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AN ELEMENTARY TEXT-BOOK OF ZOOLOGY

FOR INDIAN STUDENTS

PREFACE

DURING recent years a considerable advance has taken place in the teaching of Zoology in Indian Colleges, and the want of a suitable text-book describing the Indian types has been keenly felt for some time. English text-books have had to be used so far, and the students had to be constantly warned as to the differences that might exist between the anatomy of the type actually used for study and the corresponding one described in such text-books. After a fairly long experience gained in teaching the subject, I made up my mind to do something to remove this long-felt want, so far as the Intermediate students in Indian colleges were concerned. Yet I felt that no useful purpose would be served in entirely re-writing the descriptions of several familiar animals, where the existing accounts could with comparatively slight modifications serve the purpose equally well. It was consequently decided to adapt the well-known "Elementary Course of Practical Zoology" by T. J. Parker and W. N. Parker for the purpose I had in view, and my obligations are due to the publishers and to Professor W. N. Parker for their ready acquiescence in my proposal.

I found myself in close agreement with the views of the original authors as regards the general plan of the book, and the following chief points on which they had originally agreed among themselves :—

"1. To adopt the method pursued in Huxley and Martin's 'Elementary Biology' of giving a connected

account of each example. 2. To give brief practical directions which should serve mainly as a guide, the student being able to refer, in case of difficulty, to the descriptive account preceding them. 3. In the larger animals, to arrange for as much work as possible to be done on one specimen: there is much to be said in favour of this plan apart from the fact that the average student cannot give sufficient time to the subject to dissect a fresh specimen for each system of organs. 4. To begin the course of instruction by an introductory study of one of the higher animals; to include in this introduction the elements of Histology and Physiology; and to select the Frog for the purpose: after trying various methods, I have found this plan to be the most satisfactory in practice. 5. To give drawings and diagrams of difficult dissections, and of details which the beginner cannot as a rule make out satisfactorily for himself. . . . 6. To include a short account of methods and technique limited to the barest essential outlines. . . ."

The following paragraphs might also be quoted from the preface to the original book, as indicating its general plan. "The time such students can devote to an elementary course in the subject is limited; and throughout the book I have borne in mind that the main object of teaching Zoology 'as a part of a liberal education is to familiarize the student not so much with the facts as with the ideas of the science,' but at the same time that he should be provided with a sound basis of facts so arranged, selected, and compared as to carry out this principle."

"Our original intention was to include one or more example of each of the larger phyla, and also to add a practical exercise after each type, giving general directions for the examination of an allied form for comparison. But I found that this would be impossible within the

space of a single volume, and it was therefore necessary to limit the descriptions mainly to those animals to which the students for whom the book is chiefly intended have to give special attention. This has resulted in rather a heavy balance on the side of Vertebrates; but, on the whole, I think that if sufficient work is done on the lower animals to illustrate certain main facts and generalizations, a comparative study of several vertebrates forms as good a training as any for beginners—more especially in the case of medical students."

The original being avowedly an elementary course of "Practical Zoology" is naturally based on the "type-system," the advantages and dangers of which are now well-known and fully recognized. In converting the book therefore into a more general text-book, an effort has been made to include after the description of each type a brief summary of the characters of the class to which the type belongs, and a number of other animals are also mentioned which the students would do well to examine. In Part I and Chapters I, II, IV, V, and IX of Part II such modifications have been made as were necessitated by the substitution of Indian types for those dealt with before. Chapters III, VI, VII, X of Part II are written specially for this book. Chapter XI, dealing with Mammalia, has been revised and enlarged by the addition of a general elementary survey of the class. And finally two chapters dealing with the important subjects of Evolution, Variation, and Heredity have been added at the end. In these chapters an attempt has been made to introduce the student to some of the more important generalizations and conclusions so far arrived at in the domain of biological thought, only to an extent that would be justified on the basis of facts which he may be supposed to have gathered together. In its present form the book will

be found to cover fully the syllabuses for the Intermediate Examination in Science as laid down by the various Indian Universities.

In order to make the book more useful, about one hundred extra diagrams have been added, of which a certain number are new, and specially drawn for this book from actual specimens or dissections made by the author. Others have been modified or copied from the works of well-known authors, to whom due acknowledgment is made in every case.

I am deeply indebted to Professor J. Stephenson, D.Sc., C.I.E., University Professor of Zoology in the Punjab University, under whom the author has had the privilege of working for the last thirteen years, and to whose great learning and unrivalled experience as a teacher in this country the author himself owes so much, for his kindness in reading through a considerable part of the manuscript and suggesting many useful additions and alterations.

B. L. BHATIA.

GOVERNMENT COLLEGE, LAHORE,
November, 1919.

NOTE TO THIRD EDITION.

THE text has been thoroughly revised and brought up-to-date. Description of certain types and new matter has been added in order to cover the syllabuses for the Intermediate Examination of all the Indian Universities or Boards. In order to make room for new matter, practical directions formerly given at the end of each chapter, have been throughout omitted.

B. L. B.

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AN ELEMENTARY TEXT-BOOK OF ZOOLOGY

PART I

THE FROG—AN INTRODUCTION TO ANIMAL LIFE

CHAPTER I

SCOPE OF THE SCIENCE OF BIOLOGY—THE FROG: PRELIMINARY SKETCH OF ITS STRUCTURE, LIFE-HISTORY, AND VITAL FUNCTIONS

Biology, Zoology, and Botany.—Biology (Gk. *bios*, life, and *logos*, discourse) is the science which deals with all living things, under whatever aspect they may be studied. As the living objects are either animals or plants, Biology comprises the two sister sciences of Zoology (Gk. *zoon*, animal), which is the study of animals, and Botany (Gk. *botane*, plant), which deals with plants. Each of these has several divisions. Morphology (Gk. *morphe*, form) deals with the form and structure, and Physiology (Gk. *phusis*, nature) with the functions of the organisms concerned. Thus under Zoology we will be studying animal morphology and animal physiology. Morphology includes the study of the grosser structure of the organism

as seen by the naked eye, which goes by the name of Anatomy (Gk. *ana*, up; *tome*, cutting), and the study of the structure as revealed by the aid of the microscope, which is known as Histology (Gk. *histos*, tissue). Thus Botany and Zoology deal with the study of the structure, the mutual relations, and the arrangement or classification of plants and animals. But biology may also be pursued, and very profitably pursued too, quite independently of teachers, classrooms, and examinations. The country boy who knows the song of every bird, its nesting-place, the number of its eggs, the nature of its food, the lurking-place of the trout in the stream or the frogs in the marsh; who has watched the ants with their burden of grain, or the bees with their loads of honey or pollen; has begun the study of biology in one of its most important branches. The intelligent gardener who observes the habits of plants, their individual tastes as to the soil, moisture, sunshine, and the like, is also something of a biologist without knowing it. So also is the collector of eggs, shells, or insects, provided he honestly tries to learn all he can about the objects he collects, and does not consider them merely as a hoard or as objects for barter. Indeed, all that is often spoken of as natural history, so far as it deals with living things—plants and animals—and not with lifeless natural objects, such as rocks and minerals, is included under the head of biology.

What then is the connection between biology in this wide sense and the kind of thing you are expected to learn in a limited number of lessons? Simply this:—In the classroom Nature cannot be studied under her broader aspects: indeed, much out-door natural history cannot be *taught* at all, but must be picked up by those who have a love of the subject, a keen eye and patience. But there is one thing we can do within the narrow

limits of the classroom: we can confine ourselves to some department of biology small enough to be manageable: we can take, for instance, one or more familiar animals and plants and, by studying them in some detail, get some kind of conception of animals and plants as a whole. This book deals with the zoological side of biology only; and what we have now to do is, in fact, what you have often done in the study of English: you take a single verse of a poem at a time, analyse it, parse it, criticise its construction, try to get at its exact meaning. If you have any real love of literature this detailed study of the part will not blind you to the beauty of the whole. And so if you have any real love of Nature, the somewhat dry and detailed study we have now to enter upon should serve to awaken your interests in the broader aspects of biology by showing you, in a few instances, what wonderful and complex things animals are.

One word of warning before we begin work. You must at the outset disabuse your mind of the fatal error that zoology or any other branch of natural science can be learnt from books alone. In the study of languages the subject-matter is furnished by the words, phrases, and sentences of the language; in mathematics, by the figures or other symbols. All these are found in books, and, as languages and mathematics are commonly the chief subjects studied at school, they tend to produce the habit of looking upon books as authorities to which a final appeal may be made in disputed questions. But in natural science the subject-matter is furnished by the facts and phenomena of nature; and the chief educational benefit of the study of science is that it sends the student direct to Nature, and teaches him that a statement is to be tested, not by an appeal to the authority of a teacher or of a book, but by careful and repeated observation and experiment.

The object of this book, therefore, is not only to give you some idea of what animals are, but also to induce you to verify for yourself the statements contained in it. The description of each animal you should follow with the animal before you; and if you find the account in the book does not agree with what you see, you must conclude, not that there is something wrong with your subject, but either that the description is imperfect or erroneous, or that your observation is at fault and that the matter must be looked into again. In a word, zoology must be learnt by the personal examination of animals: a text-book is merely a guide-post, and all doubtful points must be decided by an appeal to the facts of nature.

It matters very little what animal we choose as a starting-point—a rabbit, a pigeon, or an earthworm—one will serve almost as well as another to bring out the essential nature of an animal, how it grows, how it is nourished, how it multiplies. On the whole, one of the best subjects to begin with is a frog: partly because it is easily obtained, partly because its examination presents no difficulties which an intelligent student may not be expected to surmount by due exercise of patience.

Let us therefore begin our studies by catching a **frog** and placing it in a convenient position for examination, as, for instance, under an inverted glass bell-jar or even a large tumbler.

External Characters.—Notice, first of all, the short, broad *trunk*, passing insensibly in front into the flattened *head*—there being no trace of a neck—and ending behind without the least vestige of a tail: these constitute the *axial* parts of the animal. In the ordinary squatting position the back has a bend near the middle, producing a peculiar humped appearance. The head ends in front

the water, where the powerful hind-limbs and the webbed toes enable it to swim. The name *digit* is conveniently applied both to fingers and toes. Between the bases of the thighs, at the hinder end of the trunk, is a small aperture, the *vent* or *cloacal aperture*.

In the squatting posture the body is raised upon the arms, which are kept slightly bent at the elbows, with the fingers spread out and directed forwards. In this position the innermost of the four fingers corresponds with our own index-finger, the frog having no thumb. The hind-limb, in similar circumstances, is bent into a sort of Z, the knee being directed forwards and the ankle-joint backwards. The toes are turned forwards, and the inner one, which is the smallest of all, corresponds with our own great toe.

Owing to the bent position of the limbs, we cannot very well, as in our own arms and legs, speak of their upper and lower ends. It is therefore customary to call the end of a limb, or of any division of a limb, which is nearest to the trunk, the *proximal* end, that which is farthest away the *distal* end. Thus the proximal end of the fore-arm is the elbow region, the distal end of a digit is its tip.

In the largest Indian Frog (*Rana tigrina*), which is common all over India and Ceylon, the whole body, including head, trunk, and limbs, is covered with a soft, slimy skin of a green or olive colour, irregularly mottled with dark spots of varying size on the upper or *dorsal* surface, and whitish on the under or *ventral* surface. The colouring is, however, not constant; in a frog kept in the dark the black spots increase to such an extent that the whole animal becomes almost black, while if kept in full daylight a corresponding brightening of the tints takes place. Moreover, the spots and patches of brighter colour are very variable: if you examine a

dozen specimens you will see at once that no two are alike in this respect. The skin on the dorsal surface shows longitudinal folds with a strong fold above the tympanum.

Sexual Characters.—As in so many of the more familiar animals, there are two sexes of frogs, easily distinguished from one another. If you examine several of them you will find that a certain number have on the palm of the hand, towards the inner side, a large swelling, rather like the ball of our own thumb, but much more prominent and of a black colour, especially at the breeding season. Frogs having this structure are males; it is not present in the females. Moreover, the males among the commonest Indian type (*Rana tigrina*) are usually of a darker colour than the females, and on the ventral surface of the head possess loose folds of skin, one on each side of the throat, a little behind the articulation of the jaws. These allow the expansion of the underlying vocal sacs, which help to intensify the noise produced by the frog, familiarly known as the croak.

Actions Performed by the Living Frog.—Kept under suitable conditions a frog shows *evidences of life.* If touched or otherwise alarmed it attempts to escape by making a series of vigorous leaps—suddenly extending the hind legs and jumping to a considerable height. Thrown into water it swims by powerful strokes of the hind-limbs. It has thus, like so many living things with which we are familiar, the power of *voluntary movement.*

If a young frog is kept under observation for a sufficient time—weeks or months—it will be found that it *grows* until it reaches a certain limit of size. Growth, in the case of the frog, is an increase in size and weight affecting all parts of the body, so that the proportions remain practically unaltered, and no new parts are added.

Careful observation shows that the throat is constantly

rising and falling, and the nostrils opening and shutting. These movements, like the expansion and contraction of the human chest, are *respiratory* or breathing movements, and serve to pump air into and out of the lungs.

It requires frequent watching and sharp observation to see a frog *feed*. It lives upon insects, worms, slugs, and the like. Opening its mouth it suddenly darts out a tolerably long, nearly colourless, and very sticky *tongue*; if the prey is a small insect, such as a fly, it adheres to the end, and the tongue is quickly drawn back into the mouth, the whole operation being performed with almost inconceivable rapidity.

Like other animals the frog discharges *waste matters* from its body. Its droppings or *fæces*, discharged from the vent, are black and semi-solid. From the same aperture it expels periodically a quantity of *urine*, which is a perfectly clear and colourless fluid, and contains water with a minute quantity of certain substances dissolved in it.

Sometimes a frog will escape from confinement, leaving its damp box or vivarium for the warm, dry atmosphere of an ordinary room. When this happens the animal is usually found next morning dead and shrunken, and with its naturally moist skin dry and hard. From this it may be inferred that there is a constant *evaporation of water* from the skin, which, in ordinary circumstances, is checked by a damp atmosphere or by occasional immersion in water.

Hibernation.—In winter frogs bury themselves in damp places, and become sluggish, manifestations of life becoming hardly apparent until the following spring, when they emerge from their holes. In this way they escape the dangers of frost which would otherwise be fatal to them. This suspension of activity during winter is known as *hibernation*, or the winter-sleep.

Reproduction and Development.—If you examine a number of frogs in summer, you will find that the full-grown females are distinguished from the males, not only by the absence of the pad on the hand, but also by the swollen condition of the trunk, due to the interior being distended with *eggs*. In the rainy season, the frogs go into water for sexual union. The male frog clasps the female, and the swelling covered with rough skin on the ventral surface of its hand prevents the female from slipping. The female passes out of its vent a mass of eggs. Each egg is a little globular body about $\frac{1}{12}$th inch in diameter, half black and half white, and surrounded by a sphere of clear jelly, by means of which the eggs adhere together in large irregular masses, the well-known "frog-spawn." As the eggs are laid, the male passes out of his body, also by the vent, a milky *spermatic fluid*, which gets access to the eggs and *impregnates* or *fertilises* them. Without impregnation they are incapable of developing.

Neither male nor female takes the slightest care of the eggs when once they are deposited and fertilised. They are simply left in the water unprotected in any way; and, naturally enough, the mortality among them during the course of development is very great, the majority being eaten or otherwise destroyed, and only a very small percentage coming to maturity.

The first noticeable change in the spawn is that the sphere of jelly surrounding each egg swells up so as to acquire several times the diameter of the enclosed egg. The egg itself, or *embryo*, as it must now be called, gradually becomes entirely black, then elongates, and takes on the form of a little creature (Fig. 2, 1) with a large head, a short tail, and no limbs; which, after wriggling about for a time, escapes from the jelly and fixes itself, by means of a sucker on the underside of its head,

to a water-weed. Great numbers of these *tadpoles*, as the free-living immature young or *larvæ* of the frog are called, may be seen attached in this way. At first they

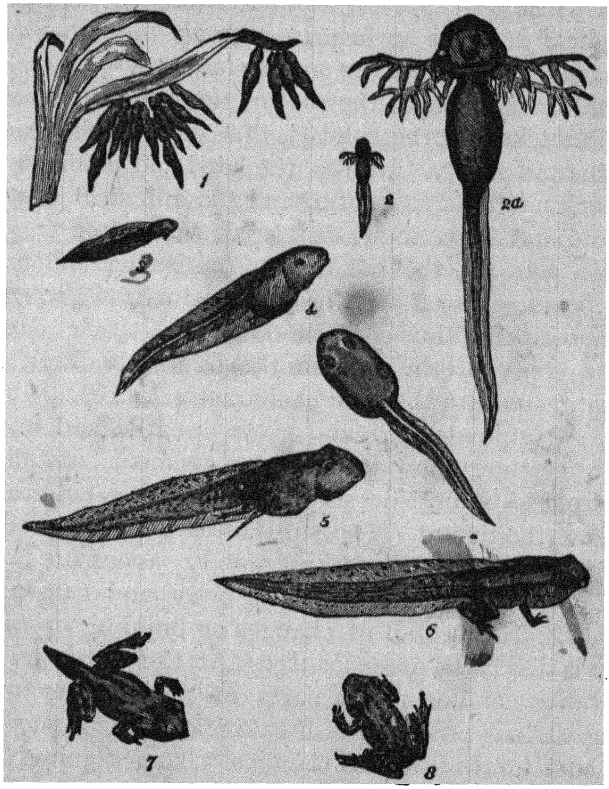


FIG. 2.—Stages in the life-history of a Frog, from the newly-hatched tadpoles (1) to the young frog (8). Natural size.—2*a* is a magnified view of 2. (After Mivart.)

are sluggish and do not feed, but, before long, they begin to swim actively by lashing movements of their tails, and to browse on the weeds. They are thus in the main vegetable-feeders, not carnivorous, like the adult frog. On each side of the head appear at first two, later three,

little branched tufts or *gills*, which serve as respiratory organs (2, 2^a), the tadpole, like a fish, breathing air which is dissolved in the water. After a while the gills begin to shrivel up (3, 4), and the tadpole then comes periodically to the surface to breathe, lungs having in the meantime made their appearance. A pair of little hind-limbs appears at the root of the tail, and a pair of fore-limbs behind the head (5, 6). As these increase in size the tail slowly dwindles, the head and trunk assume the characteristic frog-form, and the animal now comes on land and hops about as a small tailed frog (7). As growth goes on, the tail further diminishes and finally disappears altogether, the transformation or *metamorphosis* being thus completed (8).

The study of the frog in the living condition thus acquaints us with the general characteristics of all animal life. All animals feed and grow, breathe and excrete waste matter, show voluntary movement, irritability or response to outside stimuli, and sooner or later reproduce their kind. The substances taken as food are digested, absorbed and ultimately assimilated, becoming part and parcel of the body and causing its growth. This sequel of changes or building up of the body is described as *anabolism*. At the same time the substance composing all parts of the body is undergoing various processes of breaking down or *katabolism*. The sum total of all the chemical changes going on in the living body is described as *metabolism*.

Death and Decomposition.—Frogs may live for many years, but, sooner or later, either in the ordinary course of nature or by accident, they die. The heart stops beating, the flesh undergoes what is called "death-stiffening," becoming hard and rigid, and all vital manifestations cease. Before long the process of decomposition ensues, the flesh, viscera, etc., soften and emit a bad smell, and

in course of time rot away completely, leaving only the bones.

Summary of Chapter.—The very brief and cursory study we have made so far shows us (1) that a frog has certain definite *parts* arranged in a particular way; (2) that it performs characteristic *movements*, some of them, such as leaping and swimming, voluntary; others, such as *breathing*, involuntary; (3) that it takes in *solid food*, consisting mainly of vegetable matter in the tadpole, of living animals in the adult, and grows; (4) that it gives off *waste matters*; (5) that it *reproduces* its kind by laying eggs, which develop only if impregnated; (6) that it undergoes transformation or *metamorphosis*, the egg giving rise to a *larva*, the tadpole, which, after living for a time the life of a fish, gradually changes into a frog.

CHAPTER II

THE FROG (*continued*): GENERAL INTERNAL STRUCTURE

YOU have now seen that a frog can perform a number of very complicated actions; and, if you have any curiosity in these matters, you will probably want to know something of the mechanism by which these actions are brought about. Now, the best way to understand the construction of a machine, such as a clock or a steam-engine, is to begin by taking it to pieces; and, in the same way, you can find out the parts of which the living machine we call a frog is made, and the way they are related to one another, only by taking it to pieces, or *dissecting* it.

First notice, in addition to the external characters described in the last chapter, that the various parts of the body are strengthened or stiffened, as in ourselves, by a number of *bones*, which together form the greater part of the *skeleton*. It is quite easy to ascertain by feeling that the head contains a hard *skull*; the lower jaw, a lower-jaw-bone, or *mandible*; that running through the back is a jointed backbone or *vertebral column*; that the region of the chest is protected by a breastbone or *sternum*; and that each division of the limbs has its own bone or bones.

The Mouth-cavity.—There are also several points to be observed in the interior of the mouth. All round the edge of the upper jaw is a row of small conical *teeth*

(Fig. 8). There are no teeth in the lower jaw; but on the roof of the mouth, a short distance behind the snout, are two little patches of teeth, called the *vomerine teeth* (*vo. t*), and nearer the jaw are two apertures, called the *internal nostrils* (*p. na*): a guarded bristle passed into one of the external nostrils and pushed gently backwards and downwards will be found to enter the mouth by the corresponding internal nostril.

Behind the internal nostrils are two large hemispherical projections, due to the roof of the mouth being bulged out by the huge eyes, as can be readily made out by pushing the eyes from outside.

On the floor of the mouth is the large, flat *tongue* (*tng*), remarkable for the fact that it is attached at its front end, its hinder end being free and double-pointed. When the frog uses it to catch insects it is suddenly thrown forwards, almost like a released spring. The surface of the tongue being sticky, the prey is held fast and devoured as a whole, by the tongue being withdrawn, as quickly, back into the mouth-cavity. Just behind the backwardly-turned tips of the tongue is an oval elevation, having on its surface a longitudinal slit, called the *glottis* (*gl*), which leads, as we shall see afterwards, into the lungs.

The back of the mouth narrows considerably, and the soft skin or *mucous membrane* lining it is here thrown into folds. A probe gently pushed backwards passes, as we shall see, into the stomach. The narrowed region of the mouth is the throat, or *pharynx*. On its upper wall, near the angles of the mouth, are two openings leading into tubular passages: a guarded bristle passed into one of these will be found to come into contact with the corresponding tympanic membrane, which will be pierced if sufficient force is used. The tubes are known as the *Eustachian tubes* (*eus. t*).

Dissection of the Frog: Skin and Muscles.—If a slit is made in the skin of the belly, and a probe pushed in under it, it will be seen that the skin, instead of being firmly attached to the underlying flesh, as in a rabbit or a sheep, is for the most part quite loose, a spacious cavity lying between it and the flesh. Not, however, a single continuous cavity for the whole body: the probe, gently pushed in various directions, is stopped, in front, at about the level of the arms; behind, at the junction of the thighs with the trunk; and at each side, along an oblique line joining the armpit with the thigh. Moreover, by opening the skin of the back, throat, and limbs, and inserting the probe as before, similar cavities will be found in these regions, all separated from one another by partitions, along which the skin is firmly united to the underlying flesh. It will be noticed also that the probe, when withdrawn from any of these cavities, is wet. The cavities contain a watery fluid, called *lymph*, and are hence known as *subcutaneous lymph-sinuses* (Fig. 8, *d. ly. s*, *v. ly. s*).

When the skin is removed it will be seen that under the skin and separated from it by the lymph-sinuses is a nearly colourless, semi-transparent, fibrous substance, the flesh. At first this appears to be continuous over the whole body, but, by careful dissection with a sharp scalpel, a very delicate, transparent skin, called the *fascia*, can be separated from the flesh, which is then seen to consist of a number of separate bands (Fig. 3, *my. hy*, *pct*, *rct. abd*; see also Fig. 19), covered as aforesaid by the fascia, and separated from one another by a kind of packing substance, also very delicate and transparent and known as *connective-tissue*. These bands or sheets are the *muscles*, and the whole of the flesh is made up of distinct muscles, readily separated from one another when once the requisite anatomical skill is attained.

Here and there—for instance on the top of the head and the front of the shanks—there are no muscles, and the bones are covered only by skin and connective-tissue.

Passing along the middle line of the belly is a dark

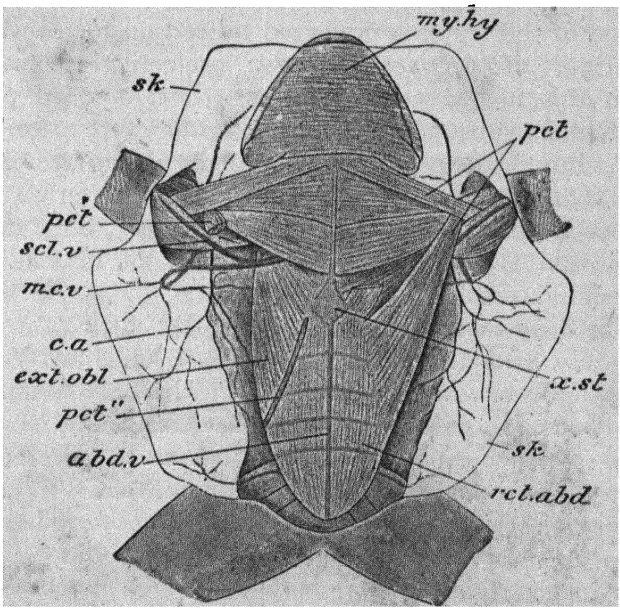


FIG. 3.—A Frog with the skin (*sk*) of the ventral surface cut through and turned back right and left, so as to expose the muscles. Of these the mylohyoid (*my. hy*), pectoralis (*pct*), external oblique (*ext. obl*), and rectus abdominis (*rct. abd*) are lettered. On the right side (left in the figure), the posterior portion of the pectoral muscle is cut away, its two ends (*pct'*, *pct''*) only being left. The cartilaginous extremity of the breast-bone (xiphisternum, *x. st*) is shown, as well as the abdominal (*abd. v*), musculo-cutaneous (*m. c. v*), and brachial (*scl. v*) veins, and the cutaneous artery (*c. a*). (Natural size.)

longitudinal streak (Fig. 3, *abd. v*) : this is a *blood-vessel*, the *abdominal vein*. On each side of the body another vein (*m. c. v*) is seen forming a loop, one limb of which is on the turned-back flap of skin, while the other passes between the muscles not far from the armpit : this vessel

is the *musculo-cutaneous vein.* Both these veins, and many others which will be seen in the course of the dissection, are thin-walled tubes full of *blood*, as will be proved if you should happen to cut one of them, when the blood will escape in considerable quantity.

Between the right and the left fore-limbs the ventral region of the trunk is protected by certain bones which form part of the *shoulder-girdle*: projecting backwards from this in the middle line is a flat, bi-lobed plate of a softer substance, known as *cartilage* (compare Fig. 14). Immediately between the thighs a cartilage called the *pubis*, part of the *hip-girdle* (Fig. 17), can be felt. Between the shoulder- and hip-girdles the ventral body-wall is soft, being formed only of muscle and connective-tissue.

The Body-cavity and its Contents.—By cutting through the muscles of the belly or *abdomen*, a large cavity, the *body-cavity* or *cœlome*, is exposed, in which are contained numerous structures presently to be described. In order, however, to open the whole of the cavity the ventral part of the shoulder-girdle must be removed.

In the middle line, between the fore-limbs, and therefore covered in the entire animal by the shoulder-girdle, is a pink conical body (Figs. 4 and 5, *v*) connected in front with a thin-walled bag (*r. au*, *l. au*), of a purplish colour. The whole thing is the *heart*: the pink posterior portion is called the *ventricle*: the purple anterior part consists of two chambers, the *auricles*. The heart is enclosed in a transparent, membranous bag, the *pericardium*, which contains a lymphatic fluid.

Just behind or posterior to the heart are two large masses (*lr*) which have a dark reddish-brown colour; these are the right and left lobes of the *liver*. They extend forwards, one on either side of the heart: between them is a globular bag of a greenish colour (Fig. 4, *gl. bl*),

is turned forwards, and the abdominal vein (*abd. v*) is severed and turned backwards. The right ovary and fat-body are removed, and the right oviduct (*r. ovd*) is slightly displaced outwards. (× 1½.)

abd. v. abdominal vein; *cœl. mes.* cœliaco-mesenteric artery; *cp. ad.* corpus adiposum, or fat-body; *d. ao.* dorsal aorta; *gul.* gullet; *hu.* cut end of humerus or upper-arm bone; *l. au.* left auricle; *l. lng.* left lung; *l. ovd.* left oviduct; *l. ovd'.* its opening into the body-cavity; *l. ovd''.* its posterior dilatation; *l. ovy.* left ovary; *lr.* portion of liver; *pt. cv.* postcaval vein; *pt. cv'.* its anterior portion passing between the liver and the heart; *r. au.* right auricle; *rct.* rectum; *r. kd.* right kidney; *r. lng.* right lung; *rn pt.* renal portal vein; *r. ovd.* right oviduct; *r. ovd'.* its opening into the body-cavity; *r. ovd''.* its posterior dilatation; *syst. tr.* systematic arterial trunks at their point of union; *u. bl.* urinary bladder; *ur.* ureter; *v.* ventricle.

cavity by a sheet of peritoneum. These bodies are the *ovaries*, or organs for producing the eggs; the rounded bodies of which they are largely composed are the *eggs* themselves. To each ovary is attached a yellow structure, produced into a number of streamer-like lobes (*cp. ad*); this is the *fat-body*, which serves as a storehouse of reserve nutriment.

By lifting up either of the ovaries there is seen beneath it—in the natural position of the parts, above or dorsal to it—a greatly convoluted colourless tube (*l. ovd, r. ovd*) of about the same diameter as the intestine. This is the *oviduct*, through which the eggs pass from the ovary to the cloaca. If the specimen is allowed to remain long in water the oviducts will be found to swell and finally to become disintegrated; this is due to the fact that in them is formed the jelly in which the laid eggs are enclosed, and which, as already mentioned (p. 9), swells in water.

