræ only, and only one pair meet the small sternum, features which give the baleen-whales a greater freedom of respiration than the *Odontoceti.*

On the other hand, the external nares are paired and partially covered by the nasal bones and there is a distinct olfactory organ. In these respects the *Mystacoceti* are not so completely adapted to aquatic habit as the *Odontoceti.*

## ORDER XII.—*Carnivora.*

The dog and cat have been taken as types of the order *Carnivora.* They really represent the highest of the *Carnivora,* and the characters of the order are somewhat wider than those deduced from these two types. As in the case of the *Ungulata,* they present a series in which certain structural characters graduate from one end to the other. They have chiefly to be distinguished from the *Insectivora* and, in a more remote degree, from the *Ungulata.*

The great majority are carnivorous or flesh-eaters and are terrestrial cursorial types. They have usually at least four toes, which are armed with claws or unguiculæ, never hoofs or unguæ, as the limbs are nearly always called upon to perform other duties than locomotion.

The diet reflects itself in the dentition. They are always diphyodont and may have a large number of teeth. The teeth never have persistent pulps, the canines are always prominent, long and pointed; the incisors are usually $\frac{3}{3}$, small and pointed, and the molars are usually cusped with cutting edges, often tritubercular. The enamel is usually little worn and there is no cement.

There is always a more or less prominent postglenoid process of the squamosal, preventing backward motion of the mandible, and the condyle is transversely elongated; these modifications being connected with the "grip" as described in the "Cat" and "Dog."

The stomach is simple and the intestine comparatively short, with a short or simple cæcum. The uterus is bicornuate and the placenta zonary and deciduate.

Other skeletal characters to be noticed are the almost entire absence of the clavicle, the complete condition of radius, ulna, tibia and fibula, the fusion of the scaphoid and lunare bones into a *scapholunar* and the common occurrence of an entepicondylar foramen (in the humerus).

All the *Carnivora* show a well-convoluted cerebrum which partially covers the cerebellum.

As in the case of several orders, the *Carnivora* are sharply divided into two sub-orders, differing mainly in their habits and the structural modifications involved. The sub-order *Fissipedia* are terrestrial and the *Pinnipedia* are aquatic.

### SUB-ORDER I.—FISSIPEDIA.

The *Fissipedia* (or *Carnivora Vera*) have always the full complement of incisors ($\frac{3}{3}$), and one of the cheek-teeth in each jaw is formed by the carnassial tooth (see page 525). The limbs are formed for terrestrial locomotion and, as in the typical pentadactyle limb, have the third digit as long as, or longer than, the rest.

The present day *Fissipedia* can be divided into the *Æluroidea*, *Cynoidea* and *Arctoidea*, having affinities with the cats, dogs and bears respectively.

The *Æluroidea* are the most specialised. Their teeth are reduced in number and the skull is shortened. They are nearly all digitigrade. The characters of the auditory region are found to form a useful distinction between these and the other two divisions. Thus in the *Æluroidea* the auditory bulla is large, divided into two by an internal bony septum and partially covered externally by the paroccipital process of the exoccipital bone.

Family 1.—**Felidae.**—The *Felidæ* comprise the true cats, with retractile claws. Amongst them are the lion and leopard of the Ethiopian and Oriental regions, the jaguar of Neogœa, the tiger of Asia, the puma of America and the wild-cats and lynxes of Europe.

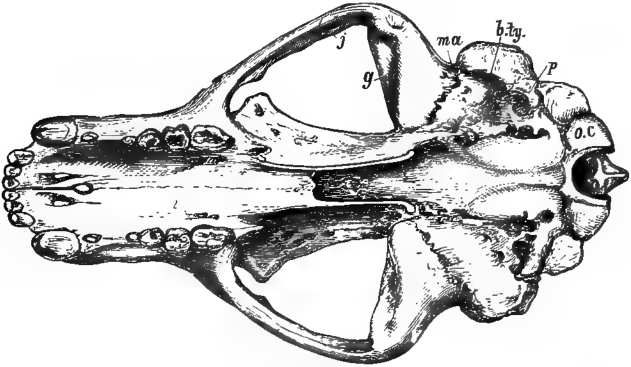
Family 2.—**Viverridae.**—The *Viverridæ* comprise the civets and mongooses, found only in Arctogœa. They have more teeth than the *Felidæ* and non-retractile claws.

Family 3.—**Protelidae.**—The *Protelidæ* consist of a single genus (*Proteles*), the aard-wolf of South Africa, a nocturnal burrowing animal of degenerate necrophagous habits.

Family 4.—**Hyænidae.**—Lastly, the *Hyænidæ* comprise the hyænas of Arctogœa, with more teeth than the *Felidæ*, but with no septum to the auditory bulla.

The *Cynoidea* have a larger number of teeth ($\frac{3\,1\,4\,2}{3\,1\,4\,3}$) and longer jaws than the *Æluroidea*, in correlation with which they are less strictly carnivorous. There is only a trace of an auditory septum and the paroccipital process does not overlap the bulla. They are mostly digitigrade but never

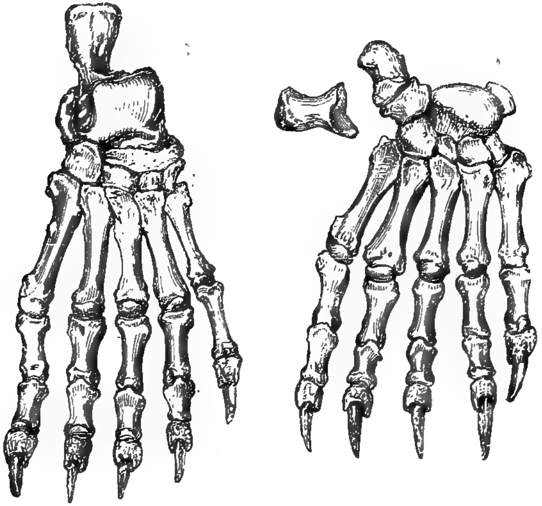
FIG. 392.—VENTRAL VIEW OF BEAR'S SKULL × ¼.



Note the flattened tympanic bulla, the long palate and the broad molars. The second premolar has been lost.

*b.ty.*, Tympanic bulla; *o.c.*, occipital condyle; *ma.*, auditory meatus; *g.*, glenoid cavity; *j*, jugal; *p*, paroccipital process.

Fig. 393.—FEET OF BEAR SEEN FROM THE UPPER SURFACE × ¼.



Note the flat broad sole or palm, the scapholunar bone and the five complete digits in each limb.

have retractile claws. The toes are usually $\frac{5}{4}$. The single family of the *Canidæ* is of world-wide distribution and comprises the dogs, foxes, wolves and jackals.

The *Arctoidea* have, like the dogs, a large number of teeth (often $\frac{3\,1\,4\,2}{3\,1\,4\,3}$). They are largely omnivorous and the molars are tuberculated with crowns worn to a flat surface. The auditory septum is absent and the bulla itself is flattened. The paroccipital process is quite free from it and projects downwards, as in other orders. All are either plantigrade or semi-plantigrade and there is the full complement of toes.

Family 1.—**Ursidae.**—The largest forms are the *Ursidæ* or bears, which are found everywhere except in Notogœa and the Ethiopian region.

Family 2.—**Procyonidae.**—The *Procyonidæ* are a small family of fox-like animals, such as the American raccoons and coatis and the panda of the Oriental region.

Family 3.—**Mustelidae.**—The third family, *Mustelidæ*, have a small number of molars ($\frac{1}{2}$) and comprise the otter, the skunk of America, the badger of the Palæarctic region, and a series of small fur-animals, such as the marten, sable and weasel.

### SUB-ORDER II.—PINNIPEDIA.

The sub-order *Pinnipedia* have the limbs adapted for aquatic locomotion. The fore-limbs, as in *Cetacea*, form the paddles or flippers, but the hind-limbs are not aborted but reflected back to form a double "tail," the true tail being correspondingly reduced. They still retain their hair and, to a large extent, their power of terrestrial progression. All the digits are retained and the first and fifth of the hind-limb are longer than the rest, forming a strong edge to the flipper. Between the digits is suspended a web. The claws of the hind-limb, when present, are situated on the upper surface of the digits and do not reach to their ends. The teeth vary considerably, but the incisor dentition is never complete and there is no carnassial tooth.

Family 1.—**Otariidae.**—The eared-seals or sea-lions *(Otariidæ)* are the most terrestrial. They can place the sole of the hind-limb upon the ground and thus shuffle along. They are piscivorous in diet and congregate in herds at the breeding season. Their fur, with the longer hair removed, furnishes the "sealskin" of commerce.

Family 2.—**Trichechidæ.**—The walruses (*Trichechidæ*) are Arctic and of large size. The teeth are blunt and reduced in number, the adult dentition being $\frac{1130}{0130}$. The canines are long, forming the tusks: they grow for some time from persistent pulps. The condition of the teeth is correlated with the molluscan diet. As in the sea-lion, the walrus can use its hind-limbs for terrestrial locomotion.

Family 3.—**Phocidæ.**—The seals (*Phocidæ*) have no pinnæ to the ears and the hind-limbs are permanently bent backwards. Hence the seals are more exclusively aquatic than the preceding families. The teeth are of the typical carnivorous type, with cusped ridged molars.

## ORDER XIII.—*Insectivora.*

The mole is a member of this order and has been described as illustrating the fossorial or burrowing habit. As implied in the name, the *Insectivora* are all feeders upon insects, worms and other small *Invertebrata*. This diet must of necessity be much more primitive than that of the *Carnivora* or the *Ungulata*, for the invertebrate animals are antecedent in time to the warm-blooded animals which constitute the food of the former and to the grasses devoured by the latter. Hence the *Insectivora* appear to retain many dental features in common with the early *Eocene* mammals. Their small size and general habits are also usually of the primitive terrestrial type, though as in all primitive groups certain members are very specialised for particular habits. They are all diphyodont and heterodont, the molars are usually sharp-cusped and of the tri- or quadri-tubercular types. On the whole, the dentition most resembles that of certain *Carnivora*, but the canines are never so prominent as in this order. The typical Eutherian dentition of $\frac{3143}{3143}$ is common. In external appearance a number are closely similar to the *Rodentia*, but they never possess the peculiar incisor teeth of this order. There are always more than two pairs of incisors on each side of the lower jaw and they do not grow from persistent pulps. The dental characters of *Insectivora* and *Rodentia* are therefore quite distinct.

In the limbs the *Insectivora* are little modified from the mammalian type. There are five digits on each limb and they are plantigrade; in these respects they differ from a great number of *Carnivora*, but in addition they nearly all have a well-developed pair of clavicles, bones which are absent or vestigial in the latter order. Other generalised features are the presence, in some, of ossified intervertebral discs (see Mole), and of an episternum and the frequent occurrence of an entepicondylar foramen and a third trochanter. The placenta, like that of the *Rodentia*, is discoidal and deciduate.

Many of the *Insectivora* are fossorial or arboreal, but most are terrestrial They are widely distributed throughout the Arctogœan realm, but are absent from Neogœa and Notogœa. In both these realms their place in nature is occupied by insectivorous *Polyprotodontia*.

### SUB-ORDER I.—DERMOPTERA.

The sub-order *Dermoptera* is constituted for the remarkable so-called "flying-lemur" (*Galeopithecus*) of the Malay Islands. It has a large patagium stretched from the neck to the fore-limb, between the fingers laterally to each hind-limb and thence to the tail. It is arboreal and uses its patagium for "gliding" from tree to tree in much the same way as Australian phalangers and the flying-squirrels.

Its structural peculiarities are chiefly as follows:—The lower incisor teeth are deeply pectinated or cleft and the second upper incisor and the canine have double roots, the tibia and fibula are distinct, and there is an intertarsal joint to allow of the hind-foot being rotated inwards for climbing. The mammæ are axillary.

### SUB-ORDER II.—INSECTIVORA VERA.

The sub-order *Insectivora Vera* comprises the remainder of the order, including the moles (*Talpa*) found in the temperate parts of Eurasia, the hedgehogs (*Erinaceus*), with great numbers of spines in addition, confined to Europe, Asia and Africa, the shrews (*Sorex*) of the Holarctic region, closely resembling mice in external appearance, the tree-shrews (*Tupaia*) of the Oriental region and the jumping-shrews (*Macroscelides*) of the Ethiopian region. In all these five families the molar teeth are multi- or quadritubercular, presenting a broad crown. The other four families are the water-shrew (*Potamogale*) and the golden-moles (*Chrysochloris*) of the Ethiopian region, the tenrec (*Centetes*) of Madagascar and the mole-like *Solenodon* of West Indies (strictly speaking, comprised in the Neogœan realm). These families retain the more primitive tritubercular teeth with a V-shaped cutting edge.

## ORDER XIV.—*Chiroptera.*

The fox-bat has been used as an illustration of the *Chiroptera*. They are evidently closely allied to the *Insectivora* but have the fore-limbs modified for flight, the rest of the skeleton also undergoing important modifications which have been noticed under the type. They resemble the *Insectivora* in their simple brain (the cerebrum having few convolutions and not extending over the cerebellum), in the abdominal testes and in the discoidal and deciduate placenta.

### SUB-ORDER I.—MICROCHIROPTERA.

The sub-order *Microchiroptera* comprises a number of smaller insect-eating bats, with cusped molars and with greater adaptation for flight than the other sub-order, as shown by the presence of a claw on the first digit only and the part taken by the tail in the formation of the interfemoral membrane (see page 553). The common British bats and the South American vampires belong to this sub-order.

### SUB-ORDER II.—MEGACHIROPTERA.

The sub-order *Megachiroptera* comprises the large frugivorous bats typically represented by the *Pteropodidæ*. They have flat cuspidate or comparatively smooth molars, a claw on the first two digits of the manus and an interfemoral membrane free from the tail. The *Pteropodidæ* have a peculiar distribution, being found in Australia, the Oriental region and Madagascar.

## ORDER XV.—*Primates.*

The *Primates* stand at the head of the orders of *Mammalia* and of the animal kingdom. They are essentially generalised and belong to the transition arboreal group. The possibilities of movement in the pentadactyle limb and vertebrate skeleton are seen in this order at their maximum. Many of the order are omnivorous, though a frugivorous or insectivorous diet is common. The incisors are usually reduced to $\frac{2}{2}$ and may be $\frac{1}{1}$; they are commonly chisel-shaped. The canines are mostly longer than the incisors and nearly always present. The cheek-teeth are usually quadrituberculate and have flat grinding crowns.

In the limbs the five digits are usually all present and the hallux is with one exception opposable to the other toes (arboreal). The claws have a tendency to become flattened into nails. The radius, ulna, tibia and fibula are all complete and the full movement of supination and pronation is retained. For similar reasons the clavicle is always well developed and there is little or no fusion of the tarsal or carpal bones. Terrestrial locomotion is plantigrade.

The orbits tend to face forwards instead of laterally and they are always complete.

The brain is highly developed, the cerebrum being much convoluted and covering the cerebellum. Its proportion to the body is very high (see page 463).

The placenta is either diffuse and non-deciduate or metadiscoidal and deciduate.

The *Primates* are, like a good many other preceding orders, sharply divided into two sub-orders, *i.e.*, the *Lemuroidea* and *Anthropoidea*.

### SUB-ORDER I.—LEMUROIDEA.

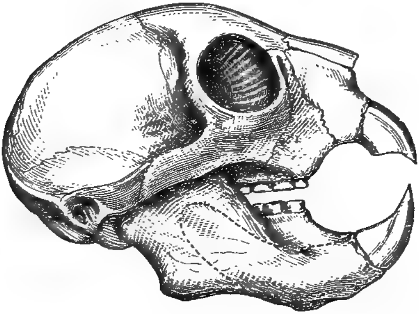
The *Lemuroidea* unquestionably rank lower than the other sub-order. They are more quadrupedal and in Eocene strata they appear to gradate into the *Insectivora*. They differ from the *Anthropoidea* in the invariable presence of all five digits, in the lengthened facial region of the skull, the orbit being only separated from the temporal fossa by a (postorbital) bar of bone, not a partition, and the lacrymal foramen being outside the orbit, in the lower type of brain with smaller and less-convoluted cerebrum, in the possession of a diffuse, or dome-shaped, non-deciduate placenta and somewhat bicornuate uterus.

Family 1.—**Lemuridæ.**—The true lemurs. Found in Madagascar, Africa and the Oriental region.