In the male there is seen, on turning the intestines aside, a pair of yellow ovoidal bodies (Fig. 8, *ts*) about half an inch long, attached by peritoneum to the dorsal wall of the body-cavity. These are the *spermaries* or *testes*; they manufacture the spermatic fluid by which the eggs are impregnated. To the anterior end of each is attached a *fat-body* (*cp. ad*), like that of the female. In young specimens of both sexes the reproductive organs—spermaries, ovaries, and oviducts—are very small.

When the intestine is turned aside there will also be seen, in both sexes, a pair of flattened, irregularly-oval bodies (Figs. 5, *r. kd* and 8, *kd*) lying in the posterior part of the abdominal cavity just above or dorsal to the ovaries or spermaries. These are the *kidneys*. With the outer edge of each is connected a tube, the *ureter* (*ur*), by which the urine, formed in the kidneys, is carried to the cloaca (Fig. 8).

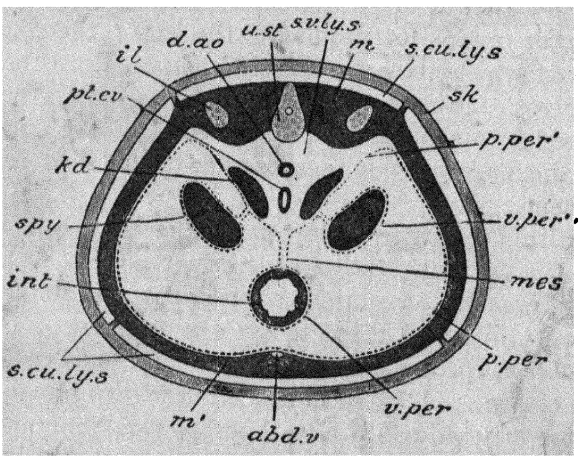


FIG. 6.—Diagrammatic transverse section through the trunk of a Frog, to show the relations of the peritoneum. (× 2½.)
abd. v. abdominal vein; *d. ao.* dorsal aorta; *il.* ileum; *int.* intestine; *kd.* kidney; *m.* muscles of back; *m'.* muscles of abdomen; *mes.* mesentery; *p. per.* parietal layer of peritoneum; *p. per'.* the same, turning down to cover the kidney; *pt. cv.* postcaval vein; *sk.* skin; *s. cu. ly.* s. sub-cutaneous lymph-sinuses; *spy.* spermary; *s. v. ly. s.* sub-vertebral lymph-sinus; *u. st.* urostyle (part of the vertebral column); *v. per.* visceral layer of peritoneum, investing intestine; *v. per'* the same, investing spermary.

It has been pointed out that the abdomen is lined by peritoneum, and that the various organs are suspended by folds of the same membrane, called, in the case of the alimentary canal, the mesentery. The relations of this membrane are best seen in a diagrammatic transverse section of the body (Fig. 6), though many points can be perfectly well made out from the

actual specimen. The body-cavity is lined by what is called the *parietal layer* of the peritoneum (*p. per*), which adheres closely to the body-wall except in the middle dorsal region, where it becomes closely applied to the ventral surface of the kidneys and reproductive organs. Leaving these, the peritoneum of the right side approaches that of the left, and the two, coming into contact, form a double vertical sheet, the *mesentery* (*mes*), which extends ventrally towards the alimentary canal. On reaching the latter, the two layers diverge again and surround the canal, forming the *visceral layer* of the peritoneum (*v. per*). The liver, oviducts, etc., are suspended and covered in the same way. Thus the lining of the body-cavity, the investment of the various organs contained in it, and the folds by which they are suspended, are all parts of one continuous membrane. The space left between the two diverging layers of peritoneum, in the mid-dorsal region, contains lymph, and is known as the *sub-vertebral lymph-sinus* (*s. v. ly. s*).

We have already noticed the abdominal and musculocutaneous veins. Other veins of greater or less size will be seen everywhere, passing, for instance, to the head and limbs (Fig. 4), and in the mesentery. Running parallel with many of the veins are smaller vessels, which are of distinctly stouter texture. These are the *arteries*. They contain little blood in the dead animal, and, owing to the thickness and elasticity of their walls, do not collapse when empty. Hence they are quite easy to see in a frog from which all the blood has been drained, while the thin-walled veins are almost invisible in like circumstances. Finally, there will be seen in many parts of the body, often lying parallel to an artery and a vein, white cords, the *nerves*.

The Neural Cavity and its Contents.—By turning the frog with its back upwards and cutting through

the muscles of the back and the arches of the vertebræ as well as, in front, the roof of the skull (see Fig. 7), you will see that the backbone contains a distinct cavity, the *neural canal*, in which lies a white rod, made of the same soft kind of substance as the nerves, and called the *spinal*

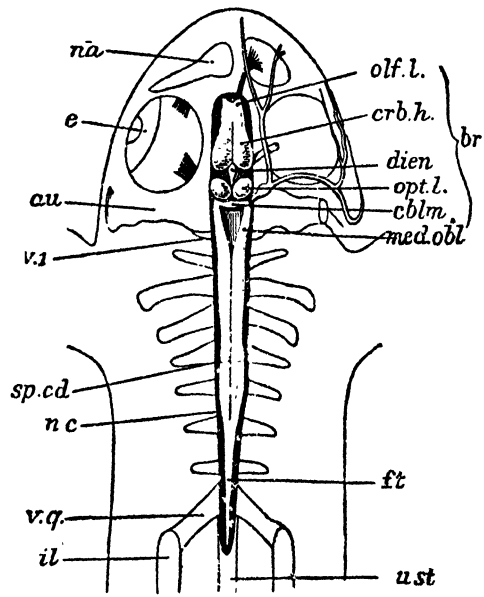


FIG. 7.—Dissection of a Frog in which the entire neural canal (*n. c*) has been opened from above, and the brain (*br*) and the spinal cord (*sp. cd*) laid bare. The brain consists of olfactory lobes (*olf. l*), cerebral hemispheres (*crb. h*), diencephalon (*dien*), optic lobes (*opt. l*), cerebellum (*cblm*), and medulla oblongata (*med. obl*), which will be referred to in Chapter X. The spinal cord ends in a delicate prolongation, the filum terminale (*f. t*). The nasal bones (*na*), eyes (*e*), auditory region of the skull (*au*), transverse processes of the nine vertebræ (*v. 1—v. 9*), urostyle (*u. st*) and illa (*il*) are indicated in outline, and serve as landmarks. (× 1½.) (After Howes, slightly altered.)

cord (*sp. cd*), which ends behind in a thread-like prolongation (*f. t*), some distance in front of the thighs. It will also be found that the neural canal is continued, with a slightly increased diameter, into the skull, and that the spinal cord becomes continuous with the *brain* (*br*), a

complex organ formed of several parts, which will be referred to hereafter.

General Structure of the Limbs.—A transverse section cut across one of the legs, at about the middle of the thigh, will show in the middle of the cut surface the thigh-bone, around it the flesh or muscles, and around this again the skin. Similar cuts through various parts of both fore- and hind-limbs show that these appendages of the body are solid, containing no cavities, except the sub-cutaneous lymph-sinuses previously observed.

Summary.—We thus get a notion of the general plan of construction of a frog as follows. It consists of a central or *axial portion*, the head and trunk, and of two pairs of lateral offshoots or *appendages*, the fore- and hind-limbs. The trunk is hollowed out into two cavities: the *body-cavity* (*cœlome*) below, and the *neural canal* above; of these the neural cavity alone is continued into the head. The body-cavity contains the greater part of the alimentary canal, the liver, gall-bladder, pancreas, spleen, lungs, heart, kidneys, urinary bladder, and reproductive organs. The neural canal contains the brain and spinal cord. The anterior end of the alimentary canal is continued forwards into the head, forming the mouth-cavity, and opens externally by the aperture of the mouth; its posterior end opens externally by the vent. The alimentary canal passes through the containing body-cavity, having no communication with it. The lungs open into the pharynx, and thus communicate with the exterior not only by the mouth but also by the nostrils. The kidneys, bladder, and oviducts communicate with the cloaca, and thus with the exterior through the vent. Neither the neural nor the abdominal cavity has any communication with the exterior. The walls of the head and trunk consist largely of bones and muscles covered with skin. The limbs are solid out-

growths of the trunk, formed mainly of muscle, with bony supports and a covering of skin.

Organs.—Notice that the body consists of various definite parts, or *organs* as they are technically termed,

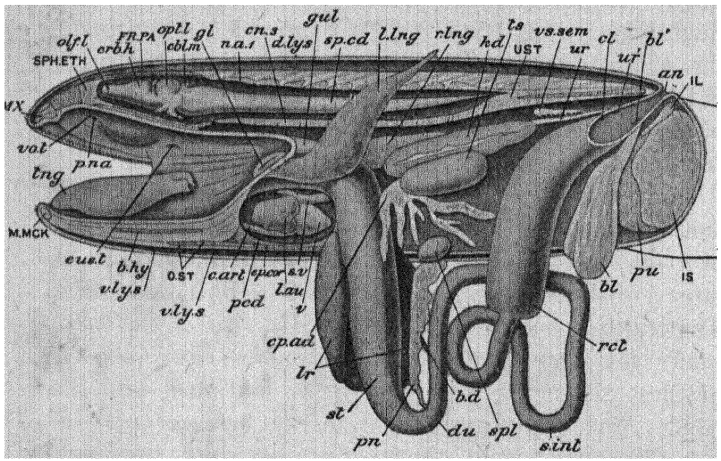


FIG. 8.—Dissection of a Male Frog from the left side. The left fore- and hind-limbs and the left sides of the head and trunk have been cut away, the alimentary canal and liver are displaced downwards, and the mouth, pharynx, and cloaca laid open. (× 1½.)

an. vent; *b. d.* bile-duct; *b. hy.* body of hyoid; *bl.* urinary bladder; *bl'.* its opening into the cloaca; *c. art.* conus arteriosus; *cblm.* cerebellum; *cl.* cloaca; *cn. 3*, centrum of third vertebra; *cp. ad.* fat body; *crb. h.* cerebral hemisphere; *d. ly. s.* dorsal lymph-sinus; *du.* duodenum; *ep. cor.* epicoracoid; *eus. t.* Eustachian tube; *FR. PA.* fronto-parietal; *gl.* glottis; *gul.* gullet; **IL.** ilium; **IS.** ischium; *kd.* kidney; *l. au.* left auricle; *l. lng.* left lung; *lr.* liver; **M.MCK.** mento-meckelian bone; *n. a. 1*, arch of first vertebra; *ol. f.l.* olfactory lobe; *opt. l.* optic lobe; **O. ST.** omosternum; *pcd.* pericardium; *PMX.* premaxilla; *pn.* pancreas; *p, na.* internal nostril; *pu.* pubis; *rct.* rectum; *r. lng.* right lung; *s. int.* ileum; *sp. cd.* spinal cord; **SPH.ETH.** sphenethmoid; *spl.* spleen; *st.* stomach; *s. v.* sinus venosus; *tng.* tongue; *ts.* spermary; *ur.* ureter *ur'.* its aperture into the cloaca; **U.S.T.** urostyle; *v.* ventricle; *v. ly. s.* ventral lymph-sinus; *vo. t.* vomerine teeth; *vs. sem.* seminal vesicle. (From Parker and Haswell's *Zoology*.)

which have various purposes or *functions* to perform. The alimentary canal, together with the liver and pancreas, are *organs of digestion*; the lungs and skin, *organs of respiration* or breathing; the heart and blood-vessels *organs of circulation*, serving as they do to propel

and conduct the blood through the body; the kidneys, aided by the skin, *organs of excretion*, for getting rid of waste matters; the ovaries and spermaries, *organs of reproduction*; the muscles, *organs of movement*; the brain and spinal cord, together with the nerves, *organs of control*, serving to direct or control the actions of the body; the skin, nose, eye, and ear, *sensory organs*, by which communications are kept up with the external world.

Tissues.—Notice also that the various organs of the body are built up of different materials, or *tissues* as they are called. We have already distinguished muscle, bone, cartilage, connective-tissue and nervous tissue. Other tissues we shall meet with in the course of a more careful examination.

CHAPTER III

THE FROG (*continued*) : THE SKELETON

If you have followed the description given in the preceding chapter with a frog before you, testing every statement as you proceeded by reference to the specimen, you will now have a very fair notion of the general build of the animal. The next thing to do is to study its various parts in somewhat greater detail.

As the bones and cartilages form the framework on which all the other parts are supported, it is convenient to begin with them. You may study them on a prepared skeleton, but a far better plan is to make a skeleton for yourself.

Parts of the Skeleton.—The skeleton consists of the following regions :—

1. *The skull* (Figs. 10 and 11) : a complex mass of mingled bone and cartilage, enclosing the brain and the organs of smell and hearing, and supporting the upper jaw. Connected loosely with the skull, but really forming part of it, are the lower jaw and a cartilage in the floor of the mouth known as the *hyoid.*

2. The *vertebral column* or *backbone,* consisting of nine movably united pieces, the *vertebræ* (Fig. 9, v. 1—v. 9), and of a long bony rod, the *urostyle* (UST), representing a number of fused vertebræ belonging to the tail-region of the tadpole.

3. The *shoulder-girdle* or *pectoral arch* (Figs. 13 and 14), an inverted arch of bone and cartilage nearly encircling the anterior part of the trunk and giving attachment to—

4. The bones of the *fore-limbs* (Fig. 16).

5. The *hip-girdle* or *pelvic arch* (Figs. 9 and 17), an apparatus shaped somewhat like a bird's "merry-thought": it is attached in front to the ninth vertebra and behind gives attachment to—

6. The bones of the *hind-limbs* (Fig. 9).

The Vertebral Column.—The essential structure of a vertebra may be best studied by examining any of the vertebræ from the second to the seventh: the first, eighth, and ninth present certain peculiarities, and so may be left till last.

The whole vertebra (Fig. 9, B) has somewhat the form of a signet-ring with its sides produced into two outstanding projections. The part comparable to the stone of the ring is ventral in position, and is called the *body* or *centrum* (*cn*), the form of which is *procœlous*, *i.e.*, its anterior face is concave, its posterior face convex, and both faces are covered with a thin layer of cartilage. The part corresponding with the circle of the ring is the *neural arch* (*pd*, *lm*): it arches over the spinal cord and is produced in the middle line above into a blunt projection, the *neural spine* (*n. sp*). From the arch is given off, on either side, the large outstanding projection already referred to, the *transverse process* (*tr. pr*), which is tipped with cartilage. These cartilaginous epiphyses found upon the distal ends of transverse processes are particularly noticeable in *R. tigrina*, those upon the third vertebra being very large and backwardly directed.

The neural arch gives off from its anterior face, just above the origin of the transverse processes, a pair of small shelf-like projections, the *articular processes* or *zygapophyses* (*a. zyg*). Each has its upper surface flat

and smooth, and covered with a thin layer of cartilage. A similar pair of processes spring from the posterior face of the arch, but have the smooth, cartilage-covered surface or *facet* looking downwards.

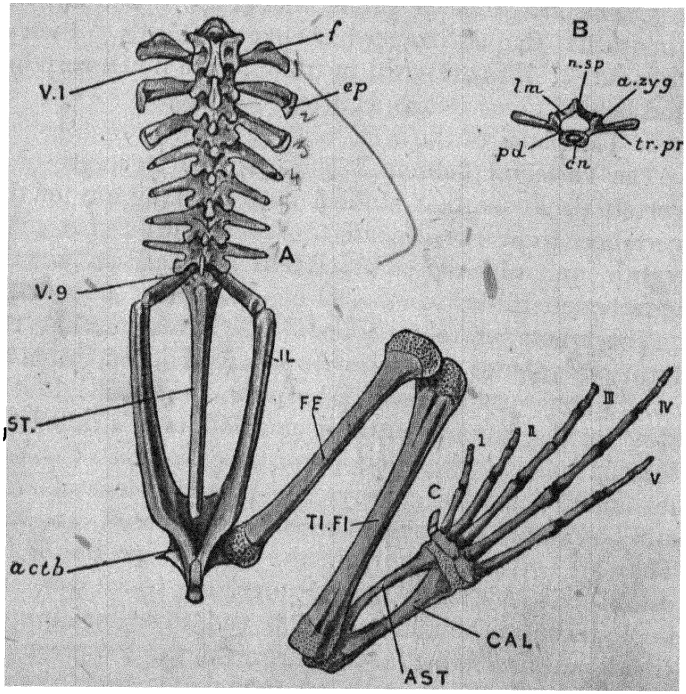


FIG. 9.—A, the vertebral column, hip-girdle and hind-limb of *R. tigrina*; B, anterior face of the fourth vertebra. (B.L.B.)

actb. acetabulum; *ast.* astragalus; *a. zyg.* anterior articular processes or prezygapophyses; *C.* calcar; *Cal.* calcaneum; *cn.* centrum; *ep.* epiphyses on the tips of transverse processes; *f.* flange-like projection on the transverse process of the second vertebra; *FE.* femur; *IL.* ileum; *lm.* roof of neutral arch; *n. sp.* neural spine; *pd.* base of neural arch; *TI. FI.* tibio-fibula; *tr. pr.* transverse process; *UST.* urostyle; *v. 1*, first vertebra; *v. 9*, ninth or sacral vertebra; *I—V.* digits.

When two vertebræ are placed in position, the convex posterior face of the foremost centrum fits into the concave anterior face of its successor, like a cup and ball, and at the same time the posterior articular processes of

the first fit over the anterior articular processes of the second. All the touching surface is, as we have seen, covered with cartilage, and the vertebræ can be moved upon one another, either up and down or from side to side.

The centra and articular processes are the only parts of the vetebræ which are in contact when the bones are in their natural positions. The neural arches are, relatively, greatly developed antero-posteriorly in *R. tigrina*. When viewed from above, the vertebral column of this species (Fig. 9) does not show a series of gaps between the arches (as the common European species of frog do), but, on the contrary, there is a very marked overlap of each arch dorsally upon that immediately posterior to it. There are gaps between the sides of the arches, bounded by the articular processes above and the centra below. These are called the *inter-vertebral foramina*: through them the nerves pass from the spinal cord.

The only difference of importance between the vertebræ now under consideration is in the form and direction of their transverse processes, which are specially large in the second, third, and fourth vertebræ.

The first vertebra has no transverse processes, and on either side of the very small "body" its anterior face bears, instead of the ordinary articular processes, a pair of obliquely placed, oval, slightly concave surfaces or facets, covered with cartilage, and serving for the articulation of the condyles of the skull, presently to be described. The transverse processes of the ninth or *sacral* vertebra are very long and strong, directed obliquely backwards, and tipped with cartilage: to them the arms of the hip-girdle are articulated.

The eighth vertebra differs from its predecessors in having its body concave behind as well as in front. Corresponding with this, the ninth (v. 9) has its centrum convex in front,

while behind it presents two little rounded elevations placed side by side.

It will be seen that the vertebræ are all corresponding structures, following one another in a regular series from before backwards. A correspondence of this kind, in which there is a repetition of similar parts along the body, is termed a *serial homology*, and thus not only the vertebræ as a whole, but also their various parts are serially homologous, each to each, the correspondence being disturbed only by the first vertebra, in which the transverse processes are absent and the anterior face is modified for articulation with the skull.

The urostyle (UST) is a long bone with a gradually diminishing ridge along its dorsal surface (see p. 30). Its anterior face has somewhat the appearance of a small vertebra with no transverse processes, and has a double concavity for articulation with the double convexity on the ninth vertebra. Some distance behind the anterior end there is on each side a small aperture, representing an intervertebral foramen, for the last spinal nerve. These foramina are very imperfectly developed, and sometimes absent on one or both sides of the urostyle in *R. tigrina*.

The **skull** is a very complex structure, consisting partly of bone, partly of cartilage. It is divided into the following regions :—

1. The *brain-case* or *cranium*, a sort of oblong box containing the brain (Figs. 10 and 11) : it forms the middle portion of the skull and is a direct forward continuation of the vertebral column.

2. The *auditory capsules*, a pair of outstanding masses arising, right and left, from the posterior end of the brain-case. They lodge the organs of hearing.

3. The *olfactory capsules*, smaller masses proceeding from the anterior part of the brain-case and united

with one another in the middle line. They lodge the organs of smell.

4. The *suspensoria* (*q*), a pair of projections springing from the outer and upper portions of the auditory capsules, and directed downwards, outwards and backwards. To them the ends of the lower jaw are attached.

5. The *upper jaw*, a half-circle of bone and cartilage, united in front to the olfactory capsules and behind to the suspensoria. On either side of the skull, between the cranium and upper jaw, is a large space, the *orbit*, in which the eye is contained.

6. The *lower jaw*, a roughly semicircular bar of bone and cartilage, articulated at its ends with the suspensoria.

7. The *hyoid* (Fig. 8, *b. hy*), a shield-shaped cartilage connected by delicate curved rods with the auditory capsules.

On the posterior surface of the brain-case is a large hole, the *foramen magnum* (Fig. 10, A), on either side of the lower edge of which is a large oval elevation covered with cartilage, the *occipital condyle*. The foramen magnum leads into the cavity in which the brain is contained. If the first vertebra is placed in its natural position with regard to the skull it will be seen that the foramen magnum corresponds with the neural canal of the vertebra, and that the condyles fit into its articular surfaces. Thus the skull readily moves up and down upon the vertebra, the condyles acting as rockers; a space between the neural arch and the dorsal edge of the foramen magnum covered by membrane in the fresh state allows of the requisite amount of play.

The discrimination of the separate bones and detailed structure of the skull is rather difficult, and may very well be omitted by the beginner at the present stage.

The occipital condyles are borne on a pair of irregular bones (*eo*), which bound the sides of the foramen

magnum, nearly uniting above and below it, and extending over a considerable portion of the posterior surface of the auditory capsule. These bones are the

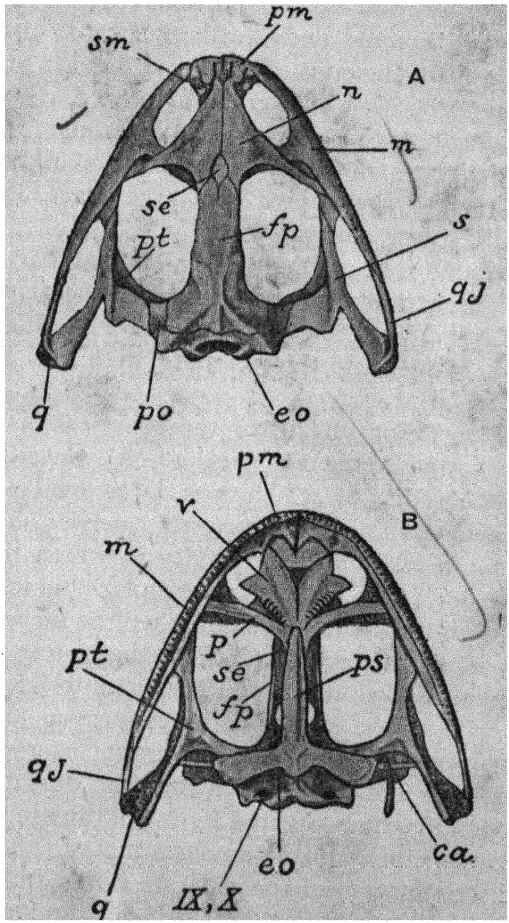


FIG. 10.—Skull of *R. tigrina*. A, dorsal view; B, ventral view.
c.a. columella auris; *eo.* exoccipital; *fp.* fronto-parietal; *m.* maxilla; *n.* nasal; *p.* palatine; *pm.* premaxilla; *po.* pro-otic; *ps.* parasphenoid; *pt.* pterygoid; *q.* quadrate cartilage; *qj.* quadrato-jugal; *s.* squamosal; *se.* sphenethmoid; *sm.* septo-maxillary; *v.* vomer; IX, X, foramen for the exit of ninth and tenth nerves. (After Bhatia and Parshad.)

exoccipitals. The exoccipital is perforated just in front of the condyle, by an aperture (Fig. 10, B, *ix*, *x*) through which two nerves, the glossopharyngeal and the vagus, pass on their way from the brain. In front of each exoccipital is another irregular bone (*po*) forming a considerable portion of the roof and anterior wall of the auditory capsule, and called the *pro-otic.* Each pro-otic is separated from the corresponding exoccipital, in young frogs, by a band of cartilage, but in old specimens the two bones are more or less completely united. Dorsally, each presents a quadrilateral area between the fronto-parietal and exoccipital on the inner side and the inwardly directed horizontal flange of the squamosal which partly overlaps it, on the outer. Anteriorly, the pro-otic bone forms nearly the whole of the anterior wall of the auditory capsule; a small area on the outer side of this anterior wall remains cartilaginous. On the inner side, this anterior portion curves forward to form the posterior part of the inner wall of the orbit. In this angle is situated the foramen for the exit of the trigeminal, abducent, and facial nerves (Fig. 11, B, *v*, *vii*).

In the disarticulated skull it can be made out that the exoccipital and pro-otic of either side enclose a cavity; in this the organ of hearing is contained. The ventral and the posterior walls of the auditory capsule are cartilaginous.

The dorsal surface of the brain-case is covered by two longish, flat bones (*fp*). In the young condition each of these consists of two distinct bones, the front one the *frontal*, the hinder the *parietal.* As the young frog grows the frontal and parietal of either side become completely fused, forming a single *fronto-parietal.* In this species, the fronto-parietals form a strong roof to the skull, with a notch in front, the remains of the frontal suture, but are wholly coalesced beyond this; they end

behind in two broad wings which spread over the hinder region of the cranium almost to the end. On the upper surface of the olfactory capsules are large, broad-based, triangular bones, the *nasal* (*n*) meeting each other in the median line and diverging posteriorly to meet the anterior ends of the fronto-parietals, thus leaving exposed a diamond-shaped area of the sphenethmoid.

The ventral surface of the brain-case is covered by a single strong bone (*ps*) having the shape of a T. The stem extends forwards in the middle line as far as the olfactory capsules, while the arms stretch outwards beneath the auditory capsules. This very characteristic bone is the *parasphenoid.* Its posterior border is deeply concave and bears a short median process. The stem or the longitudinal arm of the bone, besides forming the floor, rises up on each side to form a portion of the lateral wall of the cranium. On the under surface of the olfactory capsules, corresponding to the nasals above, are a pair of irregular bones, the *vomers* (*v*). They meet each other in the middle line posteriorly, but diverge anteriorly, leaving a portion of the floor of the olfactory capsules uncovered. Their outer edges are notched and help to bound the internal nostrils: their posterior borders bear the vomerine teeth.

The anterior end of the brain-case is surrounded by a bone (*se*) which extends forwards into the region of the olfactory capsules, and is partly covered by the fronto-parietals and nasals above and by the parasphenoid below. This is the *girdle-bone* or *sphenethmoid.* In the disarticulated skull it is seen to have a very peculiar shape. Its posterior half encloses a single cavity in which the fore-end of the brain (Fig. 11, A, *se*) is lodged. Its anterior half encloses two cavities, right and left, separated from one another by a vertical partition, and serving to lodge the posterior ends of the olfactory

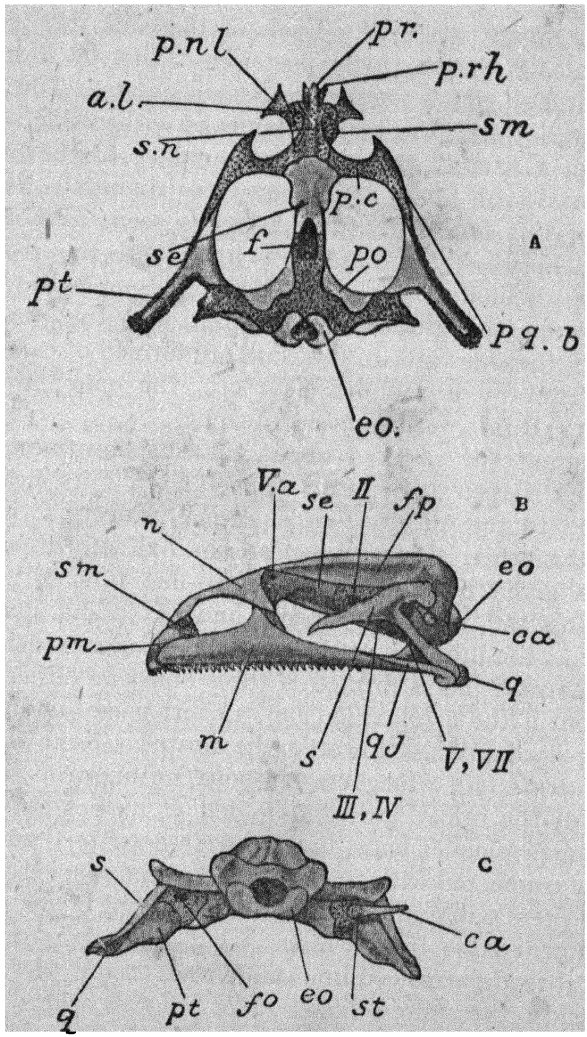


FIG. 11.—Skull of *R. tigrina*. A, Dorsal aspect of skull after removal of investing bones; B, from the left side; C, from behind.
a.l., *p.nl.*, *p.r.*, *p.rh.* different processes of the cartilages of the olfactory capsule; *f.* fontanelle; *f.o.* fenestra ovalis; *p.c.*, *pq.b.* palato-quadrate bar of cartilage; *s.n.* septum nasi; *II*, *III*, *IV*, *V*, *VII*, foramina for the exit of the cranial nerves. Other letters as in the previous figure. (After Bhatia and Parshad.)

sacs or organs of smell. Each of these cavities communicates with the single posterior cavity by a small hole through which the nerve of smell passes. Towards the anterior end, the bone extends on either side so as to form a part of the anterior boundary of the orbit. In the dorsal view a lozenge- or diamond-shaped area of this bone (Fig. 10, A, *se*) is seen, as noticed above, between the nasals in front and the fronto-parietals behind.