Family 2.—**Tarsiidæ.**—Comprising only the peculiar little *Tarsius* of the Malay Islands. Its incisors are $\frac{2}{1}$. The proximal tarsal bones are elongated and two of the hind-digits are clawed.

Family 3.—**Chiromyidæ.**—Another aberrant lemur, known as the Aye-Aye. It is found in Madagascar, nocturnal and arboreal. It has a rodent-like dentition with incisors growing from persistent pulps. Its dental formula is $\frac{1\,0\,1\,3}{1\,0\,0\,3}$. All the digits are clawed but the hallux which bears a nail. The third digit of the manus is very long.

Fig. 394.—LATERAL VIEW OF SKULL OF THE AYE-AYE (*Cheiromys*).



Note the rodent-like incisors. Dental formula $\frac{1\,0\,1\,3}{1\,0\,0\,3}$.

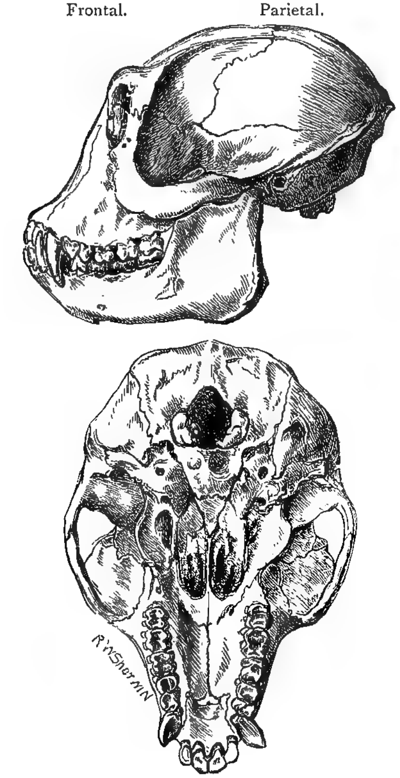
*Distribution of the Lemuroidea.*—The chief feature of the distribution of lemurs is their extraordinary abundance in Madagascar. (For an account of this, see page 602.)

### SUB-ORDER II.—ANTHROPOIDEA.

The *Anthropoidea* are advanced types of *Primates.* They have a tendency to loss of the pollex; the facial portion of the skull tends to recede below the cranial and the orbits look more forwards than those of the *Lemuroidea*, being also completely separated from the temporal fossæ by a bony partition. The lacrymal foramen in all *Anthropoidea* opens inside the orbit. The brain is of a higher type, the cerebrum being large, well convoluted and covering the cerebellum. The placenta is metadiscoidal (see page 482) and deciduate and the uterus is simple.

Fig. 395.—Lateral and Ventral Views of Skull of Semnopithecus Nemœus.

(After De Blainville.)



Note the shortened facial and expanded cranial regions, the dentition $\frac{2}{2}\frac{1}{1}\frac{2}{2}\frac{3}{3}$, the bony auditory meatus, the suture between frontal and squamosal.

Family 1.—**Hapalidæ.**—The Marmosets of Neogœa (S. America). They are the most quadrupedal of the *Anthropoidea.* As an exception to the rest of the *Primates* they have only two molars. Their dental formula is $\frac{2132}{2132}$. All the digits except the hallux are clawed and the pollex is present but not opposable to the other digits. They have a long, bushy tail and are strictly arboreal.

Family 2.—**Cebidæ.**—The American Monkeys. They are confined to Neogœa, are strictly arboreal and often have prehensile tails. Their dental formula is $\frac{2133}{2133}$, hence they differ from the *Hapalidæ* in having an additional molar. They also have a pollex to a large extent opposable. They include the Spider-monkeys and Capuchins.

Fig. 396.—FRONT VIEW OF SKULL OF A GORILLA.

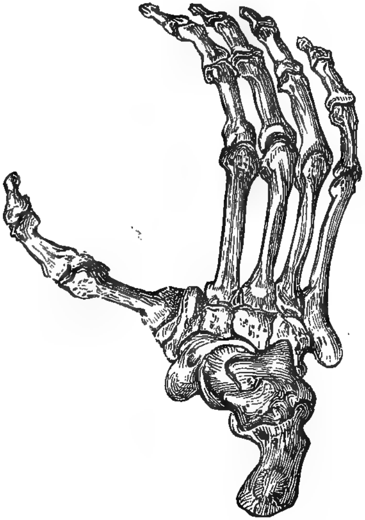
Note forward position of the complete orbits, the (vertical) sagittal crest, the two incisors $\left(\frac{2.2}{2.2}\right)$ and the rather longer canines.

Family 3.—**Cercopithecidæ.**—All this family of Monkeys is found in the Old World, mainly in the Oriental and Ethiopian regions. The tail is not prehensile but is often of great length. There are usually brightly coloured ischial callosities. The pollex, if present at all, is always opposable, and the front-limbs are always markedly shorter than the hind-limbs. The dentition is $\frac{2123}{2123}$. All the best known monkeys belong to this family, including the baboons (*Cynocephalus*) of Africa, which are not arboreal but frequent rocky regions in communities, and the familiar Macaques (*Macacus*) of Asia.

Family 4.—**Simiidæ.**—The family of Anthropoid Apes. They are all found in the Old World and comprise the Gorilla and Chimpanzee of equatorial Africa, the Orang of Borneo and the Gibbons of the Oriental region. They mostly have no tail; there are never ischial callosities. The pollex is always opposable and the front-limbs always exceed the hind-limbs in length. The dentition is $\frac{2123}{2123}$.

The two families of Old World monkeys differ so markedly from the two New World families that there is great probability of their having been independently evolved. The chief differences are as follows—In the skull the New World monkeys always have three premolars and three or two (marmosets) molars, an auditory bulla with no bony auditory meatus; the alisphenoid is suturally united with the parietal to the exclusion of the squamosal from the frontal. In the Old World monkeys there are always only two premolars and three molars, there is no auditory bulla, but there is a bony auditory meatus and the squamosal has a sutural connection with the frontal.

Fig. 397.—Bones of the Ankle and Foot of Gorilla.

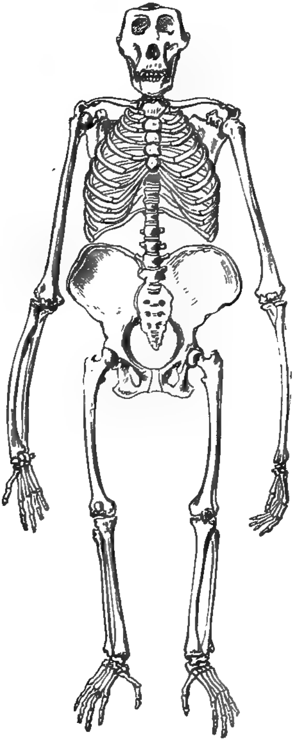


Note the opposable hallux and shortness of the "instep."

Family 5.—**Hominidæ.**—Man is now usually regarded as forming a zoological family of the Primates. He differs anatomically from the other families in the very high development of the brain, in the great proportionate length of the hind-limbs, the non-opposable hallux, the curvature of the spine and other minor features correlated with an upright gait. His dentition is $\frac{2\,1\,2\,3}{2\,1\,2\,3}$, but differs from that of all monkeys in having an even series of teeth with no diastema.

*Distribution of the Anthropoidea.*—The occurrence of two differing series of monkeys in the Old and New World respectively has already been noticed. The last family is of course at the present day cosmopolitan. A fragmentary fossil from the East Indies, called *Anthropopithecus erectus*, is said to be a link between man and the anthropoid apes, the chief evidence being based upon the cranial capacity and relative brain-weight. Fossil *Anthropoidea* are found as far back as early Miocene, but they still have their "family" characters.

Fig. 398.—Entire Skeleton of the Gorilla.
(De Blainville.)



Note opposable hallux and long fore-limbs.

# CHAPTER XXXI.

## *GEOGRAPHICAL DISTRIBUTION OF MAMMALIA.*

MAMMALS, with the exception of the ærial (*Chiroptera*) and aquatic (*Sirenia* and *Cetacea*) types, lend themselves specially to the solution of geographical problems, because, as a rule, a strait of water of a few miles (twenty or so) forms an effective physical barrier to their migratory progress. Hence the first important fact of mammalian distribution is their entire absence from (1) all oceanic islands, *i.e.*, from islands raised above the level of the sea by volcanic agency or by the growth of coral; and (2) all islands which were separated from the mainland at a date antecedent to the evolution of mammals (*e.g.*, New Zealand).

Leaving these islands out of consideration, we find that there is great diversity in the occurrence of *Mammalia* in certain districts. This diversity, like that of organic structure, must be primarily due to diversity in the physical environment.

It must be remembered that certain mammals are adapted for certain habitats. Thus arboreal forms are confined to forest lands, others to the open plains, and so on. The particular kind of habitat affected by a mammal is called its *station*, and as these natural conditions recur throughout all the large regions, they do not affect the general problems of geographical distribution. As an example, if we say that marmosets are characteristically found in South America, we do not mean to imply that they occur in the open "pampas" of the Argentine, but that having a forest *station* they usually occur in the forests of South America.

Coming to the prime physical factors which govern the spreading or distribution of mammals, we find that they act through one of the two primary functions of locomotion and food.

In the case of locomotion, certain mountain ranges offer effective barriers to certain mammals, the physical difficulties being impassable. Again, a comparatively narrow strait of water may act as an effective barrier to the great majority of mammals.

As regards food, the whole mammalian class is either directly or indirectly dependent upon vegetable food and the great determining factor in the distribution of plants is temperature. It is probable that the direct effect of temperature upon mammals is not very potent, as their hairy covering with its possible variations allows of great latitude, but the indirect effect through plants is very marked. Thus many mountain ranges act as barriers more by virtue of their great altitude than by mechanical difficulties, and ranges parallel to isothermals are more effective than those in other directions. Were there no other physical elements of diversity than temperature, it is probable that the herbivorous mammals would be evenly distributed in zones, according to the isothermals or lines of equal temperature.

Deserts may act, through absence of food and water, as effective barriers, as, for example, in the case of the Sahara.

The difficulties are multiplied when we recollect that these factors of water-isolation, rock-isolation, and sand-isolation are like all physical phenomena only transitory, and therefore act only for certain periods The present distribution of mammals cannot be satisfactorily explained by an appeal to the present isolative agencies, just as the present environmental factors of an organism will not account for its structure. In other words, the fauna of a given area is determined, firstly, by its past physical history and, secondly, by its present physical condition. Hence we must, in dealing with the characteristic fauna of the great realms, take into consideration their past as well as their present.

Throughout the Triassic and Jurassic the reptiles were the dominant group, and certain of these, the *Anomodontia* (with heterodont teeth), appear to be closely allied to the amphibio-reptilian-like ancestors of the mammals. It is in the higher strata of the Triassic that the *Allotheria* (*Prototheria*) first make their appearance, together with certain types which may be *Polyprotodontia* (*Metatheria*). The

*Allotheria* can be traced through the Jurassic and possibly into the Eocene (Tertiary). The *Polyprotodontia* can also be traced through Jurassic and Cretaceous into the Tertiary. Through the Tertiaries can be traced certain of the *Metatheria* (Didelphidæ) to the present day and the eutherian types first occur in the Eocene. In the Eocene strata there are abundant remains of many *Eutheria*, in marked contrast to their absence in the Cretaceous.

Let us now glance at the present distribution of mammals. The geographical world is usually divided up into three zoological realms :—

1. NOTOGŒA—comprising Australia, New Guinea, Polynesia and New Zealand and certain of the Malay Islands.
2. NEOGŒA—comprising South America, West Indies and part of Central America.
3. ARCTOGŒA—North America, Eurasia and Africa.

This is a very unequal division of the world's surface, but is justified by the quality of the faunistic differences in each region.

1. NOTOGŒA.—In this realm we may, from a mammalian point of view, leave out of consideration New Zealand and Polynesia, for, with the exception of bats and a rodent or two, they have no mammals. The realm has an entire monopoly of one sub-class of mammals, the *Prototheria*. Of the *Metatheria*, it contains all the order *Diprotodontia* (with one exceptional family in South America) and four out of the five families of *Polyprotodontia*. Of the third sub-class, *Eutheria*, there are extremely few representatives. There are seven genera of *Rodentia* (Muridæ) and the dingo or native dog, together with many bats, and a pig in New Guinea.

Notogœa is essentially a Prototherian and Metatherian world. Here the *Metatheria* reach an extraordinary diversity in structure and show adaptations closely resembling those met with in the *Eutheria* elsewhere. The realm gradates to the south-east of Asia by a series of islands of the Austro-Malay region, and here the characters of Notogœa and Arctogœa merge more or less sharply into each other. The line called *Wallace's line* dividing the two realms passes northwards between Bali and Lombok, between Borneo and Celebes and eastwards of the Philippines. Celebes has, however, some claims to be regarded as belonging to Arctogœa.

We may naturally ask—What is the meaning of this faunistic character of the realm Notogœa? How has this realm come to be a sort of "preserve" for the two archaic sub-classes to the almost entire exclusion of the third and more highly organised sub-class? The past history of Notogœa does not help us much, for its geological strata have not been sufficiently investigated. Remains of the modern Monotremes are found in the Pleistocene of Australia. The same is true of the *Metatheria*, including the large extinct forms of *Diprotodon* and *Thylacoleo.* Further back than the Pleistocene, or at least the Pliocene, we know nothing of the fossils of Notogœa. On the other hand, we find that remains of *Metatheria* occur in Europe and North America from the Triassic through Jurassic to Cretaceous. Indeed, Europe and North America, and possibly Asia by inference, were largely peopled by *Metatheria* during the secondary period; but, we have as yet no evidence of Eutherian mammals during this period. Hence in these important respects the fauna of Notogœa at the present day resembles that of Eurasia in the secondary period. The inference is that at that period Notogœa (Australia and New Guinea) was connected by land with the Eurasian continent, and further, that this land connection was broken at the dawn of the Tertiary epoch before the Eutherian mammals were evolved. The connection having never since been restored, the *Metatheria* in Notogœa have been free to become modified and adapted into their numerous types now existing. The few *Eutheria* now existing in Notogœa have on this assumption effected a crossing either in canoes (man and probably the native dingo), or timber (the *Muridæ*), or by flight (the bats). Man has more lately introduced the Eutherian rabbit and sheep, besides other types, and the rabbit at least appears to be making up rapidly for the time lost since the early Tertiary, during which it has been excluded from the district. If we may regard the *Allotheria* as true *Prototheria*, we may assume much the same history of events as above to have occurred in the secondary strata of Europe, America and Africa, and possibly in the Eocene of America. The *Monotremata* have, however, had to compete with the *Metatheria* even in Notogœa and have only survived in small numbers.

It is well to note that the regions of Notogœa form more or less of a gradation. (1) Polynesia has practically an oceanic fauna and there are no mammals but bats. (2) New Zealand is equally bare of mammals but has more reptiles and birds. (3) Australia has *Prototheria* and *Metatheria* with a few incidental *Eutheria*. (4) Austro-Malaysia has more *Eutheria*, *e.g.*, the pig, and approximates to Eurasia in faunistic character. The best line of separation between Notogœa and the rest of the world would pass to the east of Celebes, but the demarcation is merely arbitrary. The chief point about the mammalian fauna of Notogœa is that it essentially belongs to the two lowest sub-classes to the almost entire exclusion of the third. The assumption in explanation is that Notogœa has been isolated from the rest of the world before the evolution and spread of the last sub-class, but not before the two lowest sub-classes had spread downwards from the north.