Between the girdle-bone in front and the pro-otic behind, the side-walls of the skull are formed of cartilage perforated by a rounded aperture, the *optic foramen* (Fig. 11, B, *II*), for the nerve of sight.

Forming the outer part of the suspensorium is a hammer-shaped bone, the *squamosal* (*s*); its head is applied to the auditory capsule and projects forwards into the orbit. From the posterior half of this cross-bar is given off a horizontal shelf-like process partly covering the auditory capsule and extending inwards as far as the junction of the pro-otic and the exoccipital.

The upper jaw is formed of three bones on either side. In front is the *premaxilla* (*pm*), a short bone, sending off an upward process towards the nostril. Next follows the *maxilla* (*m*), a long, curved bone, forming the greater part of the upper jaw, and joined at its posterior end to a small, slender bone, the *quadrato-jugal* (*qj*), which is firmly connected with the lower end of the suspensorium. Both premaxilla and maxilla are produced below into a prominent edge from which spring a number of small conical teeth, arranged in a single row.

Besides these three bones there are two others which seem, as it were, to brace the upper jaw to the brain-case and suspensorium. The *palatine* (*p*) is a narrow, rod-like bone, placed transversely behind the olfactory capsule. The *pterygoid* (*pt*) is a large three-rayed bone;

one ray is directed forward and connected with the outer end of the palatine and with the inner face of the maxilla; another passes backwards and inwards and is connected with the auditory capsule; the third extends backwards and outwards and forms the inner and ventral portion of the suspensorium. The main mass or core of the suspensorium, between the squamosal outside and the pterygoid within, is a rod of cartilage (*q*), which is continued forwards by a bar (*pc, pq.b*) supporting the pterygoid and palatine.

There is an important distinction to be drawn between the bones of the skull which can be made out only by the exercise of a good deal of care and patience. By softening the connective-tissue which binds the bones together, it is possible to remove the majority of them without injuring the underlying cartilage (compare Fig. 11, A), provided, of course, that the operation is skilfully performed: these bones are the nasals, vomers, fronto-parietals, parasphenoid, pre-maxillæ, maxillæ, quadrato-jugals, palatines, pterygoids, and squamosals. A sort of foundation or groundwork is then left behind, consisting mainly of cartilage, but containing the exoccipitals, pro-otics, and sphenethmoid. These five bones cannot be removed without pulling the cartilaginous groundwork or *chondrocranium* to pieces. We thus get a distinction between *replacing bones* (so called *cartilage bones*) which take the place of pre-existing cartilage, being therefore continuous with the remaining cartilage and forming part of the chondrocranium, and *investing bones* (so called *membrane bones*) which form no part of the original chondrocranium, being united to it by connective tissue only.

The chondrocranium has a cartilaginous roof, underlying the fronto-parietals; it is pierced by one large (Fig. 11, A.*f*) space, called the *fontanelle*, covered by membrane. It has also a cartilaginous floor (Fig. 10, B) underlaid by the parasphenoid. The olfactory capsules also have a cartilaginous roof and floor of irregular form, with the posterior end of which is united the cartilaginous *palato-quadrate* bar (*pc, pq.b*), with which the palatine and pterygoid bones are connected. Posteriorly this bar is continuous with the cartilaginous groundwork (*quadrate*) or core of the suspensorium (*q*), which unites above with the auditory

capsule and below furnishes an articular surface for the lower jaw.

Notice that in describing the vertebral column no distinction was drawn between replacing and investing bones. As a matter of fact the vertebræ and the urostyle are all replacing bones; each consists, in the tadpole, of cartilage which is subsequently replaced by bone.

The **lower jaw** consists of two halves, or *rami*, united with one another in front by ligament. At its posterior end each half bears on its upper surface a shallow pit, by which it articulates with the suspensorium, and a little in advance of this pit is an elevation of the dorsal edge of the jaw, called the *coronary process*.

Each half of the lower jaw consists of a cartilaginous core, the *mandibular* or *Meckel's cartilage*, which furnishes the articular surface referred to, and in front is ossified as a small replacing bone, the *mento-meckelian*. Outside the cartilage are two investing bones. One, the *angulo-splenial*, extends along the inner surface and lower edge of the jaw and forms the coronary process, while the *dentary* forms the outer surface of the anterior half of the jaw.

A feature worth noticing is the presence of three well-marked depressions on the ventral side of the upper jaw in its anterior portion. The middle one of these depressions is between the two premaxillæ and receives a corresponding median projection from the mento-meckelians. The two lateral depressions are at the junction of the premaxilla with the maxilla of each side and accommodate a strongly developed projection of the dentary of each side.

The **hyoid** is a thin, shield-shaped plate of cartilage (Fig. 8, *b. hy*) produced, both in front and behind, into a pair of processes or *horns*, as well as into less important offshoots. The *anterior horns* are long, delicate, cartilaginous rods which curve backwards and then upwards, finally joining with the auditory capsules. The *posterior horns* are short, bony rods

which pass backwards, diverging as they go, one on either side of the glottis.

Two apparently insignificant structures connected with the skull must be described because of their connection with the organ of hearing. Behind the suspensorium is a recess, roofed over by the squamosal, and, in the entire frog, converted by muscle and other tissues

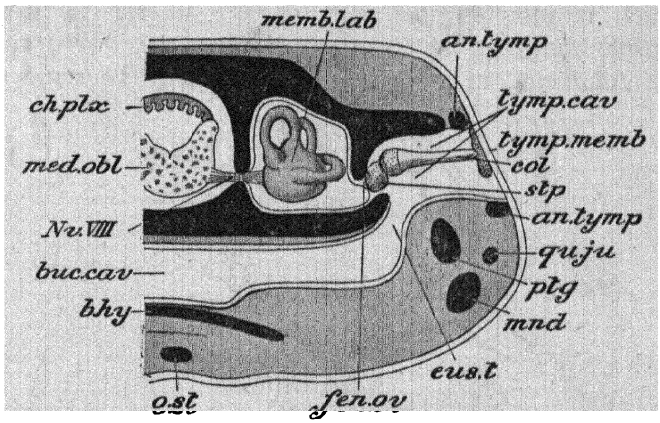


FIG. 12.—Transverse section (diagrammatic) through the head of a Frog at the level of the tympanic cavity. The various parts of the skull shown in section are black, the muscles, &c., grey, and the skin and mucuos membrane white. (× 5.) *an. tymp.* tympanic ring; *b. hy.* body of hyoid; *buc. cav.* mouth cavity; *ch. plx.* choroid plexus; *col.* columella; *eus. t.* Eustachian tube; *fen. ov.* fenestra ovalis; *med. obl.* medulla oblongata; *memb. lab.* membranous labyrinth; *mnd.* mandible; *Nv. VIII.* auditory nerve; *o. st.* omosternum; *ptg.* pterygoid; *qu. ju.* quadrato-jugal; *stp.* stapedial plate; *tymp. cav.* tympanic cavity; *tymp. memb.* tympanic membrane. (From Parker and Haswell's *Zoology*.)

into a chamber, the *tympanic cavity* (Fig. 12, *tymph. cav*), bounded externally by the tympanic membrane, and communicating with the mouth-cavity by the Eustachian tube. Supporting the tympanic membrane, as the frame of a tambourine supports the parchment, is a cartilaginous framework of the shape of a short truncated cone, broad outwards and narrowing towards the inner side, which is called the *tympanic ring* (*an. tymp*, shown in

section). Stretching across the tympanic cavity from the outer wall of the auditory capsule to the tympanic membrane is a small, hammer-shaped rod, the *columella* (Figs. 10, 11, *ca*, and 12, *col*), having a bony handle and a cartilaginous head, the latter firmly fixed to the inner face of the tympanic membrane. The inner end of the handle is tipped with cartilage, and is attached to a small cartilaginous nodule, the *stapedial plate* (*st*), which is inserted into an aperture in the auditory capsule known as the *fenestra ovalis* (*fen. ov*). With care the columella, in a wet skull, may easily be removed

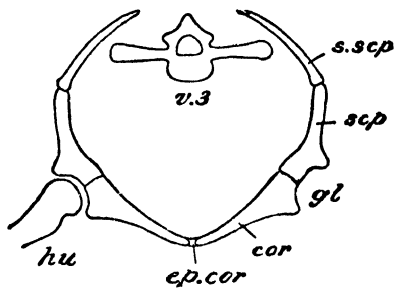


FIG. 13.—Diagrammatic transverse section through the shoulder-girdle of a Frog. (× 2.)
cor. coracoid; *ep. cor*. epicoracoid; *gl*. glenoid cavity; *hu*. humerus; *scp*. scapula; *s. scp*. supra-scapula; *v. 3*, third vertebra.

with small forceps, and examined under a magnifying glass.

The **shoulder-girdle** has the form of an inverted arch encircling the anterior region of the trunk, and having its dorsal ends turned inwards so as partly to cover the second to the fourth vertebræ (Figs. 13 and 14). The dorsal region, on either side, is formed by a broad plate, the *supra-scapula* (*s. cp*). It is mostly formed of bone, but its free edge consists of cartilage which, when dried, is seen to be impregnated with a granular deposit of lime-salts. This rough, brittle tissue is called *calcified*

cartilage, and is distinguishable from bone, which has usually a smooth, enamelled surface.

Connected with the ventral end of the supra-scapula and passing vertically downwards is a flat bone, broadened at each end, the *scapula* (Fig. 13, *scp* : Fig. 14,

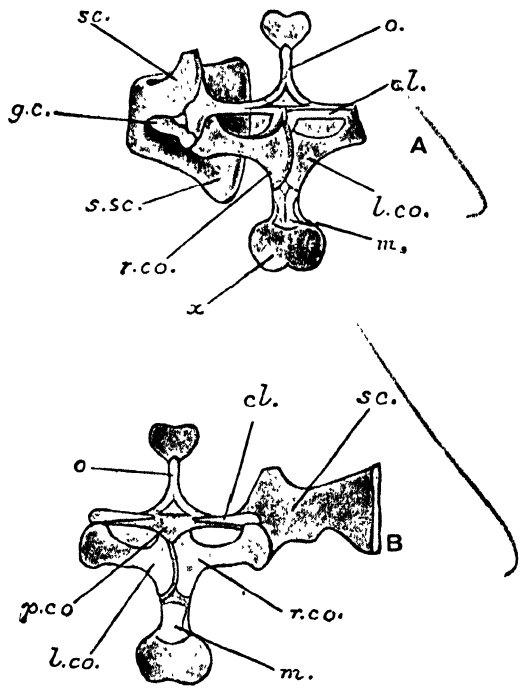


FIG. 14.—The Shoulder-girdle and Sternum of *R. tigrina*. A. Ventral view; B, Dorsal view. (B.L.B.)
cl. clavicle; *m.* metasternum; *o.* omosternum; *pr. co.* precoracoid; *r. co.*, *l. co.* right and left coracoids; *sc.* scapula; *s. sc.* supra-scapula; *x.* xiphisternum.

sc). From its lower end two bones (Fig. 14, *p. co*, *l. co*) pass directly inwards, parallel with one another, and are connected together in the middle line of the chest with their fellows of the opposite side through thin strips of cartilage called *epicoracoids*. The more anterior of these

(*p. co.*) is the precoracoid, a narrow, transverse rod of calcified cartilage which is covered over antero-dorsally with a thin investing bone, the *clavicle* (*cl*). The posterior one is broader and is known as the *coracoid* (*r. co., l. co*). In most species of frog the epicoracoids meet each other in the median line, but in *Rana tigrina* the inner ends of the coracoids, which are covered by thin strips of cartilage, overlap each other, the right lying ventral to the left, though the opposite condition is also sometimes met with. Between the scapula on the one hand and the clavicle and coracoid on the other, there is a cartilaginous interval, the posterior edge of which is scooped out into a depression, the *glenoid cavity* (Fig. 13, *gl*), for the articulation of the upper-arm bone.

Connected with the median ventral portion of the shoulder-girdle is the *sternum*, or breast-bone, which consists of two separate parts, one extending forwards, the other backwards, in the middle line, and each formed of a flattened bony rod (Fig. 14, *o* and *m*, *x*), tipped with a flat plate of cartilage. The sternum of the frog is not homologous with that of mammals as it is not derived from the separated off ventral ends of the ribs.

The anterior bony rod with its terminal cartilage is called the *omosternum* (*o*), the posterior bony rod the *metasternum* (*m*), and the bilobed cartilage at its end the *xiphisternum* (*x*).

All the bones of the shoulder-girdle and sternum are replacing bones except the clavicle.

The Fore-limb.—The upper arm is supported by a single bone, the *humerus* (Fig. 16, *h*), the first example we have had of what is conveniently called a *long bone*. It consists of a roughly cylindrical *shaft*, formed of dense bone, and of two *extremities*—the proximal of partially calcified cartilage, the distal of spongy or cancellated bone. The proximal extremity or *head* is

convex; and fits into the glenoid cavity of the shoulder-girdle (Fig. 13, *gl.*); the distal extremity or *condyle* is almost globular, and is articulated with the bone of the fore-arm.

In a longitudinal section of the humerus which has not been allowed to dry you will see that the shaft (Fig. 15, A, *sh*) is not a solid rod, but a tube, containing a

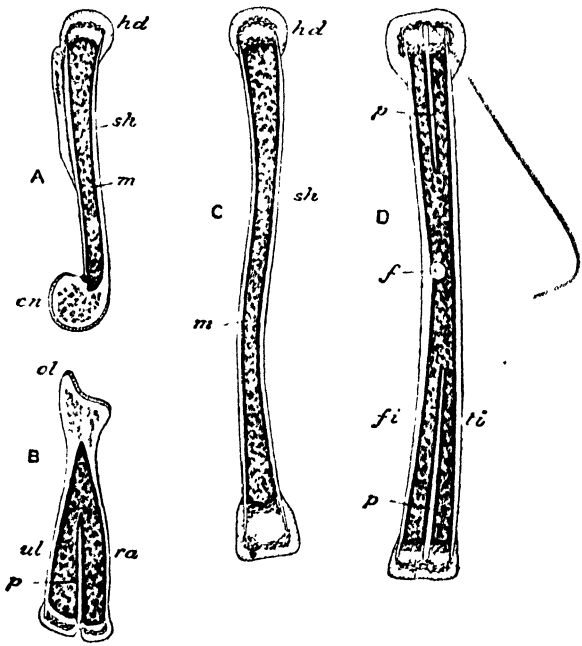


FIG. 15.—Longitudinal sections of the principal long bones of a Frog. (× 2½.) A, humerus; B, radio-ulna; C, femur; D, tibio-fibula; *cn.* condyle; *f.* foramen for artery; *fi.* fibula; *hd.* head; *m.* marrow; *ol.* olecranon process; *p.* bony partition; *ra.* radius; *sh.* shaft; *ti.* tibia; *ul.* ulna.

cavity, the *marrow-cavity*. In this way the weight of the bone is diminished without its strength being impaired. The marrow-cavity contains a substance called *bone-marrow*, composed chiefly of connective-tissue and fat, with blood-vessels. The proximal end of the hollow

shaft is, as it were, plugged by the cartilaginous extremity.

The fore-arm is also supported by a single bone, the *radio-ulna* (Fig. 15, B; Fig. 16, *r.u*). Its proximal end is concave and articulates with the almost globular condyle of the humerus: the outer or posterior edge of the concavity is produced into a short process, the *olecranon* or elbow. The distal end is incompletely divided into two articular surfaces, and between these is a groove passing for some distance towards the

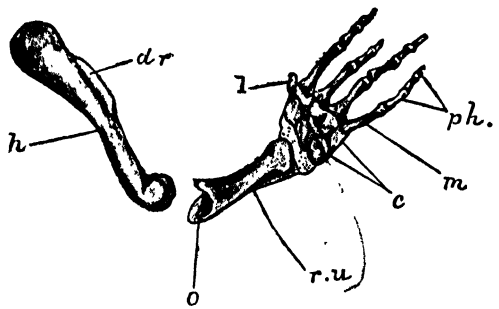


FIG. 16.—The Fore-limb of *R. tigrina*. (B.L.B.)
c. carpus; *d.r.* deltoid ridge; *h.* humerus; *m.* one of the metacarpals; *o.* olecranon process of ulna; *ph.* phalanges; *r.u.* radio-ulna; *1.* rudimentary metcarpal of the first digit.

proximal end of the bone. A section shows that at this end there are two distinct marrow-cavities, indicating that the bone is really double. That this is the case is proved by the examination of a very young frog, in which the single fore-arm bone is represented by two distinct cartilages, the *radius* on the inner or thumb side, and the *ulna* on the outer or little-finger side. The olecranon is a process of the ulna.

The skeleton of the hand is divisible into three regions: the *carpus* or wrist, the *metacarpus* or mid-hand, and the *phalanges* or finger-bones. The carpus consists of six small irregular bones, arranged in two rows (Fig. 16).

The proximal row articulates with the radio-ulna, while to the distal row are attached the *metacarpals*, which together constitute the *metacarpus*. Four of these are long, rod-like bones and support the bases of the four fingers or digits: to them are attached the phalanges, of which the first or innermost digit (II) has two, the next two, and the remaining two digits three apiece. A very small metacarpal, with a single phalanx (I), occurs on the radial side and is concealed by the skin in the entire frog: it corresponds with our own thumb, so that the apparent first digit of the frog is really the second or index finger.

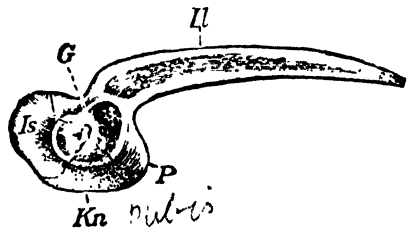


FIG. 17.—The hip-girdle of a Frog seen from the right side. (× 2. *G*. acetabulum; *Kn*. pubis; *Il*., *P* ilium; *Is*. ischium. (From Wiedersheim's *Comparative Anatomy*.)

The Hip-girdle.—This, as we have seen, has somewhat the form of a bird's merrythought. It consists of two long arms (Fig. 9, IL; Fig. 17, *Il*), which are articulated with the transverse processes of the ninth vertebra, and sweeping backwards, unite in a disc-shaped mass, having on either side of it a deep, hemispherical cavity, the *acetabulum* (Fig. 9, *actb*; Fig. 17, *G*), for the articulation of the thigh-bone.

Two *sutures*, or lines of separation, nearly at right angles to one another, divide the disc-shaped portion into three parts. One of these, dorsal and anterior in position, is continued into one of the arms of the hip-girdle and forms half of the acetabulum; this is the

ilium (Fig. 17, *Il*, *P*). The second, posterior in position, is the *ischium* (*Is*); like the ilium, it is made of true bone. The third, or *pubis* (*Kn*), is ventral, and is formed of calcified cartilage. Originally each of these elements is paired, *i.e.*, there is an ilium, an ischium, and a pubis on either side, the three together forming the *innominate*; but in the adult the right and left ischia and pubes become united in the median plane, the ilia only remaining free.

The Hind-limb.—The thigh, like the upper arm, is supported by a single long bone, the *femur* (Fig. 9, FE; Fig. 15, C), having a gently curved shaft and extremities of calcified cartilage. Its rounded proximal extremity, or *head*, fits into the acetabulum : its distal end articulates with the single bone of the shank, the *tibio-fibula* (TI. FI). This, the longest bone in the body, also has a shaft and extremities, and is further distinguished by grooves running from each end towards the middle of the shaft. Sections show that the grooved portions of the bone contain a double marrow-cavity (Fig. 15, D), and in the young animal there are found two shank-bones which afterwards unite, the *tibia* on the inner side, the *fibula* on the outer side.

The foot, like the hand, is divisible into three regions : the *tarsus* or ankle, the *metatarsus* or mid-foot, and the *phalanges* or toe-bones. The tarsus, like the carpus, consists of two rows, but with only two bones in each. Those of the proximal row (*astragalus* and *calcaneum*) are greatly elongated (Fig. 9, AST., CAL.), and furnish an additional segment to the limb, thus increasing the frog's leaping powers : those of the distal row are very small.

The metatarsals are five in number : those of the first and second digits (I, II) bear two phalanges each, those of the third and fifth, three each, and that of the fourth, four. Attached to the inner side of the tarsus is a little claw-like structure (C) composed of two or three bones and called the *calcar* or spur.

Notice the striking correspondence in structure between the fore- and hind-limbs, a correspondence which extends also, though less obviously, to the limb-girdles. The humerus corresponds or is serially homologous (p. 34) with the femur, the radius with the tibia, the ulna with the fibula, the carpals with the tarsals, the metacarpals with the metatarsals, and the phalanges of the fingers with those of the toes. Then in the limb-girdles the glenoid cavity corresponds with the acetabulum, the scapula and supra-scapula (being above the articular cavity) with the ilium, the precoracoid and clavicle (being ventral and anterior in position) with the pubis, and the coracoid with the ischium. Thus not only are the limbs and limb-girdles serially homologous structures, but their several parts are also serially homologous, each to each.

Nature of Bone.—It is a mistake to suppose that bones are made exclusively of hard mineral matter, like rocks or stones. If one of the long bones, for example, is put into weak acid, bubbles of gas will rise from the bone, showing that the carbonate of lime, of which it is partly composed, is being decomposed with the liberation of carbon dioxide. When the liberation of bubbles is over, the bone will be found to be unaltered in form, but to be quite flexible instead of hard and rigid. It can be bent in any direction, and a bone of sufficient length, such as a sheep's rib, can be tied in a knot. This shows that the bone contains a large amount of organic or animal matter. On the other hand, a bone may be completely *calcined* by heating to redness in a closed vessel, when its animal matter is completely consumed and its mineral matter left. Under these circumstances it becomes very brittle, falling to pieces at a touch, and its appearance is far more altered than by the removal of the mineral matter.

CHAPTER IV

THE FROG (*continued*) : THE JOINTS AND MUSCLES

In the previous chapter the bones—more than 150 in number—which together constitute the greater part of the skeleton of a frog have been considered as so many separate parts, fitting into or against one another in certain ways. We must now see how they are joined together in the entire animal so as to afford the requisite support, and, at the same time, to allow of free movement.

The Hip-joint.—Let us begin by a study of the hip-joint (Fig. 18).

The acetabulum (*actb*), as you have already seen (p. 49), is a hemispherical depression on the outer surface of the hip-girdle. It is formed of cartilage, continued into a projecting rim round the edge of the cavity. The head of the femur (*hd*) is also formed of cartilage, and fits accurately but rather loosely in the acetabulum.

The acetabulum is lined, and the head of the femur is covered, by a thin layer of connective-tissue, the *perichondrium* (*p. chd*), which, in both cases, is continued on to the adjacent bone, where it receives the name of *periosteum* (*p. ost*).

Attached all round the rim of the acetabulum is a strong sheet of connective-tissue called the *capsular ligament* (*cps. lg*), forming a short, fibrous tube. The other

end of this tube is fixed to the femur, just below the head, the ligament being continuous, in each case, with the perichondrium. There is thus a space between the head of the thigh-bone and the acetabulum, closed all round by the capsular ligament. This space is filled with a delicate, fibrous, closed bag, the *synovial capsule* (*sy. cps*), one side of which fits closely into the acetabulum, while the other as closely invests the head of the femur.

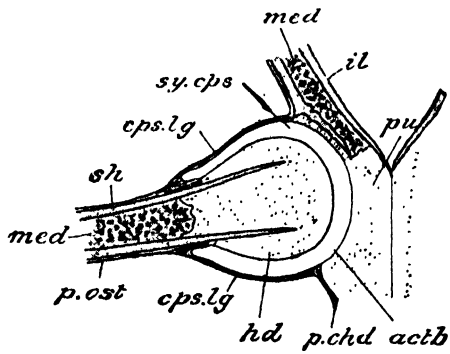


FIG. 18.—Horizontal section of a Frog's hip-joint. (× 5.)
acth, acetabulum; *cps. lg.* capsular ligament; *hd.* head of femur; *il.* ilium; *med.* marrow; *p. chd.* perichondrium; *p. ost.* periosteum; *pu.* pubis; *sh.* shaft of femur; *sy. cps.* synovial capsule.

The capsule is filled with a watery fluid, the *synovia*, and thus forms a buffer or water-cushion between the adjacent parts of the skeleton. Thus the synovial capsule keeps the two parts slightly apart and prevents friction, while the capsular ligament keeps them together and prevents dislocation.

It is obvious that, in such a joint as this, movement is possible in all directions. The femur can be inclined either upwards, downwards, or sideways, and is capable of a certain amount of rotation. The joint is, in fact, a *cup-and-ball joint*, and is capable of movement in any plane. A similar but less perfect cup-and-ball joint is

that of the shoulder, in which the cup is furnished by the glenoid cavity, the ball by the head of the humerus.

Other Joints.—The elbow- and knee-joints are constructed on the same general plan, but, owing partly to the form of the adjacent surfaces, partly to the mode of attachment of the ligaments, they are capable of movement in one plane only, *i.e.*, up and down, but not from side to side. They are therefore distinguished as *hinge-joints.*

The vertebræ are connected with one another in a similar way. Between the convex hinder face of one centrum and the concave front face of its successor is a synovial capsule, and the two centra are bound together by ligament, a shallow cup-and-ball joint, with a very limited range of movement, being produced. There are also synovial capsules between the articular processes, which, being in contact with one another by flat surfaces and working mainly from side to side, form *gliding-joints.* Strong ligaments connect the neural arches with one another and join the first vertebra to the skull.

In all cases where free movement is necessary the joints are formed in the same way; the bones are bound together by ligaments, and a synovial capsule is interposed between their adjacent cartilage-covered surfaces. Where little or no movement is required, as between the bones of the shoulder- and hip-girdles, the union is effected by cartilage or ligament only, and there is no synovial capsule. Such joints are therefore distinguished as *immovable* or *imperfect joints.*

The Muscles.—We see then that the bones of the skeleton are attached to or articulated with one another by means of ligaments, so arranged, in most cases, as to allow of more or less free movement between the bones.

upwards or towards the thigh, the foot will instantly be bent backwards, so as to come into a straight line with the shank, the action being one of those performed by the living frog when leaping. It will be seen that the proximal tendon is attached to a relatively fixed point: it is distinguished as the tendon of *origin*, or the muscle is said to *arise* from the femur and tibio-fibula. The distal tendon is attached to a relatively movable part, the foot, and is called the tendon of *insertion*, the muscle being said to be *inserted* into the plantar fascia.

Muscular Contraction.—Obviously, however, there is nothing to pull upon the muscle from outside in the living frog. We must, therefore, try to form some idea as to how the action of bending the foot, roughly imitated in the dead subject, is performed during life. If the gastrocnemius be exposed in a recently killed frog, the foot bent up as before, and a smart pinch be given to the belly of the gastrocnemius, the foot will be bent back, although no pull has been exerted on the muscle. The same thing will happen if you drop on the gastrocnemius a single drop of weak acid or of a strong solution of common salt, or if you touch it with a hot wire, or if you apply to it the electrodes from an induction coil so as to pass an electric current through it.

Careful observation shows that what happens in either of these circumstances is that the belly of the muscle decreases in length and at the same time increases in breadth, so as to become shorter and thicker (Fig. 20). The result of this must necessarily be to cause its two ends to approach one another. As the tendon of origin is attached to the femur, which we suppose to be fixed, it is unable to move, and the insertion is therefore drawn upwards, bringing with it the movably articulated foot. In fact exactly the same thing takes

place as when we raise our own fore-arm. This action is performed by means of the biceps muscle which arises from the scapula and is inserted into the fore-arm. When the latter is raised we feel a lump rise on the front of the upper arm due to the thickening of the biceps.

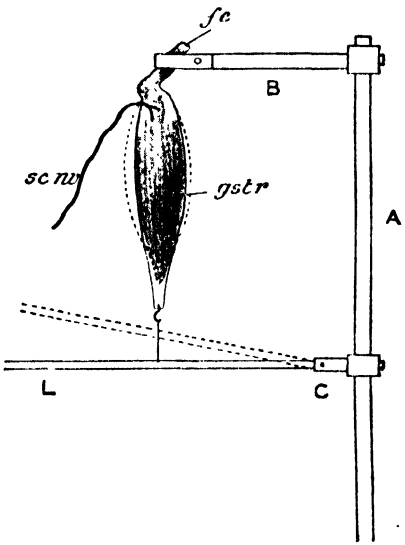


FIG. 20.—Diagram of apparatus for demonstrating the contraction of the gastrocnemius muscle.

A, upright, bearing two adjustable horizontal arms. To the upper of these (B) is fixed by a clamp the femur (*fe*), having the gastrocnemius (*gstr*) in connection with it. To the lower arm (C) is fixed a light lever (L) movable in a vertical plane, and having the tendon of insertion of the muscle attached to it by a thread. The dotted lines show the form of the gastrocnemius and the position of the lever during contraction of the muscle. *sc. nv.* the sciatic nerve.

This shortening and thickening of the muscle is termed a *contraction.* Do not fail to notice that this word is used in a special sense. When we say that a red-hot bar of iron contracts on cooling, we mean that it becomes smaller in all dimensions—undergoes an actual decrease in bulk. But in muscular contraction there is no alteration in bulk : the decrease in length is

balanced by an increase in thickness, as when a stretched piece of india-rubber is relaxed.

The external influence by which a contraction is induced is called a *stimulus*. As we have seen, a stimulus may be produced by actual contact of some external object (*mechanical stimulus*), or by chemical action (*chemical stimulus*), or by heat (*thermal stimulus*), or by an electrical current (*electrical stimulus*).

Relation of Muscle and Nerve.—Evidently, however, we have by no means got to the bottom of the matter. In the living frog movements are always going on, and all are due to the contraction of muscles, and yet no stimuli of the kind enumerated are applied to any of them. As the muscles retain the power of contraction for some little time after the death of the animal, it is easy to make such experiments as that described in the next paragraph.