**Extant Mammalia of Notogœa.**

| SUB-CLASS. | ORDER. | FAMILIES. |
|---|---|---|
| Prototheria | Monotremata | 2 (Duckmoles, Echidnæ.) |
| Metatheria | Diprotodontia | 3 (Kangaroos, wombats, phalangers.) |
| | Polyprotodontia | 3 1 (Dasyurus, bandicoots, marsupial-moles.) |
| Eutheria | Rodentia | 1 7 Species. |
| | Carnivora | 1 1 |
| | Ungulata | 1 1 |
| | Chiroptera | 5 Large number. |

2. Neogœa.—This realm contains the remainder of the sub-class *Metatheria*, not found in *Notogœa*. These are the opossum-rats and the opossums, representatives respectively of the orders *Diprotodontia* and *Polyprotodontia*. Of the *Eutheria* there is no lack in point of numbers. It has a monopoly of one sub-order, the *Xenarthra*, or sloths, anteaters,

and armadillos, whilst there are also an enormous number of *Rodentia*, especially of the sub-order *Hystricomorpha*, including the porcupines, squirrels, chinchillas, cavies and agoutis. On the other hand, the *Ungulata* are very few. A few deer, tapirs, llamas and alpacas, and peccaries representing four families, make the total list. The *Carnivora* are fairly represented, though, except for the raccoon family, not by many special types. The jaguar and puma represent the larger cats, whilst there are several of the dog family. There is but one bear and these are no civets nor hyænas; a few "weasels," such as the skunk and otter, and several peculiar raccoons, such as the coati and kinkajou, give a complete general list. The *Insectivora* and *Lemuroidea* are entirely absent (save the *Solenodontidæ* of West Indies), but three families of bats are found, of which one, the vampires, is confined to the realm. The *Anthropoidea* are represented by two families, the marmosets and spider-monkeys.

Such then are the general characters of the realm. Of this large assemblage we may note which are confined to the realm, for upon this largely depends the claim for such an important distinction. Of the *Metatheria*, the *Diprotodontia* are elsewhere confined to Notogœa, but the *Polyprotodontia* are still found in North America. Of the *Rodentia*, Neogœa has four peculiar families, forming the majority of the *Hystricomorpha*. In the *Ungulata*, one family, the peccaries, is peculiar to the realm. In the *Carnivora* there are no peculiar families but a number of peculiar genera. The vampires are only found in this realm, as also are the marmosets and spider-monkeys.

It is well to note that the absence of many types is as much a feature of the realm as the presence of others. The most striking of these deficiencies are perhaps the sub-class *Prototheria*, the order *Insectivora*, the sub-orders *Nomarthra* and *Lemuroidea*, *Proboscidea* and *Hyracoidea*, and the important families of *Viverridæ* (civets), *Bovidæ* (oxen, sheep, antelopes), *Suidæ* (pigs), *Equidæ* (horses), *Pteropodidæ* (fox-bats) and *Rhinolophidæ* (horse-shoe bats), *Cercopithecidæ* and *Simiidæ* (old-world monkeys).

But one of the most extraordinary discoveries with regard to this realm is the fact that it has had a great past history. The fossils teach us, firstly, that the *Xenarthra* at one time were so numerous and attained such large dimensions as to form quite the leading feature of the realm. The giant ground-sloth or *Megatherium* and its near ally the *Mylodon* are found in the Pleistocene and Recent, whilst the equally ponderous *Glyptodons* or giant armadillos occurred at about the same period. These *Edentata* as a group appear to have extended back at least as far as the Miocene, if not the Oligocene, and at present we have no good evidence that *Edentata* have ever occurred in other parts of the world, with the reservation that one or two types appear to have made their way into North America during the Miocene epoch, just as some armadillos have done at the present time.

The second lesson learnt from the fossil beds is that the peccaries, vicuñas, guanacos, deer and tapirs which now form the very sparse representatives of the great order *Ungulata*, and the *Carnivora* are all comparatively recent immigrants from the North, no trace of any of them occurring below the Pliocene of Neogœa, though abundant remains are found in North America. On the other hand, there appears to have been a very rich ungulate fauna during the past, though they in their turn may have originated in the North and migrated southwards. However that may be, the horse flourished here in Pleistocene times, as also the Mastodon, both probably northern immigrants. In addition, there were from the Miocene onwards an enormous number of strange ungulates, some like rhinoceroses in size and other features. At least four entirely peculiar sub-orders of the *Ungulata* have to be instituted to hold these extinct forms.

The *Carnivora*, for the same reasons as stated above, appear to have been comparatively recent immigrants from the North, like the peccaries and others. We therefore have a considerable light thrown upon the past history of Neogœa which enables us, at any rate to some extent, to explain its peculiarities at the present day. Put succinctly the history of events appears to have been as follows :—The land-union between North and South America appears to have been of recent date, and from some unknown time up to at least the close of the Miocene epoch, the two continents were separated by the sea. South America then had its peculiar fauna of abundant *Edentata* and *Ungulata*, differing from any other part of the world, but upon the establishment of the land connection between the two continents the Neogœan realm was flooded with up-to-date immigrants from the north. Vicuñas and guanacos, "cats" and "dogs" (*Felidæ* and *Canidæ*), raccoons and skunks, deer, horses, peccaries and mastodons, opossums and many rodents rapidly spread over the land and may have contributed considerably to the extermination of many of the indigenous types. Through the Pliocene and Pleistocene this hybrid fauna flourished until all the larger types were for some unknown reason exterminated and the present fauna remained.

But we still have the indigenous fauna of Neogœa and cannot help attempting to trace its origin. Whence arose all the primitive Ungulates, the Edentates, hystricomorphous rodents, the monkeys and the marsupials other than opossums (opossum-rats and fossil allies in the

Miocene). Of this we *know* nothing, but it has been suggested that a land-connection with Australia would account for the marsupials, that a similar junction with Africa would give monkeys, hystricomorphous rodents and the selenodonts, and, lastly, that an early connection with North America would give the *Ungulata* from primitive allies in the Eocene there. But these are all surmises and none of the evidence *pro* or *con* can be here given. Of this we may be fairly certain that Neogœa has a remarkably primitive "indigenous" fauna of primitive Eutherian animals belonging to the *Edentata*, *Rodentia*, early *Ungulata* and low Anthropoid types, the greater number of which have perished, that these have been enabled to survive and to reach a climax of adaptation owing to an isolation of the realm up to nearly the commencement of the pliocene epoch, and that subsequent connection led to an introduction of a northern fauna of higher Eutherian types.

We may say that the peculiar isolation of Notogœa and of Neogœa have furnished us with an example of the evolutionary possibilities of the *Metatheria* and of the *Edentata* respectively, taken in the former case from the prevalent fauna of the early dawn of the Tertiary epoch and in the latter of some slightly later date.

**Extant Mammalia of Neogœa.**

| SUB-CLASS. | ORDER. | FAMILIES. |
|---|---|---|
| Metatheria. | Diprotodontia. | 1 (Opossum-rats). |
| | Polyprotodontia. | 1 (Opossums). |
| Eutheria. | Edentata. | 3 (Sloths, anteaters, armadillos). |
| | Rodentia. | 9 (Squirrels, beavers, cavies, porcupines). |
| | Carnivora. | 5 (Jaguars, pumas, coatis raccoons). |
| | Ungulata. | 4 (Peccaries). |
| | Insectivora. | 1 (Selenodonts). |
| | Chiroptera. | 3 (Vampire-bats). |
| | Anthropoidea. | 2 (Marmosets, Spider-Monkeys). |

3. ARCTOGŒA.—This third zoological realm comprises a vast extent of land, including nearly all North America, Europe, Asia and Africa. It has very distinctive faunistic characters, separating it from the other two realms. Taking the present-day fauna first, we find that there are no *Prototheria*, and only one family of *Metatheria* (Opossums). On the other hand, the *Eutheria* are abundant and of great diversity. It has a monopoly of the sub-order *Nomarthra* (Aard-varks and Pangolins); of *Rodentia* it has the families of Beavers (*Castoridæ*), the Jerboas (*Dipodidæ*) and the Picas (*Lagomyidæ*) to itself, and abundant representatives of other families, such as *Muridæ*, the hystricomorphous Neogœan types being the most conspicuous absentees. Of *Carnivora* the hyænas and civets and earth-pig (*Protelidæ*) are confined to

the realm, whilst all the other families are present. Of *Ungulata* all the families of *Perissodactyla* and *Artiodactyla* are found, and all are confined to the realm except the pigs, tapirs, camels and deer. In addition, the two sub-orders of the elephants and hyraces are only found here. Of *Insectivora*, the realm has almost a monopoly, one family alone (the *Solenodontidæ* of West Indies) being found outside its borders. The lemurs are also confined to the realm, as are three of the anthropoid families.

Thus the realm has a practical monopoly of the order *Insectivora* and of the large order *Ungulata* (except four families), including the whole of the two sub-orders *Proboscidea* and *Hyracoidea*, of the sub-orders *Nomarthra* and *Lemuroidea*, three families of the cosmopolitan *Carnivora* and three (of five) of the *Anthropoidea*, besides a great number of rodent families. On the other hand, the absence of *Prototheria*, and all the families of *Metatheria* but one, is equally diagnostic.

The past history of Arctogœa shows that in the secondary epoch its fauna was remarkably uniform, not only as regards reptiles but in mammals. Of these the *Prototheria* were represented by the *Allotheria* occurring in Europe, North-America and Africa, and the *Metatheria* by numerous small *Polyprotodontia* from North America and Europe. No evidence of *Eutheria* in this realm (or indeed anywhere else) has yet been forthcoming from secondary strata, and we have already seen that at this period (Jurassic and Cretaceous) Notogœa was in direct connection with this realm, as probably was Neogœa as well. Thus all the realms probably had much the same reptilian and early mammalian fauna. At the base of the Eocene, there appear early *Lemuroidea* and very primitive *Carnivora* (Creodonta) and *Ungulata (Condylartha)*; all were very generalised with simple tritubercular teeth and pentadactyle limbs. During the Eocene the greater number of the orders make their first appearance, together with numerous types now extinct, and at the commencement of this period, the Metatherian types disappear, with the exception of the opossums. Hence the Arctogœan realm assumed its general diagnostic characters in early Tertiary times and has continued onwards to differentiate into several important regions. Apparently it has by later communication given of its types considerably to Neogœa and to some extent (incidentally) to Notogœa, but has received from them very little except perhaps a few *Edentata* from the former.

Arctogœa can be divided into five regions, as follows:—(1) Madagascar and adjacent islands; (2) Ethiopian, or Africa south of the Sahara; (3) Oriental—India, southern India and Malay; (4) Holarctic—the rest of Asia, Europe and North America north of (5); (5) Sonoran—roughly corresponding to greater part of United States.

1. Madagascar Region, comprising Madagascar, Mauritius, Bourbon, Rodriguez, Seychelles and Cornova Islands. —The mammalian fauna of Madagascar is so remarkable that it has strong claims for being placed in a region apart from Africa. The most striking feature is the huge quantity and variety of lemurs, representing three families and nearly forty known species. The allied order of *Insectivora* is represented by a large and unique family, the *Centetidæ*, in addition to a probable immigrant, the musk-shrew, and one potamogale. A cat-like carnivore (*Cryptoprocta*) and a number of mongooses represent the *Carnivora*, all belonging to the civet family (*Viverridæ*). There are in the case of Notogœa about seven species of the cosmopolitan *Muridæ*, of the *Rodentia*, and the list is completed by the bush-pig. We may note also the fox-bats (*Pteropus*) and an extinct *Hippopotamus*.

Lemurs, insectivores, carnivores and rodents occur on the mainland of Africa, but none of the genera found in Madagascar. Indeed, the only genera common to the two regions are the bush-pig and hippopotamus and the musk-shrew. The latter was probably introduced at a later date, and the two former probably introduced themselves by swimming, possibly at a date when the strait was of narrower dimensions than now.

Madagascar has the monopoly of the following families: —The *Chiromyidæ* (Aye-Aye) and *Centetidæ* (Tenrecs), and by some authorities the "Foussa" (*Cryptoprocta*) is placed in a family by itself.

Almost as strange as these inhabitants is the entire absence of all the characteristic African mammals, the large *Ungulata* and *Carnivora*.

The usually accepted explanation of these peculiarities is the assumption that Madagascar has been isolated from the mainland of Africa from early Miocene or upper Oligocene. In the Oligocene the lemurs flourished in Europe, as also the civets; and a separation effected at this period might easily isolate a sample of these two groups, together with the primitive *Insectivora*, whilst the modern *Ungulata* and *Carnivora* of Africa would not by then have reached that region. Hence the history of Madagascar is a more recent repetition on a smaller scale of the history of Notogœa. Occurring later, it merely serves to preserve a few families or at least the greater part of an order, instead of nearly two whole sub-classes.

We may here allude to the hypothetical continent of LEMURIA. Apart from the distribution of the fox-bats and a peculiar civet, the evidence for the former existence of this continent connecting Madagascar with India and Further India is based largely upon the resemblances in amphibians, land-tortoises, birds and molluscs.

The presence of lemurs in Malay has led to the supposition that one feature of this continent was an abundance of this type, hence the name. Geographical evidence for the same is found in the constitution of the Seychelles, which, unlike oceanic islands, are formed of granitic rocks of the primary period.

This sunken continent, if it existed at all, would appear to have scarcely survived into the Tertiary period, so that it can hardly be said to come into Eutherian mammalian times, and we have seen that the lemurs can be accounted for in another less hypothetical way.

2. ETHIOPIAN REGION.—The Ethiopian region comprises the continent of Africa south of the Tropic of Cancer. The area is much more isolated zoologically than geographically, for the Sahara Desert extends across its northern part, and has probably since the Cretaceous epoch formed an effectual barrier to mammalian migrations, which have hence been confined to the Nile basin on the east side. This region has four sub-divisions differing in physical characters, the pasture lands south of the Sahara, the Sahara desert itself with sparse fauna, the equatorial forests, and the area south of these.

It has a wonderfully rich mammalian fauna, though it is for the most part being rapidly exterminated. It has of course no representative of the two lowest sub-classes, but possesses in the aard-varks and pangolins two families of the very low order *Edentata.* Rodents are plentiful, including squirrels, *Anomalurus* (a peculiar flying squirrel), a large number of the ubiquitous *Muridæ*, jerboas, cape jumping hares, whilst the hystricomorphous types are represented by the octodonts, which we have already met with in Neogœa. But the most remarkable feature is the abundance of *Ungulata*; elephants and dasses, hippopotamuses, water chevrotains, bush-pigs and wart-hogs, giraffes, rhinoceroses, zebras and quaggas, and lastly antelopes of every description. Every family of this great order is represented except the *Camelidæ* and *Tapiridæ.* Of the abundant *Carnivora* we may note the lion and leopard, civets, mongooses, the aard-wolf, hyænas, jackals, foxes, and ratels. Of *Insectivora* there are the jumping-shrews, golden moles, a few hedge-hogs and shrews, the river-shrews. Of the *Primates* there are one family of lemurs, the gorillas and chimpanzee, and a great number of smaller monkeys of the family *Cercopithecidæ*, and including the baboons. Of this great and heterogeneous assemblage there is a large number peculiar to the region. No order is of this category, but there are the following families:—The aard-varks, the dasses (partly in Syria), the *Anomaluridæ*, giraffes, hippopotamuses, aard-wolf (*Protelidæ*). golden moles and jumping-shrews; and of lesser groups, the zebras and predominance of the antelopes. Again, we may note the absence of the bears, tapirs, camels and deer and poor representation of the *Mustelidæ;* and of lesser groups, sheep and goats and wolves.

The palæontological history of Africa during the Tertiary period has yet to be worked out, but the evidence of the faunistic characters of Madagascar on the one hand and of the Oriental and Holarctic regions on the other, lead us to suppose that there is a remarkable parallelism in the history of Ethiopia to that of Neogœa. As in the latter case, we can recognise an indigenous fauna of Africa flourishing during the Eocene and Oligocene periods, of which we have a kind of sample in Madagascar at the present day. Certainly, lemurs, civets and primitive types of *Insectivora* abounded. During the Miocene, or possibly later, Madagascar became separated from the mainland and subsequently there commenced a great immigration from the Oriental and partly the Holarctic regions, probably by the north-east district, of the rhinoceroses, hippopotamuses, giraffes, water-chevrotains, large "cats," hyænas and monkeys. The evidence for this is based partly upon the great present-day resemblance between the mammals of the Ethiopian and Oriental region and also upon the fossil remains of these types found in Greece, Persia and India, dating from Miocene. Thus here again we may trace the irruption of a more primitive fauna during early Oligocene into Africa from the north and later, probably during early Pliocene, a second immigration southwards of more modern types. It is usually assumed that, during the interregnum between these two migrations, Ethiopia was isolated by sea from the north, but this assumption scarcely appears to be absolutely necessary though quite probable.

3. ORIENTAL REGION.—The Oriental region comprises India, Further India, Southern China and Malay, up to the line of east of Celebes. As a whole, this region most resembles the Ethiopian, mainly owing to the late migration of Oriental types at a comparatively late date into the latter.