Running longitudinally between the muscles on the dorsal side of the thigh is a shining, white cord, the *sciatic nerve* (Fig. 20, *sc. nv*), accompanied by an artery: it gives off branches to the muscles and skin, and, amongst others, one to the gastrocnemius. If, when quite fresh, this nerve be carefully separated as it traverses the thigh and pinched with the forceps, the gastrocnemius will contract just as if the stimulus had been applied to it directly, and the same will happen if a chemical, thermal, or electrical stimulus be applied.

Thus a stimulus applied to the nerve of a muscle has the same effect as if applied to the muscle directly: it gives rise to a *nervous impulse*, which, travelling along the nerve, induces contraction of the muscle.

Once more, however, external stimuli are not applied to the frog's nerves during life, and it is obvious that we must carry our inquiry a little further. The sciatic nerve if traced upwards will be found to pass into the

trunk (Fig. 53, *sci*), and finally to join the spinal cord, which, as we have seen, is in connection with the brain. In the living frog nervous impulses originate in the brain, without the direct intervention of an external stimulus, and are conducted along the cord and nerves to the muscles. But further consideration of this subject must be deferred until we have made a special study of the nervous system.

The Muscular System in General.—All over the body the muscles, though varying greatly in form—some being elongated and band-like (Fig. 19, *sar*), others spindle-shaped (*gastr*), others in the form of broad, flat sheets (*my. hy, obl. ext*)—have the same general relation to the skeleton as in the case of the gastrocnemius. Each muscle arises or has its origin in a relatively fixed part, and is inserted into a relatively movable part. As each muscle contracts in one direction only, it follows that the more complex the movements any part is capable of performing, the more numerous must be its muscles. For instance, the femur, which, as we have seen, is capable of universal movement, has no fewer than nine muscles, arising from various parts of the hip-girdle, inserted into it. Even the minute phalanges of the fingers and toes all have their little slips of muscle by which the various movements of grasping and relaxing, approximating and separating the digits, are effected.

There are certain terms applied to muscles which it is useful to know. A muscle which raises a part, *e.g.*, the lower jaw, is called a *levator*, one which lowers a part a *depressor*. A muscle which serves to straighten one part upon another, *e.g.*, to bring the shank into line with the thigh, is an *extensor*, one which bends one part on another is a *flexor*. A muscle which draws, *e.g.*, a limb towards the trunk is an *adductor*, one which draws it away an *abductor*, one which rotates one part upon another (*e.g.*, the femur on the pelvis), a *rotator*.

Thus all the complex and accurately adjusted movements of the frog are performed by the contraction of its numerous muscles, acting either singly or in concert. The contractions of these muscles are brought about by nervous impulses sent from the brain or spinal cord along nerves which branch out and are distributed to the muscles, thus bringing the whole of the complex machinery which affects the movements of the animal under the direct control of its will.

CHAPTER V

THE FROG (*continued*) : WASTE AND REPAIR OF SUBSTANCE —THE DIGESTIVE ORGANS—NUTRITION

Waste and Repair.—The effects of prolonged muscular exertion are familiar to everyone. Sooner or later sensations of fatigue, hunger, and thirst are produced, accompanied by a loss of weight. Indeed, however little exertion we make and however often we feed, our weight always goes down between meals and rises again when we take food. The loss of substance, of which the diminution in weight is the index, takes place largely in the form of perspiration, a fluid consisting of water with certain organic and inorganic matters in solution. A further loss is due to the air breathed out from the lungs; this is always moist, *i.e.*, contains a good deal of water, and is further distinguished by containing a considerable volume of carbonic acid gas or *carbon dioxide* (CO_2). Besides these two constant sources of loss, there is an intermittent loss in the urine, which consists of water containing certain matters in solution, the most characteristic of which are two complex substances called urea (CON_2H_4) and uric acid ($C_5H_4N_4O_3$). Both of these, as well as carbon dioxide, act as poisons if allowed to remain in the system. Lastly there is an intermittent source of loss in the waste matters or fæces which are passed out from the intestine.

These losses are made good in two ways. Firstly, by breathing, in which process we constantly inhale pure air and replace the poisonous carbon dioxide by oxygen. Secondly, by eating and drinking, by which, at intervals, we make good the loss of solids and liquids. Just as a clock is constantly running down and has to be wound up in order to keep it going, so our bodies run down by loss of substance between meals, and require to be wound up by the repair of substance which results from food and drink.

The same thing is true of the frog. Every one of its numerous and often vigorous movements is done at the expense of a certain waste of substance. The various tissues of the body are constantly undergoing a process of wear and tear, expressed not as in machines of human construction, by a wearing away of surfaces and a loosening of bolts and screws, but by a slow and almost imperceptible dwindling, the lost material being carried off principally in the form of water, carbon dioxide, and urea or some allied compound containing nitrogen.

Food of the Frog : General Characteristics of the Digestive Process.—As we have seen, the food of the frog consists of worms, slugs, insects, and the like. These it catches and swallows whole, the stomach often becoming immensely distended with numbers of captured animals. After remaining for some time in the stomach the carcases are found to have undergone a marked change. Their soft parts become softer and slimy and finally semi-fluid, and in this way the food undergoes gradual disintegration. The quantity of food in the stomach decreases, some of it is passed into the intestine, which it traverses from duodenum to rectum, and certain portions of it are finally ejected from the vent in the form of fæces.

It is not difficult to assure oneself that the weight of the fæces passed during a certain time is very much less than that of the food swallowed during the same time. Obviously some constituents of the food have disappeared during its progress through the alimentary canal. The character of the fæcal matter, moreover, is very different from that of the food; the only portions of the swallowed animals discoverable in the rectum are bits of their hard parts; for the rest, the fæces form a pulpy, black mass. That this change is due to certain definite chemical processes taking place in the alimentary canal may be inferred from the fact that the contents of the stomach, as well as the walls of that organ, have an acid reaction, and turn blue litmus paper red. On the other hand, the contents of the small intestine are, to a greater or less extent, alkaline, restoring reddened litmus paper to its original blue colour.

It is also obvious that there must be some definite mechanism for propelling the food from one end of the alimentary canal to the other; its passage through so long, narrow, and coiled a tube can certainly not be accounted for by supposing it to be merely pushed onwards as fresh food is swallowed.

In order to understand the various processes connected with digestion we must make a renewed and more careful examination of the organs concerned.

The Digestive Organs.—By cutting open the alimentary canal and examining its inner surface under water with a magnifying glass, it is seen that the wall of the canal consists of two layers, easily separable from one another. The outer or *muscular layer* (Fig. 22, A, *musc*), covered by the peritoneum (p. 24), is tough and strong, the inner layer or *mucous membrane* (*m.m.*) is soft and slimy. Between the two is very loose connective-tissue, the *submucosa*, which, being easily torn, allows of

the ready separation of the muscular and mucous layers.

In the stomach the mucous membrane is raised into

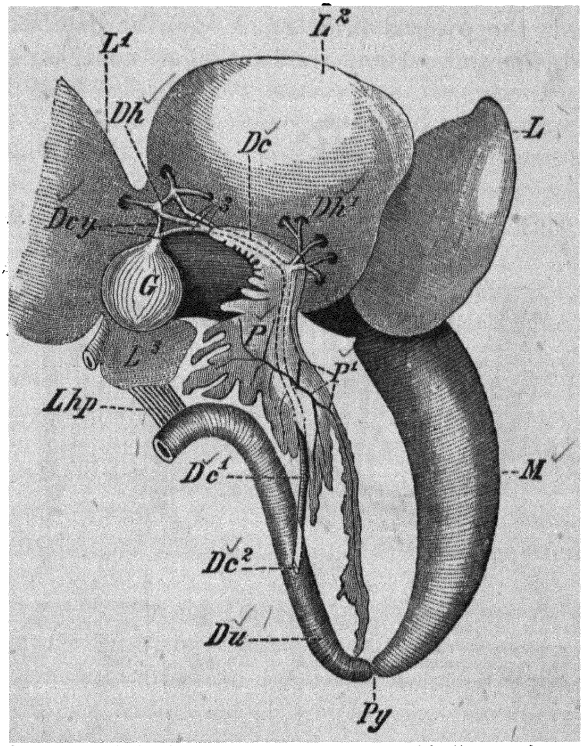


FIG. 21.—Stomach and duodenum of *Rana esculenta*, with liver and pancreas (× 2½.) *Dc*, *Dc.*¹ common bile-duct; *Dc.*² its opening into the duodenum; *D. cy.* cystic ducts; *Dh*, *Dh.*¹ hepatic ducts; *Du.* duodenum; *G.* gall-bladder; *L*, *L*¹, *L*², *L*³, lobes of liver, turned forwards; *Lhp.* duodeno-hepatic omentum, a sheet of peritoneum connecting the liver with the duodenum; *M.* stomach; *P.* pancreas; *P*¹, pancreatic duct; *Py.* pylorus. (From Wiedersheim's *Comparative Anatomy.*)

longitudinal folds (Fig. 22, *A*, *r*), in order to allow of distension; in an empty stomach these are well marked, and give the cavity a star-like cross-section (Fig. 43); in one full of food they are entirely obliterated and the

walls of the organ so stretched as to be almost transparent. Anteriorly the ridges thin out and disappear at the *cardia* or junction between the gullet and stomach; posteriorly they converge, as the stomach narrows, towards the *pylorus* (Fig. 22, A, *py*), or junction with the duodenum. Here the muscular coat is greatly

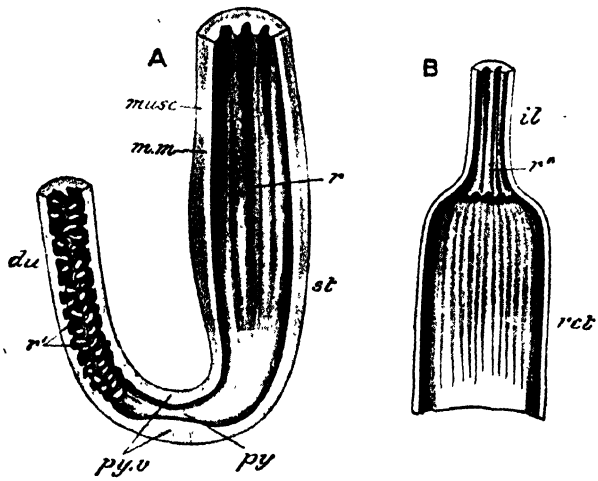


FIG. 22.—Portions of the alimentary canal of a Frog in longitudinal section. (× 3.) A, stomach and duodenum; B, part of ileum and rectum; *du.* duodenum; *il.* ileum; *m. m.* mucous membrane; *musc.* muscular layer; *py.* pylorus; *py. v.* pyloric valve; *r.* longitudinal ridges (rugæ) of stomach; *r''.* transverse ridges of duodenum; *r''.* longitudinal ridges of ileum; *rct.* rectum; *st.* stomach.

thickened in a ring-like form, forming the *pyloric valve* (*py. v*), by which the aperture of communication between the stomach and intestine is greatly narrowed, so that only small particles can pass through. In the duodenum (*du*) the mucous membrane is raised into little tuft-like elevations (*r'*); in the ileum the ridges (B, *r''*) become longitudinal again; in the rectum (*rct*) they are absent. Another ring-like muscle, or *sphincter*, is present round the vent.

When food is taken into the stomach, a fluid, the *gastric juice*, oozes from the mucous membrane. It is this fluid which reduces the slugs, insects, etc., to the pulpy condition referred to above: it is, like the bile and pancreatic fluid, a digestive juice.

Arising from the gall-bladder and passing backwards to the duodenum is an extremely delicate tube (Fig. 21, *Dc*, *Dc*^{1}), the *common bile-duct*, which opens into the duodenum. By gently squeezing the gall-bladder a drop of greenish fluid may be made to ooze out of the end of the duct (*Dc*^{2}) into the intestine; this fluid is the *bile*.

Very careful dissection shows that the common bile-duct is joined by several other tubes which are traceable into the liver and are called *hepatic ducts* (*Dh*, *Dh*^{1}). The tubes going to the gall-bladder are called *cystic ducts* (*D.cy*); by their union with the hepatic ducts the common bile-duct is formed.

The bile is manufactured in the liver, and the gall-bladder is merely a reservoir in which it is stored up, to be discharged into the intestine when required for digestion.

It requires still more accurate observation to show that the pancreas also discharges a fluid, the *pancreatic juice*, into the intestine. A very delicate branching tube, the *pancreatic duct* (*P*^{1}), joins the bile-duct, into which it discharges the pancreatic juice, the two fluids entering the intestine together. Both fluids are *digestive juices*, *i.e.*, liquids which, as we shall see, act in a particular way upon the food.

General Properties of Food.—We must now devote a little attention to the characters of the food itself and to the precise nature of the changes brought about by the digestive process.

As we have seen, the frog is a carnivorous animal.

Now, the digestible part of the substance of animals consists mainly of two classes of chemical compounds, called *proteins* and *fats*. The most familiar example of a protein is white of egg: other proteins, of varying composition, are found in muscle, in blood, and in other animal tissues. All are composed of the five chemical elements—carbon, hydrogen, oxygen, nitrogen, and sulphur—the five elements being combined in the following proportions:—

Carbon .	.	from 51·5 to 54·5	per cent.
Hydrogen	.	,, 6·9 ,, 7·3	,,
Oxygen .	.	,, 20·9 ,, 23·5	,,
Nitrogen	.	,, 15·2 ,, 17·0	,,
Sulphur .	.	,, 0·3 ,, 2·0	,,

Fats differ from proteins in containing no nitrogen or sulphur: they are formed of carbon, oxygen, and hydrogen, the number of atoms of hydrogen being typically more than twice as great as the number of atoms of oxygen.

It will be noticed that two important articles of diet are absent from the above list, namely *sugar* and *starch*—the latter the largest constituent of flour, oatmeal, rice, etc. The vegetable substances, such as corn and grass, used as food by animals, contain these bodies in varying proportions in addition to vegetable proteins, and there is no doubt that the frog must eat a small quantity of such vegetable food, if only in the stomachs of the herbivorous animals upon which it preys. Now, starch and sugar belong to a group of compounds called *carbohydrates*, composed of carbon, oxygen, and hydrogen, but differing from fats in that the number of atoms of hydrogen is always exactly double that of the atoms of oxygen, as in water. Lastly, the food always contains a certain quantity of salts or mineral

matters, vitamins and water. Vitamins are substances, minute quantities of which are essential for proper growth and for maintaining the body in a healthy condition.

Diffusible and Non-diffusible Foods.—These four classes of food materials—proteins, fats, carbohydrates, and minerals—may be arranged in two groups according to a certain physical peculiarity. If a solution of common salt is placed in a vessel with a bottom made of bladder, called a *dialyser*, which is floated in a larger vessel of pure water, it is found that, after a certain lapse of time, the water in the outer vessel has become salt. The sodium chloride has, in fact, passed by *diffusion* or *osmosis* through the bladder. The same thing will happen if a solution of sugar is placed in the inner vessel: salt and sugar are both *diffusible* substances, capable of passing through an animal membrane.

On the other hand, if the inner vessel contains white of egg, or oil, or starch well boiled in water, no diffusion takes place. Hence proteins, fats, and starch are *non-diffusible* foods, and are thus sharply distinguished from salt and sugar, which are diffusible.

The mucous membrane of the stomach and intestine are animal membranes having the same physical properties as bladder. We may consequently infer that any salt or sugar contained in the alimentary canal will diffuse through the mucous membrane and make its way, as we shall see more particularly hereafter, into the blood, thus serving to nourish the whole body. Proteins, fats, and starch, on the other hand, will be incapable of diffusing, and will, therefore, unless some change happens to them, be absolutely useless as nutriment. For, since the alimentary canal communicates with the outer world at both ends, the food, paradoxical as it may sound, is practically outside the body as long as it remains in the canal: it is only when it is absorbed into the blood or lymph that

it is actually, in the strict sense, taken into the body. Thus if proteins, fats, and starch are to be of any use to the frog, they must, in some way, be rendered capable of being absorbed, in which process the living tissues appear to exercise some degree of selection.

Action of Digestive Juices.—This is exactly what is done by the digestive juices. If white of egg or any other protein is mixed with gastric juice and kept at a suitable temperature, it is converted into a form of protein called *peptone*, which is capable of diffusing through an animal membrane. The change is effected by means of a substance called *pepsin*, contained in the gastric juice in which there is also a certain proportion of hydrochloric acid. To this the acid reaction of the gastric juice already alluded to (p. 67) is due.

By means of the gastric juice the bodies of the animals swallowed by the frog have their proteins largely converted into peptones, which, being diffusible, pass through the mucous membrane as readily as sugar or salt. Hence the great diminution in the bulk of the food during its sojourn in the stomach: a large proportion of it is absorbed there and then, and only a comparatively small quantity is passed through the pyloric valve into the intestine, where it becomes alkaline, owing to the action of the fluid which enters the duodenum through the bile-duct, and which, as we have seen (p. 67), consists of bile and pancreatic juice.

Pancreatic juice has a similar effect on proteins, the change being effected by a substance called *trypsin*, which, however, acts in an alkaline solution. It also has the property of converting starch into sugar, and of splitting up fats into fatty acids and glycerine, both of which are diffusible. The substances by which these changes are effected are called by the general name of *ferments*: pepsin and trypsin are protein-converting

ferments, and the pancreatic juice also contains a ferment which converts starch into sugar, and a fat-splitting ferment.

The exact mode of absorption of the fats is not thoroughly understood. It is usually supposed that only a small proportion of them are decomposed into fatty acids and glycerine, and that the greater part is merely broken up into particles so small that they can be taken up by the epithelial cells of the intestine. This *emulsification* of fat is effected by the combined action of the pancreatic juice and bile, the fats being reduced to the condition in which they exist in milk and in the emulsions of cod-liver oil so much used in place of the natural form of that medicine.

Thus during the passage of the food through the intestine the remainder of the proteins, the whole of the fats, and any starch which may be present, are rendered capable of being absorbed: they pass through the mucous membrane into the blood, and by the time the rectum is reached all the nutriment is extracted from the food, and there remains only a small quantity of indigestible matter which is passed out in the form of fæces.

In man and other mammals the process of digestion begins in the mouth-cavity. The food is divided into fine particles by the teeth and mixed with a secretion called saliva, which is produced in certain glands and poured into the mouth cavity by certain ducts. The saliva is, like the pancreatic juice, alkaline in reaction, and contains a ferment called *ptyalin*, which is capable of converting starch into sugar. There are no salivary glands in frogs, and the teeth also are not for the purpose of masticating the food, but for preventing the prey from slipping out of the mouth.

Most of our knowledge of the processes of digestion is derived from experiments on man and other animals. In the course of these it has been established that the mucous membrane of the small intestine also fulfils important functions in the process of digestion. When pancreatic juice is first formed, and indeed before it reaches the small

intestine, it is unable to act upon proteins. This is because trypsin is only made active and able to do its work when it meets a peculiar substance called *entero-kinase* formed by the wall of the small intestine. Besides this, certain other ferments are also formed by the tubular glands of the intestine in a small amount of the intestinal juice. One of these changes the malt-sugar formed from starchy food and another changes cane-sugar partly into grape-sugar and partly into another sugar like it, called fruit-sugar. Yet another ferment, called *erepsin*, changes peptones into still more soluble substances, called *amino-acids*. The chief function of the mucous membrane of the small intestine, however, is to absorb the digested food. This is carried out by the villi (Fig. 23). The epithelial cells covering the villi have the power of taking up, from the fluid in the cavity of the intestine, peptones, and amino-acids formed from them, sugar, salts, and water, as also finely divided fat. They have also the power of passing these substances on to the blood-vessels and lymphatics, although some of these substances become more or less altered during absorption, *e.g.*, peptones which are changed into amino-acids, sugar, most of the salts, and a great deal of water pass into the blood-capillaries in the substance of the villi, and are carried by the portal vein to the liver. On the other hand, the dissolved fat taken up by the epithelial cells passes into the lacteals and is carried away along the lymphatics, and ultimately reaches into the blood of certain veins into which the lymphatics finally open.

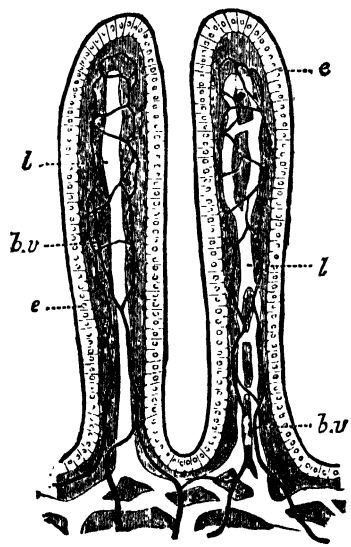


FIG. 23.—Two villi from the intestine of a mammal, highly magnified.
e. layer of epithelial cells; *b. v.* blood-vessels; *l.* lacteals. (From Foster and Shore's *Physiology*.)

Peristaltic Movements.—The passage of the food through the alimentary canal is effected by the contrac-

or spermary; *Cp. Hd.* of head; *Cp. H. L.* of hind-limb; *Cp. Kd.* of kidney; *Cp. Lng.* of lung; *Cp. Lvr.* of liver; *Cp. Pn.* of pancreas; *Cp. Sk.* of skin; *Cp. Spl.* of spleen; *cu. a.* cutaneous artery; *cu. v.* cutaneous vein; *Cu. Gl.* cutaneous gland; *d. ao.* dorsal aorta; *Ent. C.* alimentary canal; *Ep. Ent.* epithelium of alimentary canal; *Ep. Lng.* of lung; *Ep. Sk.* of skin; *Ep. Ur. T.* of urinary tubule; *glm.* glomerulus; *il. a.* iliac artery; *int. a.* artery to stomach and intestine; *int. v.* vein from stomach and intestine; *ju v.* jugular vein; *hp. a.* hepatic artery (to liver); *hp. pt. v.* hepatic portal vein; *hp v.* hepatic vein; *l. au.* left auricle; *Lng.* lung; *Lvr. C.* liver-cells; *ly. cp.* lymph capillaries; *ly. v.* lymphatic vessels; *Mlp. Cp.* Malpighian capsule; *nst.* peritoneal funnels; *p. ly. ht.* posterior lymph-heart; *Pn. C.* cells of pancreas; *Pn. D.* pancreatic duct; *pr. cv. v.* precaval vein; *pt. cv. v.* postcaval vein; *pul. a.* pulmonary artery; *pul. cu. tr.* pulmo-cutaneous trunk; *pul. v.* pulmonary vein; *r. au.* right auricle; *rn. pt. v.* renal portal vein; *scl. a.* subclavian artery; *s. c. lv.* s. sub-cutaneous lymph-sinus; *scl. v.* subclavian vein; *sp. a.* cœliaco-mesenteric artery; *spl. a.* splenic artery; *spl. v.* splenic vein; *s. v.* sinus venosus; *syst tr.* systemic trunk; *U. Bl.* urinary bladder; *Ur.* ureter; *v.* valve in vein; *vs. a.* vesical artery (to bladder); *vs. v.* vesical vein; *vl.* ventricle.

by a period of rest, during which the chamber regains its former dimensions (*diastole*).

The course of the blood through the heart will now be clear. When the sinus (Fig. 27, *s. v*) contracts, the contained blood, which, coming by the precavals and postcaval, is non-aërated, is acted upon in all directions and might therefore be forced either into the three great veins (*pr. cv. v, pt. cv. v*) or into the right auricle (*r. au*). But the veins are full of blood steadily flowing towards the heart, and any regurgitation is further prevented by their valves: the right auricle, on the other hand, has finished its contraction and is now relaxing; it is therefore empty. Thus, on the principle of least resistance, the contraction of the sinus fills the right auricle with blood from the great veins, and the sinus itself is refilled from the same source as soon as it begins to relax.

Immediately after the sinus has ceased to contract the two auricles contract together: the right, as we have seen, has just been filled from the sinus, the left (*l. au*) is full of aërated blood brought to it by the pulmonary vein (*pul. v*). The presence of the sinu-auricular valves prevents the blood in the right auricle from being forced back into the sinus: that in the left auricle is prevented from being forced back into the pulmonary veins by the steady onward flow in the latter. On the other hand

the ventricle is beginning to relax and is empty. Consequently the auriculo-ventricular valves are forced back into the ventricle (*vl*) and the blood from both auricles flows into and fills that chamber, the right half of which becomes filled with non-aërated, the left with aërated blood, the two taking an appreciable time to mingle, owing to the spongy character of the ventricular wall.

The instant it is thus filled, the contraction of the ventricle begins. As it does so the blood, getting behind the auriculo-ventricular valves, forces them together, and thus prevents any backward flow into the auricle. At the same time the semilunar valves at the entrance of the conus (*c. art*) are pushed aside and the blood flows into that chamber. Since the conus opens from the right side of the ventricle, the blood first entering it will be non-aërated; there will then follow a certain amount of mixed blood; and finally, as the ventricle reaches the limit of its contraction, the aërated blood from its left side will be forced into the conus (compare Fig. 26).

Two alternative courses are now open to the blood: it can pass either directly from the conus into the pulmo-cutaneous trunk (*pul. cu. tr*), or make its way into the bulbus aortæ (*b. ao*). As a matter of fact the non-aërated blood first entering the conus is diverted almost exclusively into the cavum pulmo-cutaneum, and passes into the pulmo-cutaneous trunks, owing to the circumstance that there is little resistance in the limited blood-system of the lungs, while that in the systemic and carotid trunks is very great. Hence the blood first received into the conus from the ventricle, which, as we have seen, is non-aërated, goes immediately to the lungs and skin to be aërated.

As these are filled, their resistance increases, and the mixed and later the aërated blood flows through the

cavum aorticum into the bulbus aortæ. The conus also by its contraction brings the free ventral edge of the longitudinal valve into contact with its ventral wall, and the blood passing on the right of the longitudinal valve flaps it over the pulmo-cutaneous aperture and prevents any further blood entering it. In the bulbus, again, the question of pressure comes in. It is easier for the blood to make its way into the wide systemic trunks (*syst. tr*) uniting immediately into the long dorsal aorta (*d. ao*) than into the comparatively narrow carotid trunks (*car. tr*), obstructed by the carotid labyrinths. Hence, the non-aërated blood having been mostly driven into the pulmo-cutaneous trunk, the mixed blood, from the middle part of the ventricle, goes into the systemic trunk, and thence to the various arteries supplying the limbs (*scl. a*, *il. a*) and the viscera (*sp. a*, etc.). Finally, when the pressure is sufficiently raised in the systemic trunks, the remaining blood, which, coming from the left side of the heart, is aërated, is pumped into the carotid trunks (*car. tr*), and thence to the head.

Thus, owing to the arrangement of the valves, and to the varying pressures in different parts of the vascular system, the non-aërated blood returned from the various parts of the body to the heart is mostly sent to the lungs and skin to be aërated. Mixed blood is sent to the trunk, limbs, and viscera, while for the head with its contained brain—the directing and controlling organ of the whole animal—a special supply of pure, aërated blood is reserved.

We see then that the course of the circulation may be proved, as a simple matter of induction, from the structure of the heart and its valves, the direct observation of its beat, and the manner in which the flow from cut vessels takes place. It was by observation and experiments of this kind that the circulation of the

blood in the higher animals was demonstrated by William Harvey in the seventeenth century. But the final and most conclusive proof of the circulation—from directly observing the flow—became possible only after the invention of the microscope. This instrument, by furnishing a sufficiently high magnifying power, allows us to see for ourselves the actual movement of the blood in an animal or organ of sufficient transparency; and at the same time clears up the question, previously insolvable, of how the blood, having reached a given part or organ by the arteries, finds its way into the veins to begin its return journey.

The Circulation in the Frog's Web.—There are two parts in the frog transparent enough to allow of the blood-flow being seen in them—the web of the foot and the mesentery. Of these the web is the most convenient, and can be examined under the microscope without any injury to the animal.

The Capillaries.—If you have the makings of a naturalist, you will acknowledge the sight to be one of the most wonderful you ever saw. In the thickness of the web is an irregular network of minute blood-vessels, called *capillaries* (Fig. 28), and through them the blood is seen to flow with great rapidity, its course being made especially evident by the minute particles or *corpuscles* it contains, the structure of which we shall study later on (Fig. 30). You will also notice much larger vessels, the smallest arteries and veins. The arteries (*a*) are distinguished by the fact that the blood in them flows in the direction from the leg towards the margin of the web, while in the veins (*v*) it takes the opposite direction. You must remember, however, that under the microscope everything is reversed; right appears left and left right, and a current actually flowing towards the observer appears to go in the opposite direction.

By careful examination you will see that both arteries and veins are in connection, by minute branches, with the capillary network, and will be able to trace the

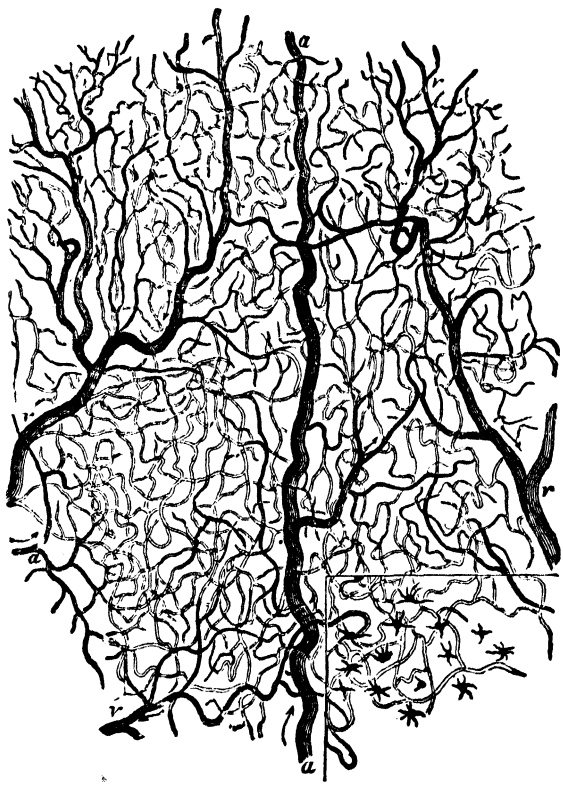


FIG. 28.—Blood-vessels of the web of a Frog's foot seen under a low magnifying power. *a*. small arteries; *v*. small veins. The minute tubes joining the arteries to the veins are the capillaries. The arrows show the direction of the circulation. In the small portion marked off, the pigment cells of the skin, which occur throughout the web, are also represented. (From Huxley's *Physiology*.)

blood from an artery, through the capillaries, into a vein.

The same thing can be seen in other transparent organs; and by injecting the vascular system with a

fluid injection-mass, such as gelatine suitably coloured, it can be proved that all parts of the body are permeated with a capillary network into which the blood is passed by the arteries, and from which it is received into the veins.

Thus by means of the microscope we are able to take the final step in demonstrating the circulation. The fact that the blood can flow in one direction only is proved by the disposition of the valves of the heart and of the veins, but the passage of the blood from the smallest arteries to the smallest vein by a connecting system of minute tubes or capillaries can be proved only by the employment of considerable magnifying powers. We see that the vascular system of the frog is a closed system of vessels: the blood is everywhere confined within definite tubes through which it flows in a definite direction, never escaping, as in some of the lower animals, into large irregular spaces among the tissues.

The Lymphatic System.—Included in the vascular system are certain cavities and vessels containing lymph, and together constituting the *lymphatic system*. We have already noticed the subcutaneous lymph-sinuses (p. 16, and Fig. 27, *s.c.ly.s*) and the sub-vertebral lymph-sinus (p. 25, Fig. 6, *s.v.ly.s*). There are also found in nearly all parts of the body delicate, thin-walled, branching tubes, the *lymphatic vessels* (Fig. 27, *ly. v*). Unlike the blood-vessels, the lymphatics are all of one kind, there being no distinction into anything of the nature of arteries and veins. They arise in *lymph-capillaries* (*ly. cp*), which are, as it were, interwoven with the blood-capillaries, but have no connection with them. By the lymph-capillaries the fluid which has exuded from the blood in its passage through the tissues is taken up and passed into the lymphatic vessels or sinuses, and these

in their turn finally communicate with certain transparent muscular organs called *lymph-hearts*. Of these there are two pairs. The anterior lymph-hearts (*a. ly. ht*) lie, one on either side, beneath the supra-scapula and just behind the transverse process of the third vertebra: the posterior pair (*p. ly. ht*) are situated one on each side of the posterior end of the urostyle. These organs pulsate regularly, like miniature hearts, and pump the lymph into the veins, the anterior pair communicating with the subclavian, the posterior with the renal portal vein.

The lymphatics of the alimentary canal have an important function to perform in that they absorb the fatty portions of the food (p. 72). The fluid they contain has a milky appearance, owing to the presence of minute suspended fat-globules, and for this reason they receive the name of *lacteals*.

The cœlome is really a great lymph-sinus (Fig. 27, *cœl*). It communicates with the veins of the kidneys through certain microscopic apertures called *nephrostomes* (*nst*).

The **spleen** (p. 21, and Fig. 4, *spl*) has important relations with the blood- and lymph-vessels, and probably acts as a blood-filter, removing old and worn-out red corpuscles and foreign micro-organisms from the blood. The white corpuscles of the blood divide and multiply in numbers in the spleen.

Ductless Glands.—There are found in the different parts of the body small glands which do not possess any ducts and pour their secretions directly into the blood-stream. The secretions are minute in quantity, but are carried to distant parts of the body, influencing their working in various ways. There is a pair of **thyroid** glands. Each is a small rounded or lobulated body, situated ventral to and in close connection with the

external jugular vein. The thyroids secret a substance rich in iodine. Nothing is known of the functions of the thyroid in the frog, but in higher vertebrates, the removal of the gland leads to serious disturbances and proves fatal. The **thymus** is another such gland. It is a small, oval, reddish-looking body, situated close behind the tympanic membrane, near the angle of the jaw. The **adrenals** are a pair of yellow streak-like bodies lying one on the ventral surface of each kidney.

The internal secretions or *hormones* of these ductless glands and various other organs perform important co-ordinating functions in the body.

CHAPTER VII

THE FROG (*continued*) : THE MICROSCOPICAL EXAMINATION OF THE SIMPLE TISSUES

BEFORE carrying our inquiries any further into the anatomy and physiology of the frog it will be necessary to devote some consideration to its microscopic structure or *histology*, since there are many matters in connection with the various organs which can be further elucidated only by the examination of the minute structure of the organs as revealed by the microscope.

Let us, first of all, examine a drop of the frog's **blood** under the low power of the microscope. It will at once be seen that the blood is not a simple homogeneous fluid, but that it contains a large number of minute solid bodies floating in it. These are called by the general name of *blood-corpuscles* : the fluid part of the blood in which they float is called the *plasma*. At first, owing to currents in the fluid, the corpuscles will be found to move to and fro, but after a time they come to rest. Under the high power you will notice that the corpuscles are of two kinds. The greater number of them are regularly oval in form (Fig. 29, C), and of a yellow colour. If the drop of blood is thick enough in one part for the corpuscles to lie over one another, so that the light passes through two or three layers of them to reach the

eye, they will appear red: they are hence called *red corpuscles*. Frequently they are seen turned on edge (D), and their appearance in this position shows them to be flat, oval discs with a swelling in the centre. They are about $\frac{1}{40}$ of a millimetre (about $\frac{1}{1000}$ inch) in long diameter.

Among the red corpuscles are found, in much smaller numbers, bodies not more than half the long diameter of the red corpuscles in size, quite colourless, distinctly granular—so as to have the appearance of ground glass—and with a slightly irregular outline (Fig. 29, A).



FIG. 29.—Blood-corpuscles of the Frog. (× 525.)
A, colourless corpuscle; B, the same in process of division; C, red corpuscle, surface view; D, the same, edge view, *nu*. nucleus. (From Parker's *Biology*.)

These are the *colourless corpuscles* or *leucocytes*. They are not flat, like the red corpuscles, but have the form of irregular lumps.

The plasma, like the leucocytes, is quite colourless, so that the colour of the blood is seen to be due entirely to the large number of red corpuscles it contains.

If the drop of blood has been prepared and examined under the high power with sufficient rapidity, a remarkable phenomenon can be made out with regard to the colourless corpuscles. This can be most easily demonstrated by making a series of outline sketches of the same leucocyte at intervals of a minute or two. You will then notice that the sketches all differ from one another: in one there will perhaps be a little projection going off to the right; in the next this will have disappeared and a similar projection will have appeared on the left, and so

on. As a matter of fact, as long as the blood is quite fresh, the leucocytes are in constant movement, sending out and withdrawing little processes of their substance called *pseudopods* or "false feet," by means of which they can crawl slowly along like independent living things. These very peculiar and characteristic movements resemble those of a microscopic animalcule known as Amœba, and are therefore called *amœboid movements*. Occasionally a leucocyte may be seen to elongate itself and divide into two (Fig. 29, B): this is a case of what is called *simple fission*. The red corpuscles neither move nor divide. Both kinds of corpuscles are unit masses of living substance known as *protoplasm*.

If a drop of some dye or staining fluid be run in under the cover-glass, the corpuscles will be seen to become rather faint in outline, transparent, and lightly tinted; but the most obvious effect is that in the middle of each is seen a rounded or oval granular body (*nu*) deeply stained by the dye, so as to make a very well-defined coloured area in the interior of the corpuscle. This body is called the *nucleus*: it is present both in the red and the colourless corpuscles.

By adding to a fresh drop of blood, in the same manner, a drop of weak acetic acid, the nucleus again becomes distinct, while the body of the corpuscle is rendered very transparent and almost invisible: indeed it finally disappears altogether. It is thus proved that the corpuscles, both red and colourless, consist of a substance which is known as *cytoplasm*, but slightly affected by dyes, and soluble in weak acids; and enclosed in this is a nucleus, stained by dyes, and unaffected by weak acids. Both nucleus and cytoplasm consist mainly of proteins (p. 68), together with water and a small proportion of mineral matters.

When distilled water is added to a drop of blood on

the slide, the corpuscles are seen to swell up and become partly dissolved: the red colouring-matter of the red corpuscles is dissolved out, the plasma becoming tinged with yellow. Thus the colouring-matter is evidently a distinct substance from the protoplasm, and is called *hæmoglobin*. It is characterised, among other things, by a strong attraction for oxygen: in combination with that gas it assumes a bright scarlet colour; when deprived of oxygen, it becomes purple. This affinity for oxygen accounts for the change undergone by the blood when exposed to the air, as described on p. 82.

Coagulated blood, as seen under the microscope, is characterised by the plasma being traversed by extremely delicate threads, forming a sort of network in which the corpuscles are entangled. These threads are formed of a substance called *fibrin*, which is separated from the plasma during coagulation, the remaining or fluid portion of the plasma constituting the *serum*. We may therefore express the coagulation of the blood in a diagrammatic form as follows:—

Fresh Blood.		*Coagulated Blood.*
Plasma . .	{ Serum, Fibrin }	Clot.
Corpuscles . . .		

Having observed the microscopic characters of a drop of blood, let us examine once more the circulation in the web, this time under the high power (Fig. 32). The red corpuscles (*F*) can be seen streaming through the vessels, those in the capillaries in single file, those in the small arteries and veins, two or more abreast: as they pass through narrow capillaries or round corners, they become bent or squeezed (*G*, *H*). The leucocytes (*I*) travel more slowly and often stick to the sides of the vessels.

Squamous or Pavement Epithelium.—By collecting the surface castings of a frog's skin and examining a very small piece in a drop of water, after staining them, the superficial layer of the skin will be found to be made up of flattened, roughly hexagonal plates (Fig. 30 and Fig. 32, C, D) set closely together, like the tiles of a mosaic pavement. Each plate has a nucleus, and, from its flattened form, is distinguished as a *squamous* or scale-like epithelial cell.

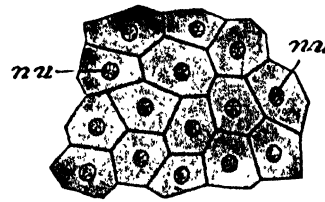


FIG. 30.—Squamous epithelial cells from the Frog's skin. (× 300.)
nu. nuclei.

Columnar Epithelium.—By carefully scraping a small piece of the inner surface of the mucous membrane of the intestine and teasing it into the smallest possible particles, it will be found that the process has detached numerous, minute, conical bodies, about $\frac{1}{30}$ mm. ($\frac{1}{750}$ in.) in length, polygonal in transverse section, and having one end flat and the other more pointed (Fig. 31). These bodies are called *columnar epithelial cells*: in the natural position they lie closely cemented to one another, like the blocks of a wood-pavement, their flattened ends facing the cavity of the intestine, while their narrower ends abut against the submucosa (p. 64). The epithelial cells together form an *epithelium* or *epithelial layer* of the mucous membrane directly bounding the cavity of the alimentary canal.

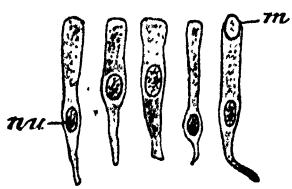


FIG. 31.—Columnar epithelial cells from the Frog's intestine. (× 500)
m. droplet of mucus exuding from cell; *nu.* nucleus.

Each cell consists of cytoplasm containing a rounded, granular nucleus (*nu*), which is made very conspicuous

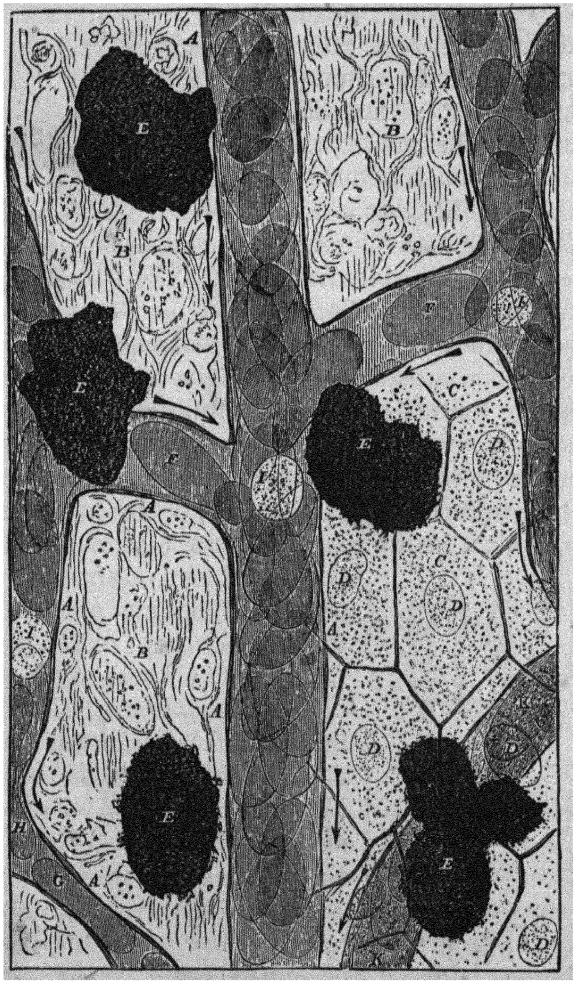


FIG. 32.—The circulation in the Frog's web, under a high power. *A*, wall of capillaries; *B*, tissue of the web in which the capillaries lie; *C*, epidermis-cells; *D*, their nuclei; *E*, pigment-cells; *F*, red corpuscles; *G*, *H*, red corpuscles being squeezed through a narrow capillary; *K*, capillary seen through the epidermis; *I*, colourless corpuscles. (From Huxley's *Physiology*.)

by staining, and in which are one or more small bodies or *nucleoli*. Certain of these cells have a space towards their free ends containing slime or *mucus*, and thus have the form of little cups or goblets: they are known as *goblet-cells* (*see* right-hand cell in Fig. 31).



Fig. 33.—Ciliated epithelial cells from the mucous membrane of the frog's mouth. (×500) (From Parker's *Biology*, after Howes.)

Ciliated Epithelium.—By the same method the mucous membrane of the mouth is also seen to be lined by an epithelium, but the cells comprising it (Fig. 33) are broader in proportion to their length, and each is produced on its free surface into a number of delicate, transparent threads of protoplasm called *cilia*, which in the living condition are in constant movement, lashing backwards and forwards like minute whip-lashes, or, more accurately, like the blades of grass in a field when acted upon by a strong wind. If you happen to get under the microscope a good-sized bit of mucous membrane with the cells in position, you will see that the cilia produce a strong current by which small particles are swept along, while detached cells swim about, like little independent animals, by the action of their own cilia. These *ciliated epithelial cells*, like the ordinary *columnar* cells of the intestine, are made of protoplasm, and each consists of cytoplasm containing a nucleus with one or two nucleoli clearly brought into view by staining.

The action of the cilia can be demonstrated, on a large scale, by placing a freshly-killed frog on its back, turning back or cutting away the lower jaw, and placing a very small cube of cork on the roof of the mouth near to the projection due to the eyes. The cork will be slowly swept back towards the throat.

Meaning of the word "Cell."—We see thus that

the body of the frog is partly made up of distinct elements, which, under a considerable diversity of forms, exhibit the same essential characters. Each is a unit mass of living *protoplasm* and is designated a *cell*. Each cell consists of a clear or more or less granular *cytoplasm* containing in its interior a rounded body, the *nucleus*, the latter specially distinguished by the affinity of parts of its substance for colouring-matters.

Unstriped Muscle.—Examination of a teased preparation of the muscular coat of the intestine, stomach, or urinary bladder will show that it is composed of delicate fibres (Fig. 34) tapering at both ends, and each with a nucleus in the middle. These are called *smooth* or *unstriped muscular fibres*: they are obviously cells which have undergone a great elongation in length.

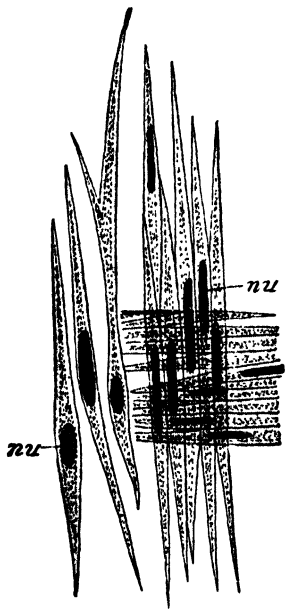


FIG. 34.—Unstriped muscular fibres from the Frog's intestine. (× 500.)
To the right are shown fibres from the longitudinal and circular layers (see Chap. VIII) crossing one another; to the left isolated fibres. (After Howes.)

During the peristaltic movements of the intestine (p. 72) each fibre alternately contracts and relaxes, becoming shorter and thicker during the former process, like the large muscles of the body (p. 58). The movements in this case, however, are not under the control of the will, and unstriped muscular tissue is therefore often spoken of as *involuntary muscle*.

Contractility of Protoplasm.—We have now studied three different kinds of movement in cells:—*muscular move-*

ment in the unstriped muscle-fibres, *ciliary movement* in the ciliated epithelial cells, and *amœboid movement* in the colourless blood-corpuscles. Muscular movement is due to the fibre undergoing a sudden shortening in a particular direction and a consequent approximation of its two ends. Ciliary movement is due to the alternate bending and straightening of the cilia; and the bending of a cilium in a particular direction is caused by the protoplasm of which it is composed shortening or contracting on the side towards which it bends. Amœboid movement is the protrusion and withdrawal of irregular processes of the cell: this results from the protoplasm undergoing a contraction or squeezing in a given direction, as a consequence of which one part of its substance is drawn in and another pushed out. Hence all three kinds of movement are movements of *contraction*; and *contractility*, or the power of contraction, may be considered as a general property of protoplasm.

Striped Muscle.—If a small piece of any of the body-muscles is carefully teased out with the grain, *i.e.*, in the direction of the length of the fibres, so as to break away the connective-tissue binding them together, the fibres, which are much larger than those of smooth muscle, will readily separate from one another, and they will be seen to be long and cylindrical. Under the microscope each fibre shows a delicate transverse striation (Fig. 35), being made up of alternate bright (*b*) and dim (*d*) bands—or more accurately discs, the fibre being cylindrical—set at right angles to its length. Hence the ordinary body-muscles or *voluntary muscles* are composed of *striped muscular fibres*.[1] In addition to the transverse striation a fainter longitudinal striation is more or less distinctly visible.

[1] The muscles of the heart, although not under the control of the will, are transversely striated; but their structure differs from that of ordinary striped voluntary muscle.

Each fibre is covered by a delicate membrane (*s*), called *sarcolemma*, beneath which nuclei (*n*) occur at intervals. It will be seen that striped muscle, unlike the tissues previously considered, does not appear to be composed of cells, although the occurrence of nuclei seems to indicate their presence. In the embryo,

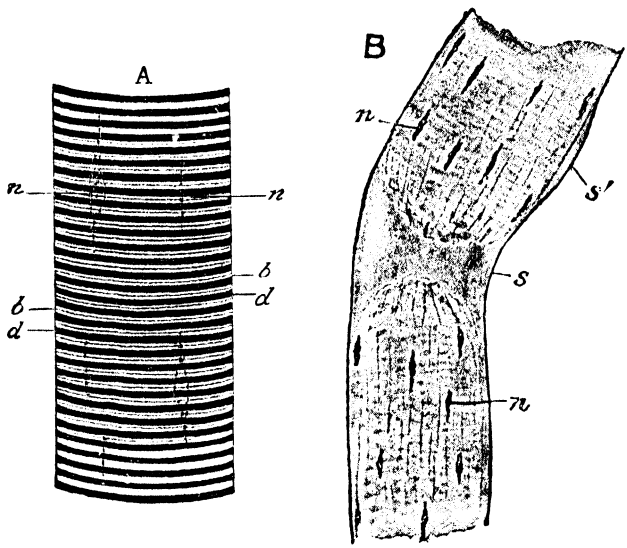


FIG. 35.—A, part of a fresh muscular fibre of a Frog. B, the same after treatment with distilled water followed by methyl-green. (× about 150.)
b. bright bands; *d*. dim bands; *n*. nuclei; *s*, *s'*. sarcolemma, rendered visible as a minute blister (*s'*) by absorption of water and by the rupture of the muscle-fibre at *s*. (A, from Huxley's *Physiology*.)

however, the muscle is formed of ordinary nucleated cells, which, as growth goes on, increase in length while their nuclei multiply by fission, each enormously elongated cell thus containing a considerable number.

Connective-tissue.—We will next examine a piece of the delicate web of connective-tissue which binds the muscles together.

Under the high power, connective-tissue is seen to be

composed of a sort of irregular network of delicate bundles of wavy fibres called *white connective-tissue fibres* (Fig. 36, *w*), which cross one another in all directions. Amongst them are found single fibres sweeping across the field in bold curves and called *elastic fibres* (*e*) : it is

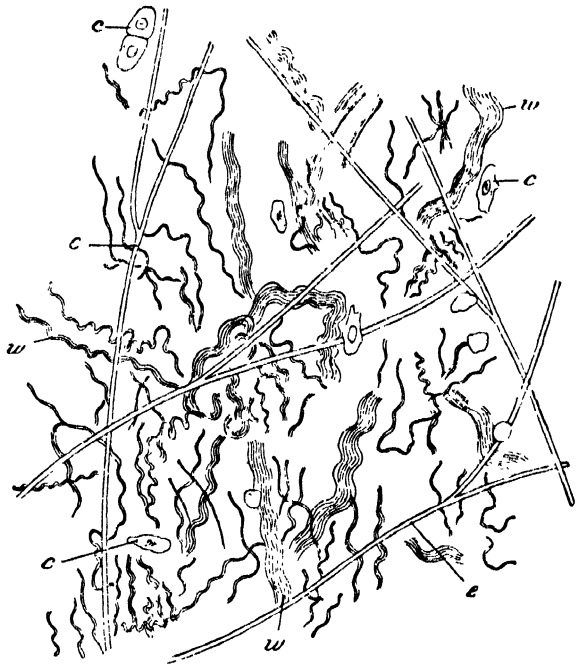


FIG. 36.—Connective-tissue from between muscles of the Frog's legs. (× about 200.) *c*. cells; *e*. elastic fibres; *w*. white fibres :—all of which are imbedded in a delicate matrix not specially indicated in the figure.

owing to their elasticity that the tissue cannot be spread out when wet. Scattered among the fibres are numerous nucleated cells (*c*) of very varied and often irregular form : these are the *connective-tissue cells*. The fibres, as well as the cells, are imbedded in a soft, homogeneous, *ground-substance* or *matrix*.

Thus connective-tissue consists partly of cells, but between these, and forming the main substance of the tissue, is a matrix or *intercellular substance*, enclosing fibres. In the embryo the tissue consists of closely-packed cells, but, as development proceeds, these separate from one another, and the ground-substance is formed between them.

Cartilage.—The ordinary clear or *hyaline* variety of this tissue is conveniently studied by examining a piece of the thin edge of the omo- or xiphi-sternum, or by

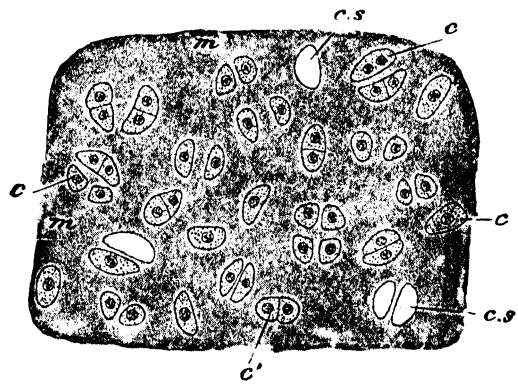


FIG. 37.—Section of cartilage, from the head of the Frog's femur. (× 200.)
c. cells; *c'.* cells undergoing fission; *c. s.* empty cell-space; *m.* matrix.

taking a thin section with a razor of the head of the humerus or femur.

Cartilage consists of a tough, elastic, transparent, homogeneous matrix (Fig. 37, *m*) containing numerous cavities or *cell-spaces* (*c. s.*), in each of which is a nucleated cell (*c*). The cell-spaces, or *lacunæ*, are in many cases arranged in groups of two or four, sometimes close together, sometimes with a narrow bit of matrix or intercellular substance between them. This is due to the fact that cartilage grows by the cells undergoing

binary fission, so that two cells are formed in one cell-space: the two then gradually separate from one another and intercellular substance is formed between them. In the embryo, this tissue consists entirely of closely-packed cells which gradually separate and form a structureless matrix which is firm and elastic, and which in some parts (pp. 44 and 46) may become calcified.

Bone.—As we have already seen (p. 51) bone is formed of two constituents, a basis of animal matter, in which

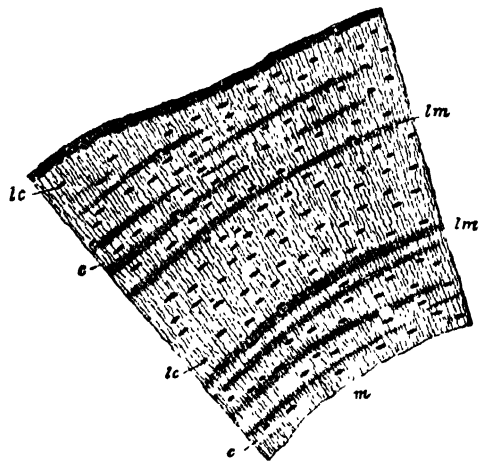


FIG. 38.—Transverse section of dry femur of Frog. (× about 125. *c.* canaliculi; *lc.* lacunæ; *lm.* lamellæ; *m.* marrow-cavity.

mineral matter—calcium phosphate and carbonate—is deposited. In microscopic examination we may therefore investigate either the mineral matter by examining dried bone, or the animal matter by examining decalcified bone.

A thin section of a dried long bone, such as the femur, shows that it is formed of very numerous thin layers or *lamellæ* (Fig. 38, *lm*), surrounding and concentric with the marrow-cavity. The lamellæ contain numerous

cavities, the *lacunæ* (*lc*), with delicate, branching tubes, the *canaliculi* (*c*), radiating from them in all directions. Both lacunæ and canaliculi commonly appear black, owing to their being filled either with air or with bone-dust produced in grinding the section.

In a section of decalcified bone (Fig. 39) the marrow is seen to be surrounded by lamellæ of a delicate fibrous substance, arranged in two layers, an outer (*b*) having the periosteum (*p*) closely investing it, and an inner (*b'*) in contact with the marrow. In the fibrous substance of

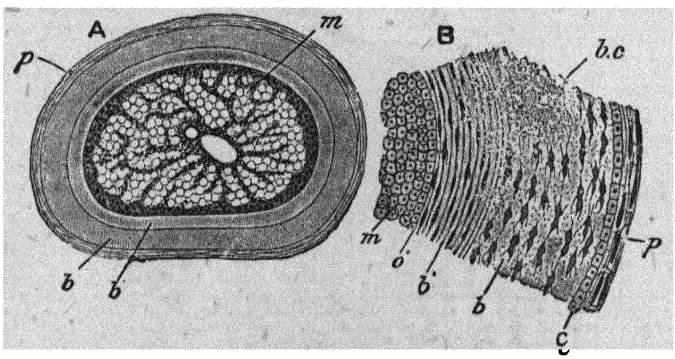


FIG. 39.—A, transverse section of decalcified Frog's femur under a low power. (× 30.) B, portion of the same under a high power. (× about 150.) *b*. outer, and *b'*, inner layer of bone; *b. c*. bone-cells; *m*. marrow; *o*. layer of osteoblasts in connection with periosteum; *o'*. layer of osteoblasts in connection with marrow; *p*. periosteum. (After Howes.)

the lamellæ are cell-spaces, corresponding with the lacunæ of the dried bone, and each containing a *bone-cell* (*b. c*), which sends off delicate branched processes of its protoplasm into the canaliculi. Thus the bone, like connective-tissue and cartilage, consists of cells with an intercellular substance: the latter is in the form of concentric layers and is impregnated with lime-salts.

The long bones of the frog grow in two directions. Between the periosteum and the bone is a layer of cells, the *osteoblasts* (*o*), by which new lamellæ of bone are

formed on the outside of those already existing: thus the outer layer of bone (*b*) grows from within outwards. Between the marrow and the inner surface of the bone is another layer of osteoblasts (*o'*) which forms new lamellæ on the inner side of the existing bone, so that the inner layer (*b'*) grows from without inwards.

A transverse section of human bone or that of another Mammal (Fig. 40) shows a different sort of arrangement of the lamellæ. Near the surface, *i.e.*, just underneath the periosteum, the lamellæ are arranged parallel to the surface, but in the interior the lamellæ are arranged in groups of concentric circles called *Haversian systems*, each system consisting of a number of lamellæ arranged concentrically round a central cavity called the *Haversian canal*, through which passes, in the living state, a small artery for supplying nourishment to the system. Between the adjacent Haversian systems there are *interstitial lamellæ*. Such an arrangement has been found in the frog also in

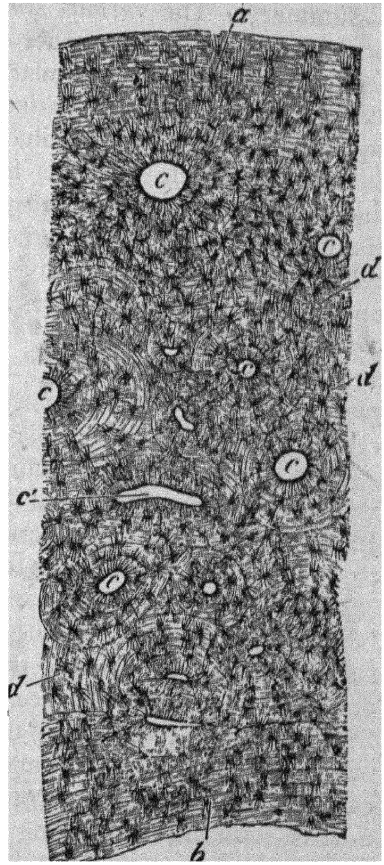


FIG. 40.—Transverse section of dry Human Femur, under a low power.
a. lamellæ of bone parallel or concentric with the external surface; *b*. lamellæ concentric with the surface next the marrow; *c*. Haversian canals cut across, with lamellæ arranged round them; *c'*. a canal just dividing into two; *d*. interstitial lamellæ between the Haversian systems. (From Foster and Shore's *Physiology*.)

the region of the bony partition in such compound bones as the radio-ulna or tibio-fibula (Fig. 15, B, D, *p*.).