The principal mammalian fauna is as follows:—The pangolins represent the *Edentata*, the aard-varks being absent at the present day. The *Ungulata* are rich in numbers and types, and elephants, tapirs, rhinoceroses, pigs, chevrotains, deer, antelopes and buffaloes are amongst the most important. The absentees are the sub-order of *Hyracoidea* and the families of *Camelidæ*, *Giraffidæ* and *Hippopotamidæ*. Of Rodents, the squirrel-family and rat-family are abundant, besides a few hystricomorphous types. There are great numbers of the cat-family, the tiger, lion, leopards and tiger-cats being representative. The civet-family is as abundant as in Africa. The striped hyæna, wolves, jackals, black bears, sloth-bears, the panda (*Procyonidæ*), and ratels complete the commoner carnivores. Of *Insectivora*, the flying lemur (*Galeopithecus*) is confined to Malay. Tree-shrews, hedgehogs and musk-shrews are found within the region, though we may note the absence of moles and shrews. Two families of the lemurs are represented, the peculiar *Tarsius* being confined to Malay. The same two families of monkeys are found as in Ethiopia. The *Simiidæ* are represented by the orang of Borneo and the gibbons of Assam and Malay, and the *Cercopithecidæ* by great numbers which mainly differ generically from the Ethiopian.

In passing over this list we find that the Oriental region is not so faunistically distinct as the Ethiopian. Whilst the latter has the monopoly of at least eight families, the Oriental has not more than three, namely, the *Tupaiidæ*, *Tarsiidæ* and *Galeopithecidæ*, though the two latter really rank as sub-orders.

Whilst the Ethiopian region was distinguished by a marked absence of bears, tapirs, deer, wolves and few pigs, these are all found in the Oriental region, the deer and pigs in abundance. On the other hand, both regions agree in small representation of *Mustelidæ* and in almost entire absence of sheep, goats, moles and shrews, features which are in marked contrast to the Holarctic region.

We have already seen that Ethiopia probably owes its faunistic similarity to the Oriental region to a migration from the latter to the former, and "during the Pliocene, India, at least, could not have been distinguished as a region from Ethiopia as it exists at the present day, and even in the Pleistocene the connection between the faunas of the two areas was much more intimate than it is now." * Why the giraffe, hippopotamus and other Ethiopian types died out altogether in the Oriental region we do not know.

4. HOLARCTIC REGION.—The Holarctic region corresponds to North America, Europe, Northern Africa and all Asia not included in the Oriental. This vast area appears to have sufficient community of fauna to comprise one region. It has characteristically large numbers of *Bovidæ*, especially sheep, goats and oxen, the deer, camels and pigs being also present (*Dasses* occur in Syria). Of rodents, the squirrels, beavers, *Muridæ*, picas, rabbits and hares. In the *Carnivora* there are abundance of bears and *Mustelidæ* (weasels, polecats, martens, wolverenes, otters, skunks and badgers), whilst the *Felidæ* are poorly represented by the lynxes and other forms, as also are the civet-family by mongooses and genets, the *Canidæ* by wolves and foxes. Of the *Insectivora*, the moles, hedgehogs and shrews are all common, and in bats only the *Microchiroptera* are found, except for those inhabiting the Pyramids. The only *Primates* are the baboons of Gibraltar.

There is hence a marked absence of a great number of large Ungulates, *Carnivora*, and of the *Edentata*, lemurs and monkeys, in comparison with the other regions. Two typical families of rodents, the beavers† and picas, are confined to the region, and the camels are not found elsewhere in Arctogœa. The walruses (*Trichechidæ*) are also peculiar to the region. The moles and shrews are very characteristic and are found only to a small extent outside the region.

At first sight it appears anomalous to separate Africa and Madagascar into regions and to unite Eurasia and North America into one region, but the large number of identical or closely allied species occurring in these two continents compel us to adopt such a classification.

As regards the past history of the region we have already referred to the widely scattered Mesozoic *Polyprotodontia* and to the lemurs of a later date. But as late as the Pleistocene epoch the mammals of the Holarctic region resembled those of the Ethiopian and Oriental far more nearly than at the present day. For example, there are well-authenticated remains from the Pleistocene of Europe, of the macaque monkeys,

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* Lyddeker. Geo. History of Mammals, page 288.

† Also found in Sonoran.

elephants, several species of rhinoceros, hippopotamus, hyænas and lions. Mixed up with these in a remarkable manner are the remains of northern forms like the wolverene, arctic fox, northern vole and reindeer.

From this it follows that the past history of the Holarctic region is to a large extent an epitome of the faunas found in the other several regions (leaving out of consideration the Sonoran). In early Oligocene of Europe we find the lemurs and civets, now so characteristic of the Madagascar region, and later on in the Pliocene and Pleistocene, the fauna with its early aard-varks, elephants, hippopotamuses, and other early ungulates approximated to the present-day fauna of Ethiopia and to the present and early past of the Oriental. As most of those occur in the Miocene of India, it is probable that they migrated thence to Europe, either directly or through northern Africa.

The resemblances in the faunas of North America and northern Eurasia are usually explained as being due to a land-connection across Behring sea, for which there is much evidence. This served to cause an approximation in faunas between the northern parts, leaving the Sonoran region and the Mediterranean district more or less distinct from each other.

5. SONORAN REGION.—This, comprising practically the United States of America, has been constituted as a separate region mainly because it is a transition zone between Holarctic and Neogœa, though it has some peculiar types of its own. Of Neogœan types, we may note the armadillos, opossums, peccaries and some *Procyonidæ*, whilst the skunks and other *Mustelidæ*, the marmots and the pouched rats, form Holarctic types. The most typical family of the region is the American prongbuck (*Antilocapra*) which has deciduous horns. This species also extends partly into Canada.

We may add here the names of some of the most characteristic mammals found at the present day in the regions of Arctogœa :—

[TABLE.

## Typical Mammalian Fauna of Arctogœan Regions.

| 1. MADAGASCAR. | 2. ETHIOPIAN. | 3. ORIENTAL. | 4. HOLARCTIC. | 5. SONORAN. |
|---|---|---|---|---|
| Lemurs. | Aard-varks. | Pangolins. | Beavers. | Opossums. |
| Tenrecs. | Pangolins. | Elephants. | Picas. | Armadillos. |
| River shrews. | Cape jumping-hares. | Tapirs. | Hares and Rabbits. | Pouched rats. |
| Civets. | Octodonts. | Pigs. | Voles. | Prairie marmots. |
| Mongooses. | Dasses. | Deer. | Marmots. | Peccaries. |
| | Elephants. | Antelopes. | Dasses. | Deer. |
| | Rhinoceroses. | Chevrotains. | Pigs. | Prongbuck. |
| | Zebras. | Lion & leopard. | Deer. | Bears. |
| | Hippopotami. | Tiger. | Sheep & goats. | Skunks. |
| | Giraffes. | Civets. | Bisons. | Raccoons. |
| | Antelopes. | Mongooses. | Musk-ox. | Shrews. |
| | Water-chevrotains. | Hyænas. | Wild-cats. | Moles. |
| | Lion & leopard. | Jackals. | Lynxes. | |
| | Civets. | Wolves. | Walruses. | |
| | Mongooses. | Foxes. | Wolves. | |
| | Aard-wolf. | Bears. | Foxes. | |
| | Hyænas. | Ratels. | Bears. | |
| | Jackals. | 'Raccoons.' | Skunks. | |
| | Ratels. | 'Flying lemur.' | Sea-otters. | |
| | Jumping-shrews. | Lemurs. | Wolverines. | |
| | | | Martens. | |
| | Golden-moles. | Orang. | Weasels | |
| | | Gibbons. | | |
| | River-shrews. | Many smaller monkeys. | Shrews. | |
| | Lemurs. | | Moles | |
| | Gorilla | | Hedgehogs | |
| | Chimpanzee. | | | |
| | Numerous Cercopithecidæ. | | | |

## The Orders of each Realm.

| | NOTOGŒA. | NEOGŒA. | ARCTOGŒA. |
|---|---|---|---|
| | Monotremata | | |
| | Diprotodontia | Diprotodontia | |
| | Polyprotodontia | Polyprotodontia | Edentata |
| Traces. | Rodentia | Edentata | Rodentia |
| | Carnivora | Rodentia | Carnivora |
| | Ungulata | Carnivora | Ungulata |
| | | Ungulata | Insectivora |
| | | Primates | Primates |

In conclusion, we may touch upon a few special points.