Summary.—The various *simple tissues* studied in the present chapter consist either entirely of cells, or of cells separated by an intercellular substance. Formed entirely of cells are the various kinds of epithelium—squamous, columnar, and ciliated, and unstriped muscle. In striped muscle the cells have elongated into fibres and their nuclei have multiplied. Of the supporting tissues, consisting characteristically of cells with intercellular substance, connective-tissue has the matrix soft and homogeneous, with fibres imbedded in it; in hyaline cartilage it is structureless and tough, though elastic; and in bone laminated and calcified. In the blood, the plasma may be looked upon as a kind of liquid intercellular substance.

Cells, wherever they occur, have the same essential structure, being formed of cytoplasm and a nucleus. In nearly all cases they increase by binary fission, first the nucleus and then the cytoplasm dividing into two.

The distribution of the various tissues throughout the body is worth noting. Epithelium always bounds a free surface—*e.g.*, that covering the outer surface of the body or lining the inner surface of the alimentary canal. Striped muscle forms the " flesh," unstriped muscle the outer layer of the alimentary canal (p. 64). Bone and cartilage form the framework of the body, while connective-tissue is the packing between the other tissues.

CHAPTER VIII

THE FROG (*continued*) : THE MICROSCOPIC EXAMINATION OF THE COMPOUND TISSUES—GLANDS—SECRETION AND ABSORPTION

WITH the exception of the tissues of the nervous system, which will be described in Chapter X, we have now studied the principal simple tissues by the method of *dissociation, i.e.*, by separating their constituent parts. We have now to consider the way in which these tissues are combined in the various organs, and for this purpose must adopt some method of examination by which they are seen in their natural relations.

The method adopted for this purpose is that of *section-cutting*. You know how, by cutting sections, in various directions, of a bit of twig, the arrangement and natural relations of its various parts—wood, bark, and pith—can be ascertained. The same thing applies to the organs of the frog and other animals, but, owing to their soft and non-resistant texture, it is impossible to cut them into sections thin enough for microscopic examination without special preparation. The methods employed are by no means easy for the beginner, especially without verbal instruction and the resources of a biological laboratory; and in the absence of facilities for section cutting, prepared slides may be examined.

The Skin.—A vertical section of the skin, *i.e.*, one taken at right angles to its surface, will be seen to have the following structure.

The skin is clearly divisible into two layers, an outer,

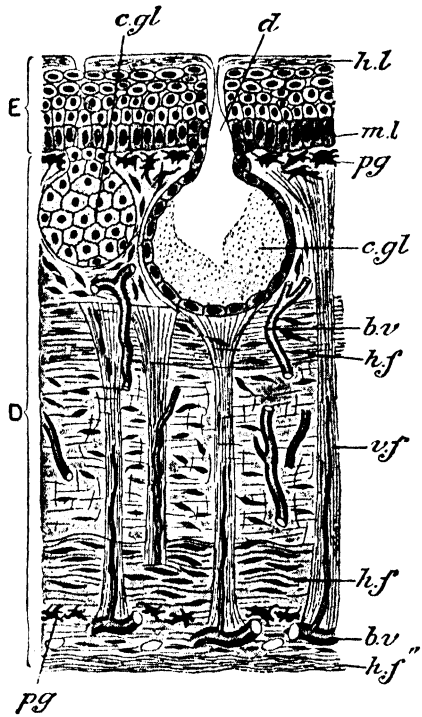


FIG. 41.—Vertical section of the Frog's skin, highly magnified. (× about 200.) D. dermis formed of *hf*, *hf'*, *hf''*. horizontal, and *v. f.* vertical fibres of connective-tissue, and containing *b. v.* blood-vessels, and *pg.* pigment cells. E. epidermis with *m. l.* active or Malpighian layer, and *h. l.* horny layer of epithelial cells; *c. gl.* cutaneous gland in section; *c. gl'.* in surface view; *d.* duct. (After Howes.)

the *epidermis* (Fig. 41, E), and an inner, the *dermis* (D). The epidermis is built up of several layers of epithelial cells. These differ greatly in form according to their position, those in the lower or internal layer (*m. l*) being columnar, while those in the upper or external layer (*h. l*)

are squamous, and have their protoplasm converted into horny matter so as to furnish a comparatively hard and insensitive covering to the body.

The horny layer is cast off periodically in shreds, and to make up for this, the cells of the inner, or deeper layer multiply by binary fission, the increase in their number necessarily resulting in a pushing upwards of the superjacent layers. There is thus a constant travelling of cells from the inner to the outer surface of the epidermis: as they pass towards the outer surface they become more and more flattened, and at last squamous and horny. The whole process takes place in such a way that the multiplication of the columnar cells in the lower layer is just sufficient to make good the loss of the squamous cells in the superficial layer.

The dermis (D) is formed of connective-tissue, the fibres of which are mostly horizontal (*h. f, h. f', h. f''*), or parallel to the surface of the skin, but at intervals are found bands of vertical fibres (*v. f*). The dermis also differs from the epidermis in having an abundant blood-supply (*b. v*), capillaries ramifying through it in all directions. It also contains nerves, the ultimate fibres of which have been traced into the deeper layers of the epidermis. Imbedded in the dermis, especially in its external portion, are irregular cells (*pg*), the protoplasm of which contains pigment, often appearing intensely black. It is to these *pigment-cells* that the coloured patches in the frog's skin are due (Figs. 28 and 31).

In this as well as in the other sections described in the present chapter the structure of the nuclei of the various cells can be more easily made out than in the fresh preparations you have already examined. Each nucleus will be seen to be enclosed by a definite *nuclear membrane*, and to contain in its interior a number of

minute bodies, which take up the stain more deeply than the rest of the nucleus. One or more of these bodies may correspond to the nucleoli already seen (p. 103), but many of them are of a different nature and can often be seen to form a network: the material of which these are composed is known as *chromatin*, and is surrounded by a semi-fluid substance forming the groundwork of the nucleus.

Cutaneous Glands—Secretion.—In the superficial part of the dermis are seen numerous rounded spaces (Fig. 41, *c. gl, c. gl'*), each of which can be proved, by taking sections in various directions, to be a nearly globular cavity, from which a narrow canal (*d*), like the neck of a flask, passes through the epidermis to open on the external surface. Both the body and the neck of the flask are lined with epithelium, the cells lining the body being nearly cubical, those of the neck squamous.

These structures are called *cutaneous glands*: they perform the function of manufacturing the slimy fluid which, as we have seen, is constantly exuding on the surface of the skin. The epithelial cells of the gland have the power of forming minute droplets of the fluid out of the materials supplied to them by the blood: the droplets escape from the cells and accumulate in the interior of the gland, whence the fluid is finally discharged by the duct.

The cells lining the duct are continuous on the one hand with those of the gland, and on the other with those of the epidermis. The whole gland with its duct is to be looked upon as a depression of the skin, lined by pushed-in epidermal cells.

Epithelial cells having the power of manufacturing and discharging a specific substance are called *gland-cells*, and the process of manufacture is known as *secretion*.

nerves, to the muscles. It may therefore be inferred that the controlling apparatus, by which the functions of the body are regulated, is lodged in either the brain or the spinal cord, or in both.

Divisions of the Nervous System.—The nervous system is divisible into (1) the *central nervous system*, consisting of the brain and spinal cord (Figs. 7 and 8), and (2) the *peripheral nervous system*, consisting of the nerves which pass from the central nervous system to the various parts of the body. The nerves are divisible into (1), *cerebral nerves* (Fig. 55), arising from the brain, (2), *spinal nerves* (Fig. 53), arising from the spinal cord, and (3), *sympathetic nerves* (Fig. 53).

The Spinal Cord.—In form the spinal cord (Figs. 7 and 8, *sp. cd*) is irregularly cylindrical. It is continuous in front with the brain, and tapers off posteriorly into a fine thread-like portion, the *filum terminale* (*f. t*), while opposite the fore-limbs, and again just anteriorly to the filum terminale, it presents an enlargement: these are known respectively as the *brachial* and *sciatic* swellings. Along its dorsal surface runs a delicate longitudinal line, the *dorsal fissure* (Fig. 50, *d. f*), and a distinct groove, the *ventral fissure* (*v. f*), extends along its lower surface.

The cord is covered with a delicate pigmented membrane known as the *pia mater* (*p. m*), and the neural canal in which it lies is lined with a stout, tough membrane, the *dura mater* (Fig. 54, *d. m*). Between the two is a space filled with a lymphatic *arachnoid fluid*, which, like the pericardial fluid, preserves the contained organ from shocks.

Examination of a transverse section of the cord under a lower power will show that the dorsal fissure is an extremely narrow vertical wall formed by an extension inwards of the pia mater. The ventral fissure is a distinct cleft. Thus the two fissures divide the cord

into paired half-cylinders, right and left, joined in the middle by a narrow bridge. This bridge is traversed from end to end by a very narrow longitudinal canal, the *central canal* (*c. c*), lined by epithelium, so that the cord is not a solid cylinder, but a tube with an extremely narrow cavity and excessively thick walls.

The section also shows that the cord is not homogeneous, but is composed of two different substances.

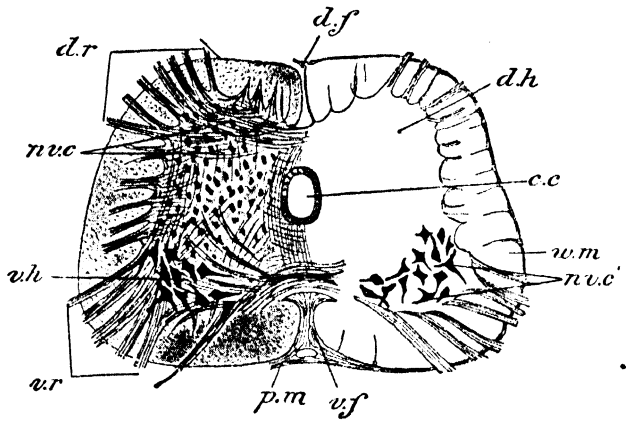


FIG. 50.—Transverse section of spinal cord of Frog. (× 35.)
c.c. central canal; *d. f.* dorsal fissure; *d. h.* dorsal horn of grey matter; *d. r.* fibres of dorsal root of spinal nerve; *nv. c.* nerve-cells of dorsal horn; *nv. c'* nerve-cells of ventral horn; *p. m.* pia mater; *v. f.* ventral fissure; *v. h.* ventral horn of grey matter; *v. r.* fibres of ventral root of spinal nerve; *w. m.* white matter. (After Howes.)

Its outer part is pure white and shining in the fresh cord, and is hence called the *white matter* (*w. m*). Its internal substance has a pinkish colour when fresh, and is called the *grey matter*. The grey matter has a squarish outline in transverse section. It surrounds the central canal, and is continued upwards and downwards, forming what are called the *dorsal* (*d. h*) and *ventral* (*v. h*) *horns* of the grey matter.

and pass out from the neural canal through the intervertebral foramina (p. 33).

There are altogether nine or ten pairs of spinal nerves in the adult frog (Fig. 53, I—IX), each of which on leaving the neural canal divides into a smaller dorsal and a larger ventral branch (Figs. 54 and 55). The first pair leaves the cord through the intervertebral foramina between the first and second vertebræ. Each passes at first directly outwards, its large ventral branch, known as the *hypoglossal*, turning forwards, and going to the muscles of the tongue (Fig. 55, 1 *Sp.*).

The second pair (Fig. 53, *II*) is very large; it emerges between the second and third vertebræ, and each is soon joined by the small third nerve (*III*), which emerges between the third and fourth vertebræ, as well as by a small branch or two from the first, thus forming a simple network or *plexus*—the *brachial plexus* (*br. pl*), from which pass off nerves to the fore-limb supplying both skin and muscles.

The fourth, fifth, and sixth nerves take a very similar course. The fourth (*IV*) emerges between the fourth and fifth vertebræ, the fifth (*V*) between the fifth and sixth, and the sixth (*VI*) between the sixth and seventh. They all pass obliquely backwards, and supply the walls of the body, being distributed to both skin and muscles.

The seventh, eighth and ninth nerves supply the muscles and skin of the hind-limbs. The seventh (*VII*) leaves the neural canal between the seventh and eighth vertebræ, the eighth (*VIII*) between the eighth and ninth, and the ninth (*IX*) between the ninth vertebra and the urostyle. They all pass almost directly backwards, and are united with one another by oblique cross branches so as to form the *sciatic plexus* (*sci. pl*), from which are given off, amongst others, two nerves

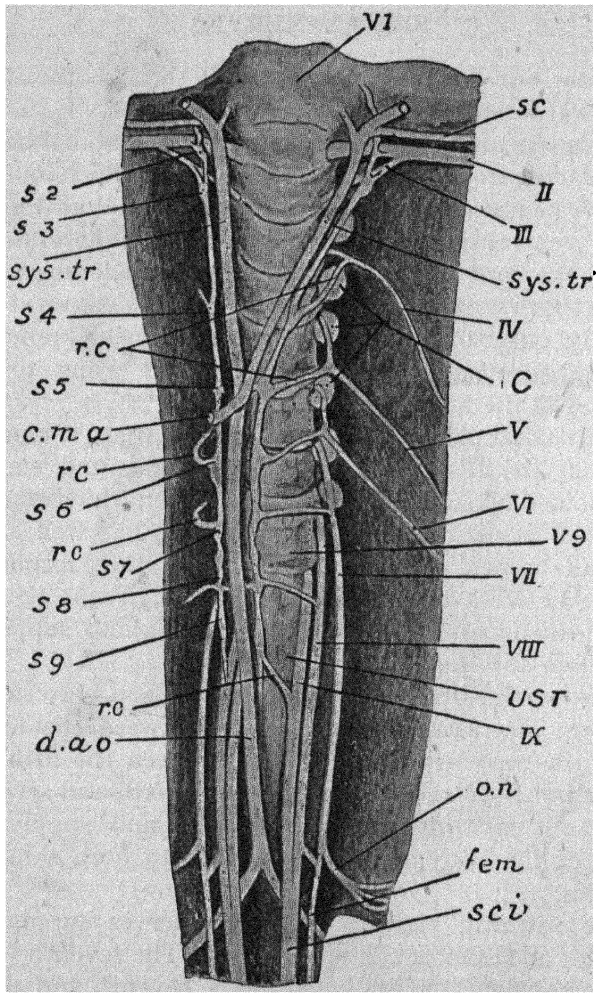


FIG. 53.—The ventral branches of the spinal nerves and the sympathetic of the Frog (*R. trigina*), ventral view. The dorsal aorta has been pulled over a little to the right, and the spinal nerves and the sympathetic are fully shown on the left side only. (B.L.B.)

II—IX, spinal nerves; *C.* calcareous bodies which surround the spinal ganglia; *c. m. a.* cœliaco-mesenteric artery; *d. ao.* dorsal aorta; *fem.* femoral nerve; *il. a.* iliac artery; *o. n.* obturator nerve; *r. c.* rami communicantes or communicating branches between the sympathetic and spinal nerves; *sc.* subclavian artery; *sci.* sciatic nerve; *S2*—*S9*, ganglia on the sympathetic cord; *sys. tr.* systemic trunk; *ust.* arostyle; V^1—V^9, centra of vertebræ.

to the leg, the largest of which, the *sciatic nerve* (*sci*), being that already mentioned in the chapter on the muscular system (p. 59).

The tenth is a very small nerve and in the common Indian frog is very frequently absent altogether, or present on one side only. It emerges when present through a small aperture in the side of the urostyle (p. 34).

It will be noticed that while the large ventral branch of the first spinal nerve—the hypoglossal—supplies muscles only, and is therefore a *motor nerve*, all the others go to both muscles and skin, and are therefore both *motor* and *sensory*, or *mixed nerves*. They all branch out in a complex manner, and are traceable to the remotest parts of the body.

The Sympathetic Nerves.—On either side of the dorsal aorta is a very delicate nerve, having at intervals little swellings called *ganglia*, each of which is connected with a spinal nerve by a communicating branch (Figs. 53 and 55, *s2—s9*, *sy*, *rc*). In front of the point where the dorsal aorta (*D. Ao*) is formed by the union of the two systemic trunks (*Ao*), these two *sympathetic nerves*, as they are called, are continued forward, one on either side of the vertebral column, towards the head, when they enter the skull and become connected with certain of the cerebral nerves.

Each sympathetic nerve has altogether nine or ten ganglia, each connected with one of the spinal nerves, and from the ganglia branches are given off which supply the heart and blood-vessels, the stomach, intestine, liver, kidneys, reproductive organs, and urinary bladder.

Origin of the Spinal Nerves.—The mode of origin of the nerves from the spinal cord is peculiar and characteristic. Traced towards the cord, each nerve is found, on

reaching the intervertebral foramen from which it emerges, to divide into two—a *dorsal root* which springs from the dorsal, and a *ventral root* which arises from the ventral region of the cord (Fig. 54, *d. r*, *v. r*). The dorsal root is distinguished from the ventral by being dilated into a *ganglion* (*gn*). In Fig. 53 these ganglia lie hidden within certain calcareous bodies (*C*) in this region. If the centra of all the vertebræ are removed, it is seen that the spinal cord is a good deal shorter in length than the neural canal which it occupies, and consequently the roots of the seventh, eighth, and

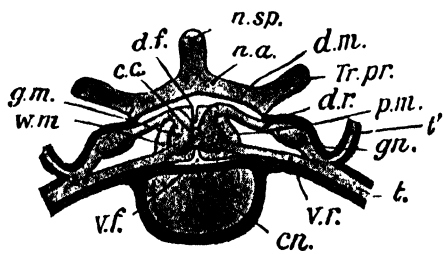


FIG. 54.—Transverse section through the vertebral column and spinal cord of the Frog, to show the mode of origin of the spinal nerves. (× 6.)
c. c. central canal; *cn.* centrum; *d. f.* dorsal fissure; *d. m.* dura mater; *d. r.* dorsal root; *g. m.* grey matter; *gn.* ganglion of dorsal root; *n. a.* neural arch; *n. sp.* neural spine; *p. m.* pia mater; *t.* nerve trunk (ventral branch), *t'.* dorsal branch; *Tr. pr.* transverse process; *v. f.* ventral fissure; *v. r.* ventral root; *w. m.* white matter. (After Howes.)

ninth nerves have to run very obliquely, in order to pass out of their respective intervertebral foramina. The filum terminale, together with roots of these nerves, presents an appearance not unlike a horse's tail, and the name *cauda equina* is consequently given to them.

Cerebral Nerves.—There are ten pairs of cerebral nerves, some of which are purely sensory, some purely motor, some mixed.

The *first* or *olfactory nerve* (Fig. 51, *I*) arises from the olfactory lobe, and passes through a hole in the transverse partition of the girdle-bone. Each is distributed

to the mucous membrane of the nasal sac or organ of smell of the same side, and is purely sensory.

The *second* or *optic* (*II*) is a large nerve which springs from the ventral surface of the diencephalon. At their origin the right and left optic nerves have their fibres intermingled, forming a structure something like a St. Andrew's Cross and called the *optic chiasma* (*opt. ch*), the other limbs of the cross passing upwards and backwards to the optic lobes. The optic nerve makes its exit from the brain-case through the optic foramen, and is distributed to the retina, a delicate membrane which lines the eye-ball, and is, as we shall see, the actual organ of sight. This nerve also is purely sensory.

The *third* or *oculomotor* (*III*) is a small nerve arising from the crus cerebrum beneath the optic lobe close to the median line. It passes through a small hole in the side of the skull behind the optic foramen, and supplies four out of the six muscles by which the eye-ball is moved, and is purely motor.

The *fourth* or *pathetic* (*IV*) is a very small nerve leaving the dorsal surface of the brain between the optic lobes and the cerebellum, and making its exit from the skull above the third nerve. It is also purely motor, supplying one of the muscles of the eye—the superior oblique.

The *fifth* or *trigeminal* (Figs. 51 and 55, *V*) is a large nerve arising from the side of the medulla oblongata. Its root dilates to form a ganglion, the *Gasserian ganglion*, and leaves the skull by the large aperture noticed in the pro-otic bone. It owes its name to the fact that it soon divides into three main branches; one, the *ophthalmic* (Fig. 55, V^1), going to the skin of the snout; another, the *maxillary* (V^2), to the upper lip and lower eyelid; and the third, or *mandibular* (V^3), to the muscles and skin of the lower jaw. The trigeminal is a mixed nerve.

The *sixth* or *abducent* (Fig. 51, *VI*) is a very small motor nerve arising from the ventral aspect of the medulla, close to the median line, and supplying one of the muscles of the eye-ball called the posterior rectus.

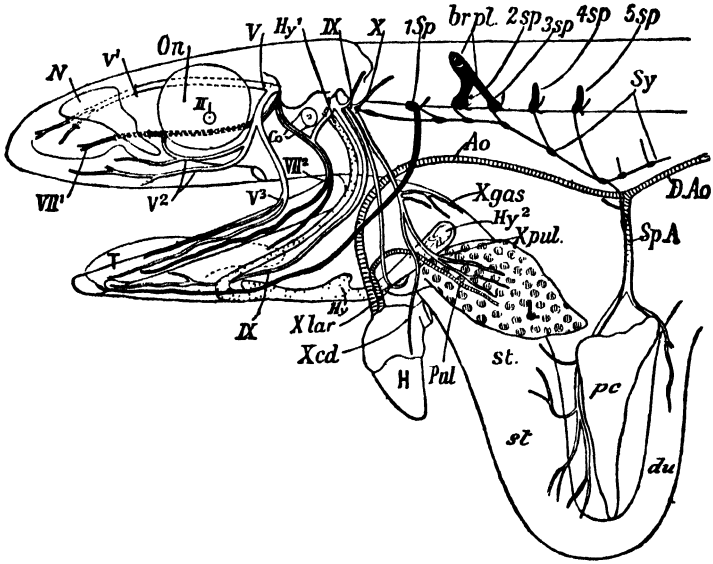


FIG. 55.—Dissection of the head and anterior part of the body of the Frog from the left side, to show the distribution of the fifth, seventh, ninth, and tenth cerebral nerves, as well as of the hypoglossal and part of the sympathetic. (× 1½.)
Ao. systemic arch; *br. pl.* brachial plexus; *co.* columella; *D. ao.* dorsal aorta; *du.* duodenum; *H.* heart; *Hy.* body of hyoid; Hy^1. anterior, and Hy^2. posterior horns of hyoid; *L.* lung; *N.* olfactory sac; *On.* orbit; *pc.* pancreas; *Pul.* pulmonary artery; *Sp. A.* cœliaco-mesenteric artery; *st.* stomach; *Sy.* sympathetic; *II.* cut end of optic nerve; V^1 ophthalmic, V^2. maxillary, and V^3. mandibular branch of trigeminal (*V*); VII^1 palatine, and VII^2 hyomandibular branch of facial; *IX.* glossopharyngeal; *X.* vagus; *Xcd.* cardiac, *Xgas.* gastric, *Xlar.* laryngeal, and *Xpul.* pulmonary branch of vagus; *1 Sp.* first spinal nerve (hypoglossal); *2 sp.*—*5 sp.* second to fifth spinal nerves. (After Howes, slightly modified.)

The *seventh* or *facial* nerve (Figs. 51 and 55, *VII*) arises just behind the fifth and soon joins the Gasserian ganglion. Both it and the sixth leave the skull by the same aperture as the fifth. It divides into two branches, one of which, the *palatine* (Fig. 55, VII^1), supplies the

mucous membrane of the roof of the mouth, and the other, or *hyomandibular* (*VII*²), sends branches to the skin and muscles of the lower jaw and to the muscles of the hyoid. It is a mixed nerve.

The *eighth* or *auditory* nerve (Fig. 51, *VIII*) arises from the medulla just behind the seventh, passes through an aperture in the inner wall of the auditory capsule, and is distributed to the auditory organ or membranous labyrinth (see Figs. 12 and 62). It is the nerve of hearing, and is purely sensory.

The *ninth* or *glossopharyngeal* (Figs. 51 and 55, *IX*) arises behind the auditory nerve. It sends a branch to join the facial, and supplies the mucous membrane of the tongue and pharynx as well as certain small muscles connected with the hyoid. It is also a mixed nerve.

The *tenth* or *vagus* (Figs. 51 and 55, *X*) is a large nerve arising in common with the ninth, and dilating, shortly after leaving the skull, into a *vagus ganglion*. It supplies the larynx (*Xlar*), the heart (*Xcd*), the lungs (*Xpul*), and the stomach (*Xgas*), and is therefore often known as the *pneumogastric*. It has thus an extraordinarily wide distribution (vagus = wandering), being in fact the only cerebral nerve which supplies parts beyond the head. It is a mixed nerve and contains many motor fibres, but its branches—some of which have to do with the regulation of the heart's contraction and with respiration—are better described as *efferent* and *afferent* than as motor and sensory: the meaning of these terms will be explained later on. The ninth and tenth nerves leave the skull close together through the aperture noticed in the exoccipital bone.

The sympathetic nerve (*Sy*) extends forwards from its junction with the first spinal nerve, joins the vagus, and finally ends anteriorly in the Gasserian ganglion.

Microscopic Structure of Nervous Tissue.—Nervous tissue consists of cells provided with processes for the purpose of receiving and conducting impulses. Every such cell or *neuron* (Fig. 57) consists of (1) a cell-body, containing the nucleus, (2) a long process known as the *neuraxon* (*nx*), along which impressions from the exterior are brought to the cell or impulses are carried away from it, and (3) other processes, usually short, numerous, and branching, known as *dendrons* or *dendrites*, which convey the impression to other neurons or along which the impulses reach the cell. The axon is often of very great length and forms the basis of a *nerve-fibre*. Examination of a piece of nerve under the microscope shows it to be composed, like striped muscle, of cylindrical fibres, bound together by connective-tissue. The latter is much more abundant than in muscle, and in particular forms a thick sheath round the nerve which must be torn off before the *nerve-fibres* are reached.

Each fibre (Figs. 56 and 57) is a cylindrical cord in which three parts can be distinguished. Running along the axis of the fibre is a delicate protoplasmic strand, the *neuraxon* or *axis-fibre* (*nx*). Around this is a sheath formed of a fatty substance and known as the *medullary sheath* (*m. s*);[1] and, finally, investing the whole fibre is a delicate, structureless membrane, the *neurolemma* (*ne*). At intervals the medullary sheath is absent, and a *node* (*n. R.*) is produced, where the fibre consists simply of the neuraxon covered by the neurolemma. Underlying the neurolemma are found at intervals *nuclei* (*ns*), which, however, do not belong to it, but have a small amount of granular cytoplasm of their own.

[1] The medullary sheath may be absent in certain nerve-fibres (*e.g.*, in the sympathetic and olfactory nerves). Such fibres are described as non-medullated nerve-fibres.

In the ganglia are found, not only nerve-fibres, but neurons, which are usually termed *nerve-cells* (Fig. 57): these are of a relatively large size, each with a large nucleus and nucleolus. In the spinal ganglia (B) the cell-body is produced into two processes, which come off from the cell by a common stalk. One of these processes (the *neuraxon*) becomes the axis of a peripheral nerve-fibre; the other (*dendron*) is also a protoplasmic process which passes into the spinal cord and sends off branches, each branch finally ending in a complicated branch-work or arborisation, which is interlaced, but not actually continuous, with a similar arborisation arising from a neuron in the spinal cord or brain (Fig. 58).

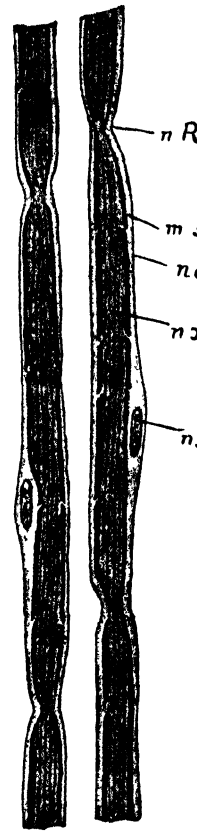


FIG. 56.—Medullated nerve-fibres, stained with osmic acid and highly magnified.
ne. neurolemma; *ns* nuclei of the sheath; *m. s.* medullary sheath; *nx.* neuraxon; *n. R.* node of Ranvier.

The white matter of the brain and spinal cord consists of nerve-fibres, those in the cord having a longitudinal direction; the grey matter contains numerous "multipolar" nerve-cells, each giving off numerous dendrons and one axon, which is continuous with a neuraxon (Figs. 50 and 57, A); they are enclosed in a tissue formed partly of the axis-fibres of nerves which enter the grey from the white matter, losing their medullary sheath as they do so, and partly of a delicate supporting tissue called *neuroglia*, in which the other elements are imbedded.

Functions of the Spinal Cord: Reflex Action.—In the fourth chapter you learned that a muscle may be

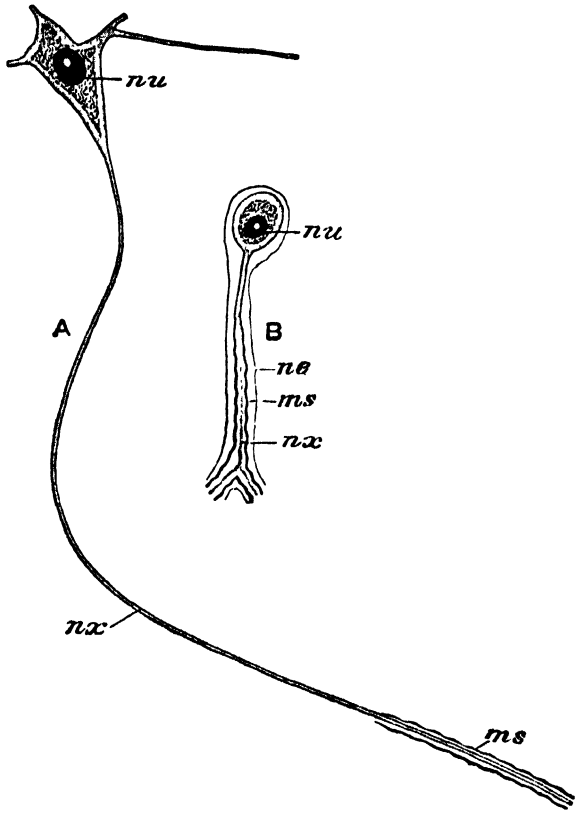


FIG. 57.—A, nerve-cell from the grey matter of the spinal cord of a Frog, and the nerve-fibre arising from it (neurolemma not shown); B, nerve-cell from the ganglion of a dorsal root. (× about 200.)
ne. neurolemma; *nu.* nucleus; *nx.* neuraxon; *ms.* medullary sheath. (After Howes.)

made to contract by a stimulus applied either to the muscle itself or to its nerve. You are now in a position to pursue a little further the subject of the control of various parts of the body by the nervous system.

The spinal cord is the great conductor of nervous impulses to and from the brain, but under certain circumstances nervous impulses originate in the spinal cord in response to outside stimuli. To illustrate this a frog is pithed, *i.e.*, the medulla oblongata is severed and the brain destroyed: there can be thus no question either of sensation or of voluntary action on the frog's part. It is then hung up by a hook or string, so that the legs are allowed to hang freely. If one of the toes is pinched with the forceps, the foot will be drawn up as if to avoid the pinch; or, if some very weak acid be applied to a toe, the foot will again be withdrawn, being raised with the regularity of a machine every time it is touched with the acid. Again, if acid be applied to various parts of the body, the foot of the same side will immediately try to rub off the irritating substance; or if that foot be held down, the other will come into play.

Movements of this kind are called *reflex actions*: the stimulus applied to the skin is transmitted by sensory nerve-fibres to the spinal cord, where it is, as it were, reflected in another form, and passed along motor fibres to one or more muscles, causing them to contract (p. 57).

It must not be concluded from the above that reflex actions are only performed by a frog in which the brain has been destroyed. A large number of the movements we ourselves are constantly performing are brought about by reflex action. If a strong light is flashed across the eyes or a finger brought near one of them, the eyelids are instantly closed; if the hand comes in contact with a hot body it is at once withdrawn; if a sudden sound is heard, we start: these are instances of reflex actions, the movements being produced by the agency of the central nervous system without the action of the will, and as the result of sensory impulses reaching it. In some of these instances the reflex action is carried out, not by the spinal cord alone, but by the intervention of the brain also, and, in the first illustration, exclusively by the latter. Many movements

of ordinary life which are originally started by the will, and are therefore voluntary, become later as reflex. Thus we can go on walking without thinking about it, every step being properly taken, the necessary muscles contracting because they receive impulses from the central nervous system, regulated in accordance with sensory impulses received by the central nervous system from the eye or the ear, or due to the contact of the feet themselves with the ground.

As already stated, the spinal nerve-trunks are mixed, *i.e.*, contain both sensory and motor fibres, which, how-

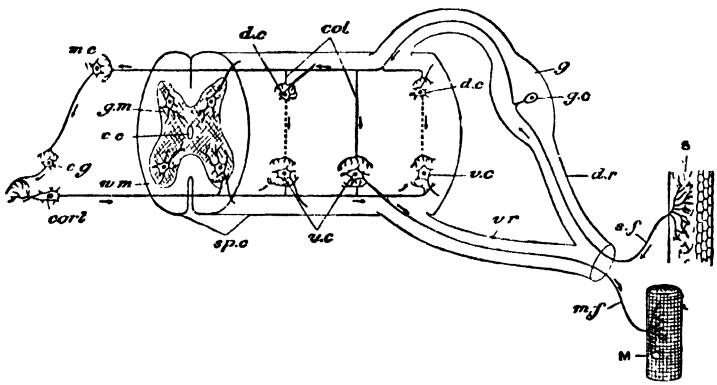


FIG. 58.—Diagram illustrating the paths taken by the nervous impulses. *c. c.* central canal; *col.* collaterals; *cort.* cell in rind or cortex of the cerebral hemisphere; *c. g.* smaller cerebral cell; *d. c.* cells in dorsal horn of grey matter; *d. r.* dorsal root; *g.* ganglion of dorsal root; *g. c.* cell in ganglion of dorsal root; *g. m.* grey matter; M. muscle; *m. c.* cell in medulla oblongata; *m. f.* motor fibre; S. skin.; *s. f.* sensory fibre; *sp. c.* spinal cord; *v. c.* cells in ventral horn of grey matter; *v. r.* ventral root; *w. m.* white matter. The arrows indicate the direction of the impulses.

ever, cannot be distinguished from one another structurally. It has been found by numerous experiments that as the nerve approaches the spinal cord these two sets of fibres separate from one another, the sensory fibres passing into the cord by the dorsal root, the motor by the ventral root. As a consequence of this, if the dorsal root be cut and its proximal or central end—

cerebral hemispheres. If the hemispheres and optic lobes are removed so as to leave nothing but the bulb and cerebellum, the frog no longer lies in any position in which it may be placed, exhibiting no movements beyond the beating of the heart, as is the case when the whole brain is removed. It sits up in the ordinary attitude, breathes, swallows food placed in the mouth—while making no attempt to feed itself, turns over and sits up if placed on its back, and swims if placed in water. If left alone, however, it remains in the sitting posture till it dies. Hence the bulb and cerebellum are evidently concerned with the *co-ordination* of muscular movements, but have no power of originating impulses. If the optic lobes as well as the medulla oblongata and cerebellum are left, the animal is affected by light, is able to perform complex balancing movements, and will even croak when stroked in a particular way. There is still, however, no voluntary action; without the application of stimuli, the animal sits motionless until it dies.

To sum up in the language of the illustration with which this chapter was begun, comparing the frog with an engine of human construction :—the grey matter of the brain may be compared with the engineer; much of the work of the engine may go on without him, certain levers, valves, etc., acting automatically; but it is only by his controlling intelligence that the whole mechanism is adapted to the circumstances of the moment.

Control over Viscera, Blood-vessels and Glands.—So far we have considered the nervous system only in its relations to the skin or general surface of the body and to the muscles or organs of movement. The other parts of the body are also under nervous control.

It has been mentioned that the heart continues to beat in a frog when the brain has been removed: not

only so, but it pulsates with perfect regularity when removed from the body. This is due to the fact that the muscles of the heart, like the cilia of ciliated epithelium, have the power of contracting rhythmically quite independently of the nervous system. It is, however, under the control of the central nervous system. We have seen that it is supplied by a branch of the vagus; when this is stimulated, the heart stops in the dilated state and begins to beat again only after a certain interval. A feeble stimulus to the vagus will not actually stop the heart, but will diminish the rate and the strength of its contractions and consequently the amount of blood propelled through the body. The vagus is accompanied by a branch of the sympathetic which has an exactly opposite effect, *i.e.*, stimulation of it accelerates the heart's action. In this way, the general blood-supply of the body is regulated by the central nervous system.

The blood-supply of the various parts and organs is regulated by the *vaso-motor nerves*. These are traceable through the sympathetic into the spinal cord by the ventral roots: distally they send branches to the muscular coat of the arteries. Under ordinary circumstances a constant succession of gentle stimuli pass along these from a group of nerve-cells in the medulla oblongata, and, as the result, the arteries are ordinarily in a state of slight contraction. Under various circumstances these stimuli may be diminished for any given artery and at the same time stimuli pass down another kind of vaso-motor fibres: the artery will then dilate and the blood-supply of the organ to which it is distributed will be temporarily increased. For instance, the presence of food in the stomach acts, through the central nervous system, upon the cœliac branch of the cœliaco-mesenteric artery, causing a dilatation of its capillaries and promot-

ing an increased secretion of gastric juice. The secretion of other glands is regulated in a similar way. In some cases, however, it has been proved that the nerves of a gland do not act simply by producing dilatation of the capillaries, but have a direct effect upon the gland-cells, causing an increased secretion.

You will thus note that there are nerve-fibres carrying impulses to the central nervous system which have nothing to do with sensation, and fibres carrying impulses from the central nervous system which have nothing to do with motion, but result in increased secretion or in stoppage of motion. It is therefore best to use the term *afferent* (which includes sensory) for a nerve carrying an impulse to the brain or spinal cord, and *efferent* (including motor) for one carrying an impulse from the brain or spinal cord.

Functions of the Nervous System : Summary.—To sum up, we have seen that the spinal cord is not only concerned with the conduction of impulses to and from the brain, but is also able to originate well-organised movements in response to an external stimulus. The medulla oblongata originates and regulates the nervous impulses which cause respiratory movements. It also regulates the rate and strength of the beat of the heart (through the vagus and the cardiac branch of the sympathetic), and also, by impulses sent through the vaso-motor nerves, the size of the small arteries. It governs the act of swallowing and the secretion of various digestive and other juices in the body. Along with the cerebellum it brings about the co-ordination of muscular movements. It is thus responsible for all the routine affairs of the body. In addition, it acts as a conductor of all impulses from the cerebral hemispheres and other parts of the brain to the spinal cord and from the spinal cord to the cerebral hemispheres. The cerebral hemi-

spheres are the seat of sensations, intelligence, will and emotions. The various cerebral and spinal nerves are concerned with the carrying of afferent (sensory) and efferent (motor) impulses of varied character to or from the brain or the spinal cord. The sympathetic nerves chiefly carry impulses which govern the muscular tissue of the viscera and the muscular coat of the small arteries of the various parts of the body. Thus the stomach may be affected through the sympathetic in severe mental distress, which may thus lead to disturbances of digestion; some emotions, such as shame, may lead to blushing, caused by the dilatation of the small blood-vessels of the skin of the face, and others, such as fright, to pallor, caused by constriction of the same vessels. It must be remembered, however, that the sympathetic nerves receive the impulses which they carry, from the central nervous system, and that these impulses do not arise in the sympathetic cord itself.

PART II

CHAPTER I

PHYLUM PROTOZOA

AMŒBA: CLASS SARCODINA

FROM your study of the frog you will have learnt some of the more important facts with regard to the morphology and physiology of a comparatively highly organized animal, and will have overcome a number of preliminary difficulties in acquiring a knowledge of zoological terminology and technique. You will now, therefore, be in a better position to undertake a systematic and comparative examination of a number of other animals—some much less complicated, some more complicated, than the frog—working upwards from the simple to the complex forms. In doing so, you must continually bear in mind the deductions in connection with the theory of evolution referred to in the previous chapter.

Amœba.—Let us begin with a very instructive animalcule usually known as *Amœba proteus*.[1] Amœbæ are often found in the slime at the bottom of pools of stagnant water, adhering to weeds and other submerged objects.

[1] Certain authorities think that the correct zoological name of the species is *Chaos diffluens*. Another giant amœba which has been recently re-discovered in America is *Chaos chaos* originally described by Linnæus in 1767. It is visible to the naked eye and attains in locomotion the remarkable length of 2 to 5 millimetres.

They are mostly invisible to the naked eye, rarely exceeding $\frac{1}{4}$ of a millimetre ($\frac{1}{100}$ inch) in diameter, so

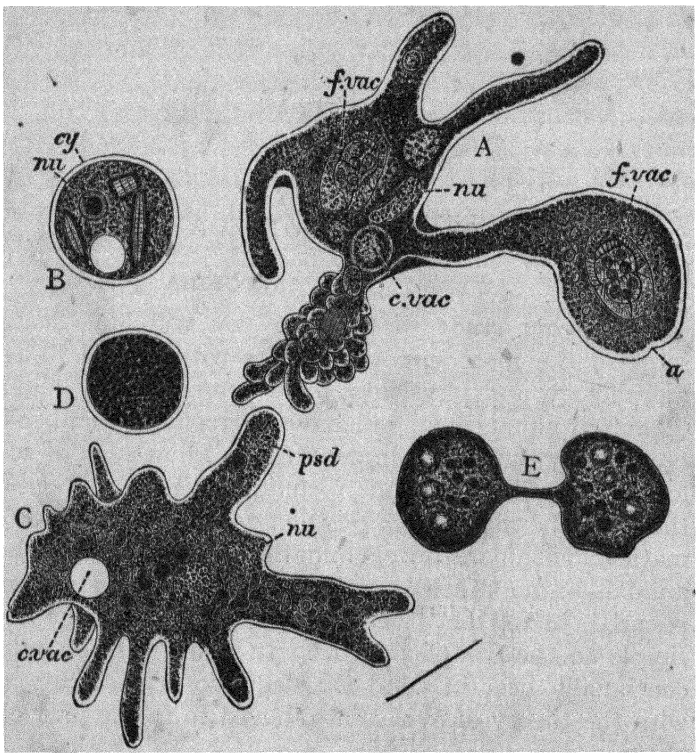


FIG. 72.—A, *Amœba proteus*, a living specimen, showing large irregular pseudopodia, nucleus (*nu*), contractile vacuole (*c. vac*), and two food-vacuoles (*f. vac*), each containing a small ciliate (see Chapter III) which has been ingested as food. The letter *a* to the right of the figure indicates the place where two pseudopods have united to enclose the food vacuole. The contractile vacuole in this figure is supposed to be seen through a layer of granular protoplasm, whereas in B and C it is seen in optical section, and therefore appears clear. (× about 300.)

B, an encysted Amœba, showing the cyst (*cy*), nucleus (*nu*), clear contractile vacuole, and three microscopic plants (diatoms) ingested as food.

C, *Amœba proteus*, a living specimen, showing several large pseudopods (*psd*), single nucleus (*nu*) and contractile vacuole (*c. vac*), and numerous food-particles embedded in the granular endoplasm. (× 330.)

D, nucleus of the same after staining, showing a ground substance containing deeply-stained granules of chromatin, and surrounded by a distinct membrane. (× 1010.)

E, *Amœba proteus*, in the act of multiplying by binary fission. (× 500.)

(From Parker's *Biology*: C and D after Gruber; A and E after Leidy; B after Howes.)

that it is necessary to examine them entirely by the aid of the microscope. Though they can be seen and recognized with the low power, the high power is necessary for the accurate examination of their structure.

Anatomy.—Examined under the high power (Fig. 72), the Amœba appears like a little shapeless blob of jelly, nearly or quite colourless, and closely resembling a colourless blood-corpuscle or leucocyte of one of the higher animals (p. 98). The central part of it, or *endoplasm*, is granular and semi-transparent—something like ground-glass—while surrounding this inner mass is a border of perfectly transparent and colourless substance —the *ectoplasm*.

One very noticeable thing about the Amœba is that, like the leucocyte, it is never of quite the same form for long together, owing to the protrusion of *pseudopodia* (*psd*), by means of which it creeps along slowly. The occurrence of *amœboid movements* is alone sufficient to show that it is an *organism*, or living thing, and no mere mass of dead matter. Moreover, it consists of *cytoplasm*, and a *nucleus*[1] (A—D, *nu*) containing *chromatin* which is rendered more apparent by staining. The Amœba is therefore a *cell* (compare pp. 99 and 101).

A very important difference is thus at once seen between the Amœba and the frog: the Amœba is *unicellular—i.e.*, it consists of a single cell—while the frog is, as we have seen, a *multicellular* animal, built up of innumerable cells which are differentiated to form various tissues and organs.

Besides the nucleus, there is another structure frequently visible in the living Amœba and not present in

[1] Instead of containing one nucleus *Chaos chaos* possesses a large number, as many as one thousand or more in some individuals. It also possesses three or four to about a dozen contractile vacuoles.

the leucocyte. This is a clear, rounded space in the protoplasm (*c. vac*), which periodically disappears with a sudden contraction and then slowly reappears, its movements reminding one of the beating of a minute colourless heart. It is called the *contractile vacuole*, and consists of a cavity containing a watery fluid.

Physiology.—We must now study the physiology of our animalcule. First of all, as we have already seen, it is *contractile*: although it has no muscles, it can move about from place to place. Its movements, like the voluntary movements of the frog (pp. 8, 156), may occur without the application of any external stimulus, *i.e.*, they are *spontaneous* or *automatic*; or they may be induced by external stimuli—by a sudden shock or by coming in contact with an object suitable for food. Movements of this latter kind, like those resulting from the stimulation of the nerves in a brainless frog, are the result of the *irritability* of the protoplasm; the animalcule is therefore both automatic and irritable, although it possesses neither nerves nor sense-organs.

Under certain circumstances an Amœba temporarily loses its power of movement, draws in its pseudopods, and becomes a globular mass around which is formed a thick, shell-like coat, called the *cyst* (Fig. 75, B, *cy*). This is formed by the protoplasm by a process of *secretion* (p. 116); its composition is not known; it is certainly not protoplasmic, and very probably consists of some nitrogenous substance allied in composition to horn and to the *chitin* (see Chapter VII) which forms the external shell of crustaceans, insects, &c.

The formation of the cyst is of great importance in preserving the animalcule from destruction by drought, so that should the pool in which it is living dry up, it may still remain alive, protected by its shell-like case, until the conditions for its active life are once more

restored. When favourable conditions return, encysted amœbæ which have been floating about in the air as particles of dust, settle on water, and escape by the rupture of their cysts. Encystment also serves to aid in the dispersal of the species.

Very often an Amœba in the course of its wanderings comes in contact with a still smaller organism of some kind or other. When this happens the Amœba may be seen to extend itself round the smaller organism until the latter becomes sunk in its protoplasm in much the same way as a marble might be pressed into a lump of clay or a drop of honey or treacle flow round an ant (Fig. 72, A, *a*). The diatom or other organism becomes in this way completely enclosed in a cavity or *food vacuole* (*f. vac*), which also contains a small quantity of water necessarily included with the prey. The latter is taken in by the Amœba as food: so that the Amœba, like the frog, *feeds*. It is to be noted that the reception of food takes place in a particular way, viz., by *ingestion—i.e.*, it is enclosed entire by the organism.

When the prey is thus ingested, its protoplasm becomes *digested*, any insoluble portions being passed out or *egested*, as fæces (pp. 9 and 71), from the surface of the Amœba as it creeps slowly on. Note that all this is done without either ingestive aperture (mouth), digestive cavity (stomach), or egestive aperture (anus): the food is simply taken in by the flowing round it of protoplasm, digested as it lies enclosed in the protoplasm, and those portions for which it has no further use are got rid of by the Amœba flowing away from them.

We have seen that the frog possesses certain digestive glands, the function of which is to secrete *digestive fluids* which have an important chemical action on the food swallowed, rendering it soluble and diffusible before it passes through the epithelial cells of the alimentary canal

into the blood: the gastric juice, for example, has the power of converting proteins into peptones by means of the ferment pepsin (p. 70); the digestion here takes place *outside* the cells, *i.e.*, is *extracellular*. There can be little doubt that the protoplasm of Amœba is able to render that of its prey soluble and diffusible by the agency of some substance analogous to pepsin, and that the dissolved matters diffuse through the body of the Amœba until the latter is, as it were, soaked through and through with them. The process of digestion in Amœba thus takes place within a single cell, *i.e.*, it is *intracellular*.

It has been proved by experiment that proteins are the only class of food which Amœba can make use of: it is unable to digest either starch or fat (p. 68). Mineral matters must, however, be taken with the food in the form of a weak watery solution, since the water in which the animalcule lives is never absolutely pure.

The Amœba being thus permeated, as it were, with a nutrient solution, the elements of the solution, hitherto arranged in the form of peptones, mineral salts, and water, become rearranged in such a way as to form new particles of living protoplasm, which are deposited among the pre-existing particles. In a word, the food is *assimilated*, or converted into the actual living substance of the Amœba, which must therefore grow, if nothing happens to counteract this formation of new protoplasm.

We have seen, however, that work results in a proportional amount of waste (p. 62), and just as in the frog or in ourselves, every movement of the Amœba, however slight, is accompanied by a proportional oxidation or low temperature combustion of the protoplasm, *i.e.*, the constituents of the protoplasm combine with oxygen, forming waste or excretory matters—carbon dioxide,

water, and certain nitrogenous substances of simpler constitution than proteins, such as urea. These products of *excretion*, formed in the case of Amœba without the agency of any special excretory organs (*e.g.*, kidneys), are given off partly from its general surface, but partly, it would seem, by the agency of the contractile vacuole, by means of which the excess of water taken in with the food is also got rid of.

With this breaking down of proteins the vital activities of all organisms are invariably connected. Just as useful mechanical work may be done by the fall of a weight from a given height to the level of the ground, so the work done by the organism is a result of its complex proteins falling, so to speak, to the level of simpler substances. In both instances potential energy or energy of position is converted into kinetic or actual energy.

The statement just made that the protoplasm of Amœba constantly undergoes oxidation presupposes a constant supply of oxygen. The water in which the animalcule lives invariably contains that gas in solution, and diffusion takes place, oxygen passing into the interior of the Amœba while carbon dioxide passes out into the water. This is the process of breathing or *respiration* (p. 127), and it occurs in Amœba without the agency of special respiratory organs.

We thus see that a very elaborate series of chemical processes is constantly going on in the interior of Amœba, as in the frog; the whole series is spoken of collectively as *metabolism—constructive* and *destructive* (p. 132). Living protoplasm is the most unstable of substances; it is never precisely the same thing for two consecutive seconds; its existence, like that of a waterfall or a fountain, depends upon the constant flow of matter into it and away from it.

It follows from what has been said that if the income of an Amœba, *i.e.*, the total weight of substances taken in (food *plus* oxygen *plus* water) is greater than its expenditure or the total weight of substances given out (fæces *plus* excreta proper *plus* carbon dioxide), the animalcule will grow : if less it will dwindle away : if the two are equal it will remain of the same weight or in a state of physiological equilibrium.

Reproduction.—It is evident that Amœba must also be able to perform the function of *reproduction*. You have learnt that the cells of the frog multiply by *simple* or *binary* fission (p. 99) : the nucleus first divides into two, and then the surrounding protoplasm ; and precisely the same thing occurs in Amœba (Fig. 72, E), the reproduction of which therefore takes place by the simplest method known, without any special reproductive organs. The animalcule simply divides into two Amœbæ, each exactly like itself, and in doing so ceases to exist as a distinct individual. Instead of the successive production of offspring from an ultimately dying parent, we have the simultaneous production of offspring by the division of the parent, which does not die, but becomes simply merged in its progeny. There can be no better instance of the fact that reproduction is discontinuous growth.

From this it seems that an Amœba, unless suffering a violent death, is practically " immortal," since it divides into two completely organized individuals, each of which begins life with half of the entire body of its parent, there being therefore nothing left of the latter to die : it therefore appears certain that " death has no place as a natural recurrent phenomenon " in that organism. In multicellular forms it is only the reproductive cells which are, physically, potentially immortal.

Some observers have found that occasionally two

Amœbæ come into contact and undergo fusion, just as the gametes of the frog (sperm and ovum) unite in the processes of fertilization (p. 177). This process of *conjugation* is followed by encystment and the production inside the cyst of a number of young Amœbæ by a process of *multiple fission*. It is important to bear in mind, however, that reproduction can take place quite independently of such a process.

Amœbæ may also be propagated artificially. If a specimen is cut into pieces, each fragment is capable of developing into a complete animalcule provided it contains a portion of nuclear matter, but not otherwise. From this it is obvious that the nucleus exerts an influence of the utmost importance over the vital processes of the organism.

If an Amœba does happen to be killed and to escape being eaten, it will, like a dead frog, undergo gradual decomposition, becoming converted into various simple substances of which carbon dioxide, water, and ammonia are the chief (p. 62).

Death results if the temperature to which an Amœba is exposed reaches about 40° C., and at freezing point its movements cease entirely and it becomes inert.

Class Sarcodina.—Amœba has been studied as one of the simplest types of unicellular animals, which are all placed in the phylum protozoa. The phylum comprises several classes, including Sarcodina, Flagellata, Ciliata and Sporozoa. Sarcodina are characterized by the body of the unicellular organism being devoid of a cuticle, and thus capable of flowing out into pseudopodia. These latter may be blunt finger-shaped processes as in Amœba, or drawn out into long fine threads, which may be stiff and radial in arrangement, or run into one another to form a network.

Certain forms closely related to Amœba live in the

alimentary canal or other organs of higher animals such as cockroach, frog, and man. They get their food ready made from the animals inside which they live, or even attack the tissues of the latter. Such organisms are known as *parasites*, and the animals harbouring them as their *hosts*. Parasitic amœbæ are placed in the genus *Entamœba*, and one of them, called *Entamœba histolytica*

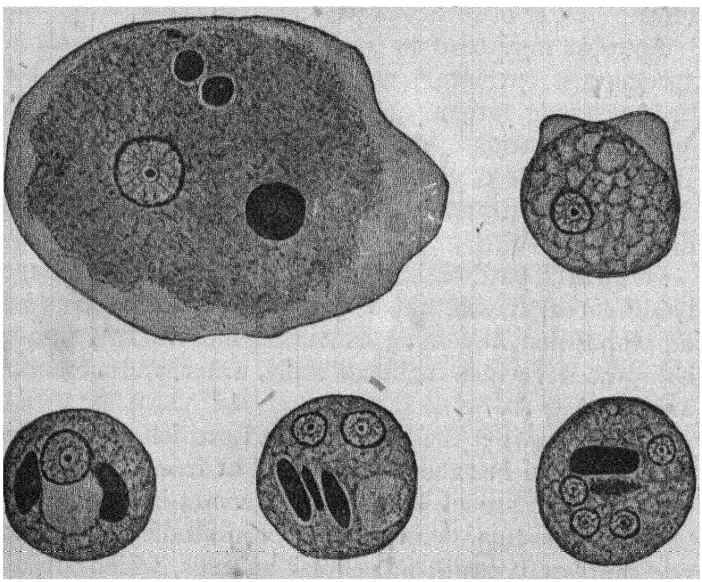


FIG. 73.—*Entamœba histolytica.*
A, large active form which has ingested three red blood-corpuscles; B, stage before encystment; C, D, E, cysts with one, two, and four nuclei respectively. (After Dobell, from Hegner and Taliaferro's *Protozoology*.)

(Fig. 73), is responsible for causing amœbic dysentery in man. The organisms invade the mucous and sub-mucous coats of the intestine, and, causing the rupture of the blood-capillaries in the latter, actually engulf the red blood-corpuscles (A). They may be carried by the blood-stream to other organs like the liver, and cause abscesses in that organ many years after the individual

had apparently recovered from the attack of dysentery. The organisms may also become encysted, and the cysts (C, D, E) may continue to live in the folds of the mucous membrane. These cysts are passed in the fæces of the host, and if they infect some article of food and get ingested by another person, the cysts may rupture and the active amœbæ set up an attack of dysentery in the latter. In this manner a person who has had an attack may serve as a *carrier* for a long time after apparent recovery.

All parasitic forms are not, however, dangerous. Another species, known as *Entamœba coli*, commonly occurs in the rectum of man, and, feeding upon the bacteria of putrefaction, serves as a harmless scavenger.

Belonging to the same class are beautiful forms, encased in shells of varied form and chemical composition. In some of them the shells are composed of calcium carbonate, and when the organisms die, the shells fall as a slow rain through miles of water to the floor of the deep sea, forming the ooze. Such deposits in the course of millions of years formed the chalk cliffs at Dover, which later must have been raised above the surface of the ocean. In another group the shells are made of silica, and under the microscope are seen to be some of the prettiest objects built by tiny architects.

CHAPTER II

PHYLUM PROTOZOA—*continued*

EUGLENA : VOLVOX : CLASS FLAGELLATA : DIFFERENCES BETWEEN ANIMALS AND PLANTS

THERE is a world of life in a drop of water. If you bring some water from the nearest pond or puddle, and carefully examine a drop under the microscope, you will find unicellular organisms of diverse form and structure. Some creep slowly by the aid of pseudopodia, others possess a more definite form and move with greater or less agility by the help of minute permanent organs of locomotion. Many different kinds of organisms will be seen to be provided with one or more fine whip-like processes or *flagella*, and a few of these we shall consider in this chapter. Others possessing minute, stiff, hair-like processes or *cilia* will be studied in the next chapter.

Euglena.—It is one of the commonest and one of the largest of these flagellate Protozoa, and will be encountered in puddles of rain-water containing decaying vegetable matter, if the water looks to be green and the green colour is not due to the presence of filamentous algæ which can be recognized by the naked eye on taking up some water in a glass tube or vessel. The green colour is imparted to the water by the presence of myriads of Euglenæ, which are green, as they contain bodies of a deep green colour. There are many species of *Euglena*, but we shall describe the one to which the name *Euglena viridis* has been given.

It is about $\frac{1}{250}$ of an inch in size, and oval in form, with one end bluntly truncated and the other pointed. The blunt end is always forward in locomotion, and so may be designated as anterior, the pointed end being referred to as posterior. The organism possesses a definite *cuticle* or *periplast*, which gives it a relatively fixed form as compared with Amœba. Arising from a conical depression at the anterior end is a long and extremely fine *flagellum*, which is seen to execute a series of rapid movements of bending and straightening, similar to the movements of a finger in beckoning. These movements of the flagellum cause the organism to progress forwards. On careful examination under highest powers of magnification, the single flagellum is seen to bifurcate and arise by two roots from the wall of the gullet (Fig. 74, B, *fl'*, *fl''*). Besides the movements of progression caused by the flagellum, the body of the organism also shows movements of contraction and expansion of its various parts, which are possible owing to the elasticity of the cuticle, and are described as *euglenoid movements*.

The cytoplasm is differentiated, as in Amœba, into ectoplasm and endoplasm. Near the anterior end are one or more small *contractile vacuoles* (*c. v.*) leading into a large non-contractile *reservoir* (*r.*), which empties itself into the gullet (*gul.*). Close to the inner end of the gullet is a bright red speck, the *stigma* (*st.*), formed of a pigment allied to chlorophyll and called hæmatochrome. The stigma is a light-perceiving organ, and is popularly referred to as the eye. In the posterior third of the body is situated a spherical *nucleus* (*nc.*), containing a central darker spot, the so-called nucleolus (*ncl.*), surrounded by a large number of chromatin particles.