The first of these is the phenomenon of *discontinuous distribution* (*cf.* p. 64). All mammalian species are found in continuous or contiguous areas, but the different species of a genus may in certain instances occur in widely separated areas A good example, usually quoted, is that of the tapirs, which are found in Malay and South America. Discontinuous distribution of a family is also fairly common; we may instance the *Tragulidæ* or Chevrotains of Africa and India. Of a discontinuous order, we may instance the *Diprotodontia*, which has one family (opossum-rats) in America and the rest in Australia, and a similar case in the *Polyprotodontia*, with the opossums in South America. An instance of much the same kind is the distribution of the *Primates*, the lemurs being found in Madagascar and Africa, on the one hand, and in Further India and Malay, on the other, and the *Anthropoidea* occurring in America, Africa and India.

There are two possible explanations of this phenomenon. The first is based on the assumption that the discontinuity is fundamental and that the genera, families, or orders have been separately evolved from the same earlier ancestors, their resemblances being due to parallel or convergent evolution. As an instance of this we may quote the *Anthropoidea*. It is quite conceivable that the New World monkeys and those of the Old World have been separately evolved from primitive types which were not monkeys. The same applies to the *Diprotodontia*, which may have been separately evolved from *Polyprotodontia*. There is very strong evidence for supposing that horses and rhinoceroses were independently evolved from primitive ungulates in each hemisphere.

Without entering into the question of the polyphyletism of the class *Mammalia*—by which we mean the separate evolution of mammalian types from pre-existent amphibio-reptiles—we may note that this very highly differentiated class would lend itself more than any other to the phenomenon of parallel evolution. *Rodentia* are specially distinguished as an order by their peculiar incisor-dentition, yet the same modification is found in the Dasse (*Hyracoidea*), the Aye-Aye (*Lemuroidea*), the Wombat (*Diprotodontia*) and the *Toxodontia*. In other words, there is no real distinction between adaptive and genetic characters.

The second explanation assumes that the two discontinuous types were at one time continuous, and that the intermediate members have now died out. Upon the evolution of a successful type it naturally spreads in every suitable direction, and later, when the type has had its day and becomes replaced by others, it dies out first in the central areas where competition is fiercest but may linger on in more remote parts. There is no doubt that this is the actual course of events in many cases. Thus we find traces of tapirs in Europe, India and North America. Remains of lemurs are also found in Europe and North America.

The second point is with regard to the course of evolution. There is much evidence for assuming that the northern hemisphere has been the scene of early mammalian evolution, and that a succession of mammalian types have radiated, especially southwards, from this centre. The Prototherian wave reached the southern limit in Australia, where it still lingers. The Metatherian wave appears to have spread down to Australia, Africa and South America. Extinguished in Africa, it still lingers in America and has reached and passed its climax in Australia. A third wave consists of the *Edentata*, the lowest of *Eutheria*. These also reached their zenith in South America, where they still linger. Yet a fourth wave, of more recent date, of the lemur type, lingers in the outlying parts of South East Asia (Malay) and reaches a climax in the isolated region of Madagascar. Finally, the most "up-to-date" types of *Ungulata*, *Carnivora* and *Rodentia* are either at their world-wide zenith or have not yet reached the outlying regions and extend mainly over the Holarctic region.

Lastly, we may recall the instances we have had of "oceanic" islands, like New Zealand, with no indigenous mammals. By gradation we are led through types like Madagascar, Ceylon, and others which have a fauna differing in degree from that of the adjoining continent, till finally we reach islands, such as Britain, which have a fauna usually approximating closely to that of the mainland, though often differing in quantity. Geological history usually gives us evidence that these "Continental" islands have been only recently separated from the mainland, and a sufficient time has not elapsed for the mammalian fauna to diverge from the parent stock. In the case of Britain, for example, it is generally accepted that in Pleistocene times the North Sea was dry land, thus accounting for the identity of fauna at that time between Britain and the Continent. The extinction in Britain of many continental types has not yet been explained, though of course the wolf, beaver, wild boar and brown bear have been exterminated by man, by whose agency have also been introduced the rabbit, brown and black rats and fallow deer.

In fact, the faunistic character of an island or a continent, like the structure of an organism, is a complex relationship in space, the facts of which are easily attainable by observation. The explanation of the facts in each case is obscure, depending upon the relationship in time, a factor in which the investigating unit is too severely limited to permit of anything beyond the slowest progress.

## THE PRINCIPAL FEA

| | EDENTATA. | SIRENIA. | RODENTIA. | UNGU |
|---|---|---|---|---|
| *Teeth* ......... | No incisors nor canines, molars simple with no enamel or absent, grow from persistent pulps, monophyodont. | No incisors nor canines, or a single pair growing from persistent pulps, molars few or absent. | Incisors $\frac{2}{1}$ or $\frac{1}{1}$ growing from persistent pulps, no canines, molars with flat complex ridges. | Often<br>inciso<br>canines,<br>cisors $\frac{1}{0}$<br>be $\frac{3}{3}$.$\frac{1}{1}$.<br>always<br>complex |
| *Limbs* ......... | Plantigrade or prehensile.<br>Digits usually $\frac{5}{5}$ but reduced to $\frac{2}{2}$ in arboreal.<br>Clavicles. | Fore-limbs paddles, hind-limbs absent.<br>Digits $\frac{5}{0}$.<br>No clavicles. | Plantigrade or subplantigrade.<br>Digits $\frac{5}{4}$ usually.<br>Clavicles sometimes absent. | Planti<br>digitigra<br>Digits<br>mostly h<br>No cla |
| *Placenta*........ | Discoidal or dome-shaped (deciduate), diffuse or zonary (non-deciduate). | Zonary (non-deciduate). | Discoidal (deciduate). | Zonary.<br>or cotyl<br>(non-deci |
| *Habit* ......... | Fossorial or Arboreal, Insectivorous or Herbivorous. | Aquatic, Herbivorous. | Terrestrial, Fossorial, Arboreal, Herbivorous. | Terre<br>Herbivo |
| *Distribution*.... | Neogœan realm and Ethiopian and Oriental regions. | Rivers of Atlantic and Indian Oceans 30° N. to 30° S. | Cosmopolitan, mainly Neogœan realm. | Wide i<br>gœan ar<br>gean rea |

## OF EUTHERIAN ORDERS.

| CETACEA. | CARNIVORA. | INSECTIVORA. | CHIROPTERA. | PRIMATES. |
|---|---|---|---|---|
| No teeth or varying number of homodont teeth. | Incisors $\frac{3}{3}$ and pointed, canines large $\frac{1}{1}$, molars secodont (cutting ridges). | Incisors $\frac{3}{3}$ to $\frac{2}{2}$ and pointed. Canines small, tubercular molars | Incisors $\frac{2}{2}$, canines small, molars tubercular or grooved. | Incisors $\frac{2}{2}$ chisel-shaped, canines moderate, molars tubercular. |
| Fore-limbs paddles, hind-limbs absent. | Plantigrade and digitigrade (paddles). | Plantigrade. | Fore-limbs wings, hind-limbs prehensile. | Plantigrade or prehensile. |
| Digits $\frac{5}{0}$ (hyperphalangic). | Digits $\frac{5}{4}$ usually (aquatic, $\frac{5}{5}$). | Digits $\frac{5}{5}$. | Digits $\frac{5}{5}$ (claw only on 1 or on 1 and 2 of fore-limb). | Digits $\frac{5}{5}$ (or $\frac{4}{5}$). |
| No clavicles. | No clavicles (or vestigial). | Usually clavicles. | Large clavicles. | Large clavicles. |
| Diffuse (non-deciduate). | Zonary (deciduate) | Discoidal (deciduate). | Discoidal (deciduate). | Diffuse (non-deciduate) or metadiscoidal (deciduate). |
| Aquatic, Piscivorous. | Terrestrial, Carnivorous (or Aquatic and Piscivorous). | Terrestrial, Fossorial or Arboreal, Insectivorous. | Ærial, Frugivorous or Insectivorous. | Arboreal or Terrestrial, Frugivorous or Omnivorous. |
| Cosmopolitan. | Cosmopolitan, few in Neogœa and Notogœa. | Arctogœan realm (except *Solenodon*) | Cosmopolitan. | Neogœa and Arctogœa. |

# INDEX.

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