The body appears to be uniformly green, only the anterior portion being colourless. When seen under a high power of the microscope, the green colour is found

to be due to the presence of a large number of oval, disc-shaped *chromatophores* (*ch.*), which are green owing

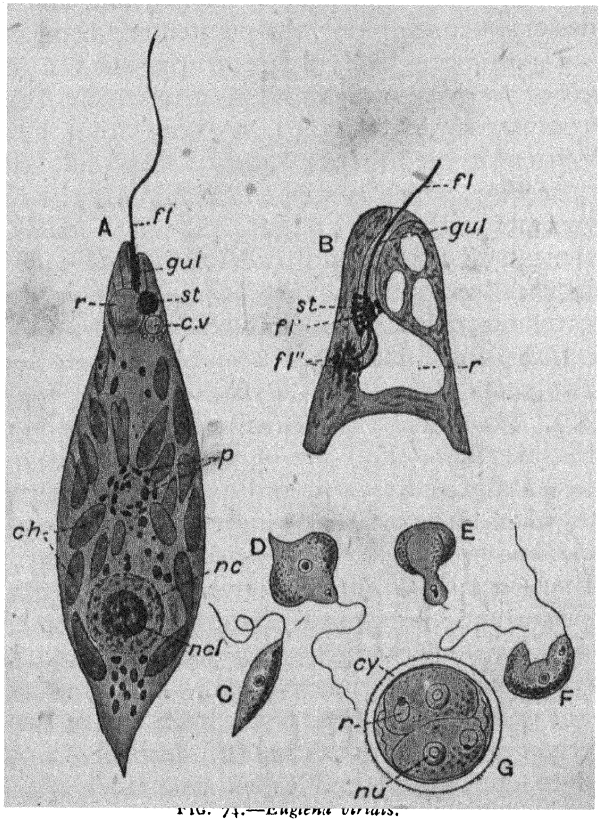


FIG. 74.—*Euglena viridis.*

A, entire organism magnified 1000 times; B, anterior end magnified 3000 times, showing origin of flagellum, etc.; C–F, showing euglenoid movements; G, encysted form showing binary fission.
Ch. chromatophores; *c.v.* contractile vacuole; *cy*, cyst; *fl.* flagellum; *fl'.* thickening on flagellum; *fl''.* two roots of flagellum; *gul.* gullet; *nc.*, *nu.* nucleus; *ncl.* "nucleolus"; *p.* paramylum bodies; *r.* reservoir; *st.* stigma.
(A, from Doflein; B, from Doflein after Wager; C–G, after Saville Kent.)

to their containing chlorophyll, the colouring-matter usually found in plants. In the more central region of

the body are to be seen a heap of rod-shaped granules of *paramylum* (*p.*), a carbohydrate allied to starch.

The nutrition of the organism is like a green plant. Through the agency of the green chromatophores, and with the help of sunlight, the carbon dioxide dissolved in the water is decomposed, setting free oxygen and combining carbon with the elements comprising water to form the carbohydrate paramylum. In bright sunlight the paramylum granules increase in size, but they diminish when Euglenæ are kept in the dark for some time. But, in addition to this characteristic vegetable (*holophytic*) mode of nutrition, it is possible that the organism also takes in solid particles of food in a characteristically animal (*holozoic*) manner. The movements of the flagellum create a whirlpool, by which minute organisms would be brought to the gullet and taken in as food. It is more probable that the organism supplements the *holophytic* mode of life by a *saprophytic* one—that is, by absorbing through the general surface the products of decaying organic matter dissolved in the water.

Sometimes the active movements of the organisms cease, and each individual encysts or surrounds itself with a cyst of cellulose (G). After remaining quiescent for some time, the organism may emerge and resume active life, or while in the encysted condition reproduction may take place. It multiplies by longitudinal *binary fission*, the plane of division passing through the long axis of the body. Sometimes *multiple fission* is known to occur inside a cyst, and a large number of flagellulæ are set free, which may pass through an amœboid stage, and develop into the adult form.

VOLVOX

Volvox.—It would be interesting to examine next an organism in which a large number of individual cells

or zooids remain adherent and form a many-celled spherical green colony. Each colony of *Volvox globator* is the size of a pin's head, and easily visible to the naked

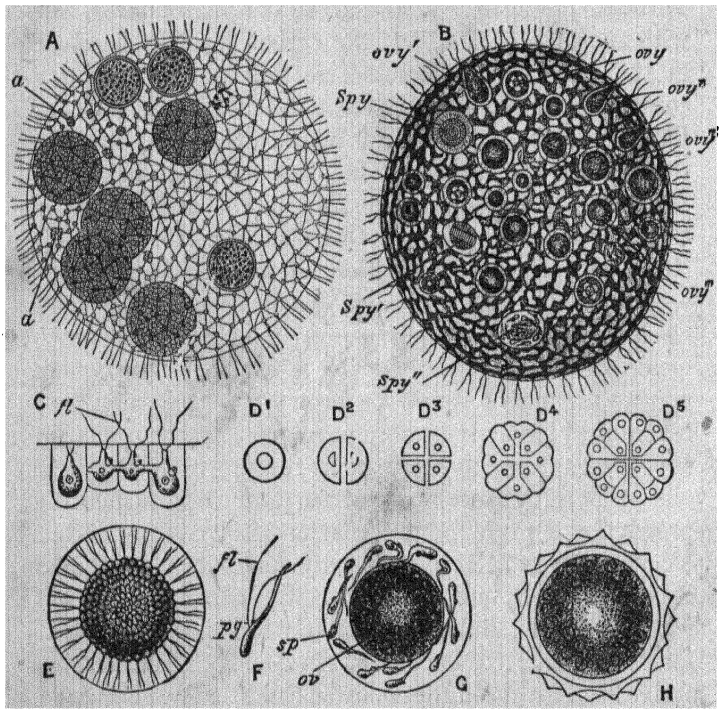


FIG. 75.—*Volvox globator.*

A, entire colony, enclosing several daughter-colonies; B, a colony during sexual maturity; C, four zooids in optical section; D^1–D^5, development of a zooid to form a daughter colony; E, ripe spermary; F, microgamete; G, macrogamete surrounded by a number of microgametes; H, zygote.

a. parthenogonidia or zooids which produce daughter-colonies; *fl*. flagellum; *ov*. ovum or macrogamete; *ovy*. ovaries each containing a single macrogamete; *pg*. pigment spot; *sp*. sperm or microgamete; *spy*. spermaries.

(From Parker's *Biology*, after Cohn and Kirchner.)

eye as it rotates in the stagnant water brought from a pond or ditch. It has the form of a hollow sphere, the wall of which consists of a jelly-like material in which 10,000 cells or more lie embedded (Fig. 75, A). Every

cell has its own cell-wall or envelope, separated from the cytoplasmic body by a considerable space (Fig. 75, C), and, being pressed against the envelope of neighbouring cells, acquires a hexagonal outline. The cytoplasmic bodies of adjacent cells are connected together by fine processes of protoplasm. Every individual cell has a nucleus, a contractile vacuole, a chromatophore, and a pair of flagella, which last project from the surface of the colony, and, along with the flagella of the other cells, serve to bring about the movement of the colony as a whole. Each cell is thus the equivalent of a single Euglena. These ordinary cells can multiply by division and increase the number of total cells in the colony, but they cannot give rise to new colonies.

The formation of new colonies takes place in one of two ways. Certain cells or zooids are set apart in the colony, which can be distinguished by their larger size and absence of flagella. Each of these zooids divides by a process of asexual reproduction resembling the segmentation of the egg in the higher animals (D^1–D^5), and forms a daughter-colony. The daughter-colonies become detached and swim freely in the interior of the mother-colony, being ultimately set free by the rupture of the latter.

The asexual method of colony formation goes on for several generations, after which colonies are formed which reproduce by the more complicated sexual method. Such a colony shows some fifty large non-flagellate cells, which are destined to produce sexual cells or gametes. Some of these cells simply enlarge, contain granules of reserve food material, and projecting into the central cavity of the colony, form the female gametes, called *macrogametes* or ova. Certain others divide repeatedly and form clusters of 128 bi-flagellate, spindle-shaped male gametes, known as *microgametes* or sperms

(E, F). By the breaking up of the cluster, these microgametes pass into the central cavity of the colony. They swim by means of their flagella towards a macrogamete, and bore their way through its thick envelope (G). A single microgamete fuses with the macrogamete, and forms a fertilized ovum or zygote. The latter surrounds itself with a double cyst-wall (H), the outer one being provided with spiny projections. In this encysted condition, the zygote passes through a long period of winter rest. The parent colony dies, and in the spring the zygote gives rise by a repeated process of cell division to a new Volvox colony.

Volvox presents many points of general biological interest. In the first place, it is an assemblage of zooids or cells comparable with other Protozoa, but linked together and forming a colony. These cells are further differentiated into ordinary vegetative or somatic cells and special reproductive cells. It thus approaches the higher animals or Metazoa, in being multicellular, and in special cells being set apart for reproductive purposes. These reproductive cells have concentrated upon one particular function, and the specialization has led to their losing the more generalized powers. Specialization has gone further, and led to sexual differentiation. Two cells have to meet together in sexual union, and it is an advantage to have stored food material for the early stages of growth of the young colony. Stored food material is a hindrance to active movement. So the microgametes or male gametes are minute but actively motile, and the macrogametes or female gametes are packed with food material but stationary.

Volvox offers another interesting problem for solution. Is it an animal or a plant? If it is an animal, owing to its possessing flagella and showing movement, it is a plant, as it feeds like one by virtue of possessing chloro-

phyll. Botanists claim it as a plant, and zoologists are unwilling to give up the study of so interesting a form. It is a highly specialized representative of early forms, from which both animals and plants were evolved.

Class Flagellata.—The class includes a very large number of forms showing a great variety in structure and habitat. The only character common to them all is the presence of one or more flagella. The class is divided into two sub-classes—viz., *Phytomastigina* the members of which, like *Euglena* and *Volvox*, are predominantly holophytic or plant-like in their mode of nutrition, and *Zoomastigina*, which have a holozoic mode of nutrition and are evidently animal in nature.

The majority of flagellates belonging to the sub-class *Phytomastigina* are free-living organisms. A few of them belonging to the genus *Copromonas* occur in stale fæces or as parasites in the intestine of tadpoles.

The sub-class *Zoomastigina* includes many free-living forms, as well as various parasitic or saprophytic flagellates which occur in man and other animals. Some of them ingest solid food at all parts of the surface of the body like Amœba by means of pseudopodia, or through a special mouth-opening, while others absorb proteid matter in solution by a process of osmosis. Some of these latter, known as Trypanosomes, live mostly in the plasma of the blood of various vertebrates, and cause some of the deadliest diseases of man and domesticated animals.

A Trypanosome (Fig. 76) has a long, narrow body, usually pointed at one or both ends, and provided with a flagellum prolonged forward beyond the anterior end. The flagellum can be traced backwards along the body and connected with the latter by a thin, undulating membrane (*u.*). The nuclear apparatus consists of a large central trophonucleus (*n.*), a smaller, more

posteriorly situated kinetonucleus (*k.n.*), and a basal granule (*b.*) from which the flagellum arises. Different species of *Trypanosoma* cause different diseases, the "Sleeping sickness" which is a fatal disease in man in certain parts of Africa being caused by *T. gambiense*, and transmitted by a biting fly popularly known as tsetse-fly.

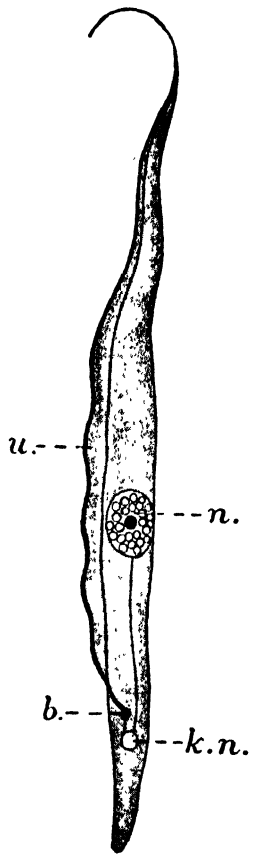


FIG. 76.—A, Trypanosome with a single flagellum. *b.* basal granule; *k.n.* kinetonucleus; *n.* trophonucleus; *u.* undulating membrane. (From Parker and Haswell, after Minchin.)

Differences between Animals and Plants.—It will be useful for the student to institute a comparison between *Amœba* or *Euglena* and any unicellular plant organism, such as *Sphærella* or *Protococcus* or the individual cells of a filamentous alga like *Spirogyra*, that he may have studied in his Botany course. He will remember that in those plant-cells there is no change of form as in Amœba, the protoplasm being surrounded by a definite *cell-wall* consisting of *cellulose*—a carbohydrate allied in composition to starch, sugar, etc., from which substances, however, it can be easily distinguished with the help of certain chemical reagents. Even when Amœba is in the encysted condition, the cyst, as stated above (p. 206), is very probably of some nitrogenous substance. In the matter of nutrition, the differences between Sphærella and Amœba are very marked, and indeed fundamental. As is well known,

these tiny plants, like other green plants, cannot and do not swallow any solid food, but live on water containing various mineral salts and carbon dioxide in solution. They absorb these substances, and in their body build up simple carbohydrates, for which purpose the green chlorophyll contained in their body and the energy supplied by sunlight are essential. The process is known as photosynthesis, and is accompanied by the evolution of oxygen gas. The carbohydrates thus formed unite with the ammonia salts or the nitrates absorbed from the surrounding water, the result being the formation of some comparatively simple nitrogenous compound. Then further combinations take place, substances of greater and greater complexity are produced, sulphur from the absorbed sulphates enters into combination, and proteins are formed. From these, finally, fresh living protoplasm arises.

As in Amœba, the final result of the nutritive process is the manufacture of protoplasm, and this result is attained by the formation of various substances of increasing complexity. But it must be noted that the steps in this process of constructive metabolism are widely different in the two cases. In Amœba we start with living protoplasm—that of the prey—which is killed and broken up into diffusible proteins, these being afterwards re-combined to form new molecules of the living protoplasm of Amœba. So that the food of Amœba is, to begin with, as complex as itself, and is first broken down by digestion into simpler compounds, these being afterwards re-combined into more complex ones. In Sphærella, on the other hand, we start with extremely simple compounds, such as carbon dioxide, water, nitrates, sulphates, &c. Nothing which can be properly called digestion, *i.e.*, a breaking up and dissolving of the food, takes place, but its various con-

stituents are combined into substances of gradually increasing complexity, protoplasm, as before, being the final result.

To express the matter in another way: Amœba can only make protoplasm out of proteins already formed by some other organism: Sphærella can form it out of simple liquid and gaseous inorganic materials.

Speaking generally, it may be said that these two methods of nutrition are respectively characteristic of the two great groups of living things. Animals require solid food containing ready-made proteins, and cannot build up their protoplasm out of simpler compounds. Green plants, *i.e.*, all the ordinary trees, shrubs, weeds, &c., take only liquid and gaseous food, and build up their protoplasm out of carbon dioxide, water, and mineral salts. The first of these methods of nutrition is conveniently distinguished as *holozoic*, or wholly-animal, the second as *holophytic*, or wholly-vegetal.

In Euglena both methods of nutrition are combined. It ingests solid particles of food through the mouth, and also carries on nutrition in a plant-like manner by means of the green chloroplasts contained in the body. Euglena is thus more of an animal than a plant. But when we come to Volvox, the balance of argument is in favour of its being regarded as plant rather than as animal.

In animals as well as plants, destructive metabolism is constantly going on side by side with constructive. The protoplasm becomes oxidized, water, carbon dioxide, and nitrogenous waste matters being formed and finally got rid of. Obviously, then, absorption of oxygen must take place, or, in other words, respiration must be one of the functions of the protoplasm of Sphærella as of that of Amœba. In many green, *i.e.*, chlorophyll-containing, plants, this has been proved to be the case: respiration, *i.e.*, the taking in of oxygen and giving out

of carbon dioxide, is constantly going on, but during daylight is obscured by the converse process—the taking in of carbon dioxide for nutritive purposes and the giving out of the oxygen liberated by its decomposition. In darkness, when this latter process is in abeyance, the occurrence of respiration is more readily ascertained.

Owing to the constant decomposition, during sunlight, of carbon dioxide, a larger volume of oxygen than of carbon dioxide is evolved; and if an analysis were made of all the ingesta of the organism (carbon dioxide *plus* mineral salts *plus* respiratory oxygen) they would be found to contain less oxygen than the egesta (oxygen from decomposition of carbon dioxide *plus* water, excreted carbon dioxide, and nitrogenous waste); so that the nutritive process in Sphærella is, as a whole, a process of deoxidation. In Amœba, on the other hand, the ingesta (food *plus* respiratory oxygen) contain more oxygen than the egesta (fæces *plus* carbon dioxide, water, and nitrogenous excreta), the nutritive process being therefore on the whole one of oxidation. This difference is, speaking broadly, characteristic of plants and animals generally; animals, as a rule, take in more free oxygen than they give out, while green plants always give out more than they take in.

Destructive metabolism is, however, manifested not only in the formation of waste-products, but in that of substances simpler than protoplasm which remain an integral part of the organism, viz., cellulose and starch.

The cell-wall in plant-cells is formed of cellulose, while the cyst covering an Amœba is probably formed of some nitrogenous substance derived from the protoplasm.

We see then that destructive metabolism may result in the formation of (*a*) *waste products* and (*b*) *plastic products*, the former being got rid of as of no further

use, while the latter remain an integral part of the organism.

We have seen that typical animal-cells, such as those of the frog (Part I, Chap. VII) are not provided with a cellulose cell-wall and do not contain chlorophyll. It is characteristic; on the other hand, of most plant-cells—which also consist of nucleated protoplasm—that they are surrounded with a cellulose cell-wall, and that, in the case of green plants, they contain chlorophyll. Speaking generally, the nutrition of animals is holozoic, and that of green plants holophytic; and in correspondence with this difference in the character of the food, most animals have an ingestive aperture or mouth for taking in the solid food, and some kind of digestive cavity, either permanent (stomach) or temporary (food-vacuole); they also have, as a rule, some kind of excretory apparatus. Moreover, animals are usually capable of automatic movement, while in most plants the organism, as a whole, exhibits no automatism, but only the slow movements of growth.

In the next two chapters we shall study certain other unicellular organisms which show an advance on Amœba and Euglena in possessing a certain amount of morphological and physiological differentiation. But the structural differentiations, as they are merely parts of one cell, cannot be spoken of as " organs " in the sense in which we have used the word hitherto, as they are not composed of numerous cells. They are, however, organs in the physiological sense, as they perform different functions.

CHAPTER III

PHYLUM PROTOZOA—*continued*

PARAMECIUM: PARASITIC CILIATES: VORTICELLA AND ITS ALLIES—COLONIAL ORGANISMS: CLASS CILIATA: BIOGENESIS AND ABIOGENESIS

WE have now to consider certain organisms in which differentiation has gone much further than in the unicellular forms already considered: which have, in fact, acquired many of the characteristics of the higher animals and plants while remaining unicellular (compare p. 226). The study of several of these more or less highly differentiated though unicellular forms will occupy the present chapter.

In the earlier stages of the putrefaction of an organic infusion, Bacteria only are found, but later Amœba and various other animal organisms make their appearance. Among these latter are much larger organisms, generally of an ovoidal form, moving about very quickly and seen by the use of a high power to be covered with innumerable fine cilia. These are called *ciliate Infusoria*; many kinds are common in putrefying infusions, some occur in the intestines of the higher animals, while others are among the commonest inhabitants of both fresh and salt water.

Paramecium.—A very common ciliate infusor is the beautiful "slipper-animalcule," *Paramecium*, which from

its comparatively large size and from the ease with which all essential points of its organization can be made out is a very convenient and interesting object of study.

Compared with the majority of the organisms which have come under our notice it may fairly be considered as gigantic, being no less than $\frac{1}{5}$–$\frac{1}{3}$ mm. (200–330μ) in length: in fact it is just visible to the naked eye as a minute whitish speck.

Form.—Its form (Fig. 77) can be fairly well imitated by making out of clay or stiff dough an elongated cylinder rounded at one end and bluntly pointed at the other; then giving the broader end a slight twist; and finally making on the side rendered somewhat concave by the twist a wide, shallow, groove beginning at the broad end and gradually narrowing to about the middle, where it ends in a tolerably deep depression.

The groove is called the *peristomial groove*: at the posterior end of the groove is a small aperture, the *cytostome*, which, however, leads directly into the soft internal protoplasm by a *cytopharynx*. The surface of the creature on which the groove is placed is distinguished as the ventral surface, the opposite surface being upper or dorsal; the broad end is anterior, the narrow end posterior, the former being directed forwards as the animalcule swims. These descriptive terms being decided upon, it will be seen that the peristomial groove begins on the left side, and gradually curves over to the middle of the ventral surface.

As the creature swims its form is seen to be permanent, exhibiting no contractions of either an amœboid or a euglenoid nature. It is, however, distinctly flexible, often being bent in one or other direction when passing between obstacles, such as entangled masses of weed. This permanence of contour is due to the presence of a

tolerably firm though delicate *cuticle* which invests the whole surface.

Structure.—The protoplasm thus enclosed by the cuticle is distinctly divisible into two portions—an external somewhat dense layer, the *cortical layer* or *ectoplasm*, and an internal more fluid material, the *medullary substance* or *endoplasm*. It will be remembered that a somewhat similar distinction of the protoplasm into two layers is exhibited by Amœba (p. 205), the ectoplasm being distinguished from the endoplasm simply by the absence of granules. In Paramecium the distinction is a far more fundamental one: the cortex is radially striated and is comparatively firm and dense, while the medulla is granular and semi-fluid, as may be seen from the fact that food-particles (*f. vac*, and see p. 231) move freely in it, whereas they never pass into the cortex. The medulla has a reticular structure similar to that of the protoplasm of the ordinary animal-cell, consisting of a delicate granular network the

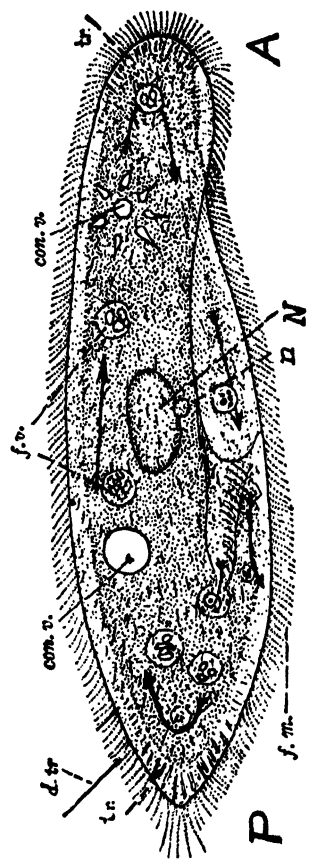


FIG. 77.—*Paramecium caudatum*. *A*, anterior end; *con. v.* contractile vacuoles, the anterior one showing the radiating canals which feed the vacuole; *d. tr.* discharged trichocysts; *f. v.* food vacuoles; *f. m.* fæcal matter which is discharged from the body at a definite spot; *N*, macronucleus; *n.* micronucleus; *P*, posterior end; *tr.* trichocyst before discharge. Arrows indicate the direction and course of the food vacuoles within the endoplasm. × 375. (From Hegner and Taliaferro's *Protozoology*, after Dahlgren and Kepner.)

meshes of which are filled with a transparent material. In the cortex the meshes of the network are closer, and so form a comparatively dense substance. The deeper part of the cortex also exhibits longitudinal striations, called *myophan striations*, which are due to longitudinal wrinkling of the under surface of the cortex.

The *cytostome* or mouth leads into a short funnel-like tube, the *cytopharynx* or gullet, which is lined by cuticle and passes through the cortex to end in the soft medulla, thus making a free communication between the latter and the external water. The cytopharynx consists of three sections, the first of which bears free cilia, the second bears a membrane formed by the fusion of cilia, and the third part contains rod-like fibres.

The cilia with which the body is covered are of approximately equal size, quite short in relation to the entire animal, and arranged in longitudinal rows over the whole outer surface. They consist of prolongations of the cortex, and each passes through a minute perforation in the cuticle. They are in constant rhythmical movement, like the cilia on the epithelial cells of the frog's mouth (p. 103), and are thereby distinguished from the flagella of Sphærella, Euglena, &c., which exhibit more or less intermittent lashing movements.

Near the middle of the body, on the inner boundary of the cortex, is a large oval nucleus, the *macronucleus* (Fig. 77, N), and against one side of it, in *P. caudatum*, is a small oval structure (*n.*) which is also deeply stained by, *e.g.*, magenta or carmine. This is the *micronucleus*: it is to be considered as a second, smaller nucleus. In the closely allied *P. aurelia* there are two micronuclei.

There are two contractile vacuoles (*con. v.*) in relation with the cortex, one situated at about a third of the entire length from the anterior end of the body, the other at about the same distance from the posterior end.

The action of the contractile vacuoles is very beautifully seen in a Paramecium at rest: it is particularly striking in a specimen subjected to slight pressure under a cover-glass, but is perfectly visible in one which has merely temporarily suspended its active, swimming movements. It is then seen that during the *diastole*, or phase of expansion of each vacuole, a number—about six to ten—of delicate, radiating, spindle-shaped spaces filled with fluid appear round it, like the rays of a star (upper vacuole in Fig. 77): the vacuole itself contracts or performs its *systole*, completely disappearing from view, and immediately afterwards the radiating canals flow together and refill it, becoming themselves emptied and therefore invisible for an instant (lower vacuole in Fig. 77), but rapidly appearing once more. There seems to be no doubt that the water taken into the body is drained into these canals, emptied into the vacuole, and finally discharged to the exterior, thus carrying the waste matter with it.

Nutrition.—The process of feeding can be very conveniently studied in Paramecium by placing in the water some finely-divided carmine or indigo. When the creature comes into the neighbourhood of the coloured particles, the latter are swept about in various directions by the action of the cilia: some of them, however, are certain to be swept into the neighbourhood of the peristomial groove and gullet, the cilia of which all work downwards, *i.e.*, towards the inner end of the gullet. The grains of carmine are thus carried into the gullet, where for an instant they lie surrounded by the water of which it is full: then, instantaneously, probably by the contraction of the tube itself, the animalcule performs a sort of gulp and the grains with an enveloping globule of water or *food-vacuole* are forced into the medullary protoplasm. This process is repeated again and again, so that

in any well-nourished Paramecium there are to be seen numerous globular spaces filled with water and containing particles of food—or in the present instance of carmine or indigo. At every gulp the newly-formed food-vacuole pushes, as it were, its predecessor before it: contraction of the medullary protoplasm also takes place in a definite direction, and thus a circulation of food-vacuoles is produced, as indicated in Fig. 77 by arrows.

After circulating in this way for some time the water of the food-vacuoles is gradually absorbed, being ultimately excreted by the contractile vacuoles, so that the contained particles come to lie in the medulla itself (refer to figure). The circulation still continues, until finally the particles are brought to a spot situated about half-way between the mouth and the posterior end of the body: here if carefully watched they are seen to approach the surface and then to be suddenly ejected. The spot in question is therefore to be looked upon as a potential *anus*, or aperture for the egestion of fæces or undigested food-material. It is a potential and not an actual anus, because it is not a true aperture, but only a soft place in the cortex through which, by the contractions of the medulla, solid particles are easily forced.

Of course when Paramecium ingests, as it usually does, not carmine but minute living organisms, the latter are digested as they circulate through the medullary protoplasm, and only the non-nutritious parts cast out at the anal spot. It has been found by experiment that this ciliate organism can digest not only proteins but also starch and perhaps fats. The nutrition of Paramecium is therefore characteristically holozoic.

It was mentioned above that the cortex is radially striated in optical section. Careful examination with a very high power shows that this appearance is due to the presence in it of minute spindle-shaped bodies

(Fig. 77) closely arranged in a single layer and perpendicular to the surface. These are called *trichocysts*.

When a Paramecium is killed, either by the addition of some poisonous reagent or by simple pressure of the cover-glass, it frequently assumes a remarkable appearance. Long delicate threads suddenly appear, projecting from its surface in all directions and looking very much as if the cilia had suddenly protruded to many times their original length. But these filaments have really nothing to do with the cilia; they are contained under ordinary circumstances in the trichocysts, probably coiled up; and by the contraction of the cortex consequent upon any sudden irritation they are projected in the way indicated. In Fig. 77 a few trichocysts (*d. tr.*) are shown in the exploded condition, *i.e.*, with the threads protruded. Most likely these bodies are weapons of offence like the very similar structures (nematocysts) found in polypes (see Chapter V, Fig. 87).

Reproduction.—Paramecium multiplies by simple fission, the division of the body being always preceded by the elongation and subsequent division of the macro- and micro-nucleus (Fig. 78).

Conjugation (p. 211) also occurs, usually after multiplication by fission has gone on for some time. Two Paramecia come into contact by their ventral surfaces; in each of these conjugating individuals or *gametes* the macronucleus takes no part in the process and degenerates, while the micronucleus undergoes a somewhat complicated series of changes; the essential part of the process being the fusion of two products of the division of the micronuclei, one from each gamete. Each of these then contains a single nuclear body, the *conjugation-nucleus*, formed by the union of nuclear matter derived from two distinct individuals, and therefore comparable to the nucleus of the oosperm in the higher animals

(p. 177). The other products of division of the micronucleus disappear, and new macro- and micro-nuclei arise from the conjugation-nucleus. In this case, however, the two entire gametes do not unite to form a zygote, but separate after the process is complete and begin once more to lead an independent existence, when ordinary transverse fission again takes place. Woodruff kept up during nineteen years a race of *Paramecium aurelia*, starting from a single "wild" individual, and after his observations on eleven thousand generations of the Paramecium in question, came to the conclusion that a single cell can reproduce itself indefinitely, under favourable conditions, without recourse to conjugation. During these investigations it was discovered that during continued binary fissions of the individuals, sometimes an internal reorganization of the nuclear apparatus, called endomixis, takes place. The macronucleus gradually disintegrates and is absorbed, and a new one is formed from the micronuclear apparatus.

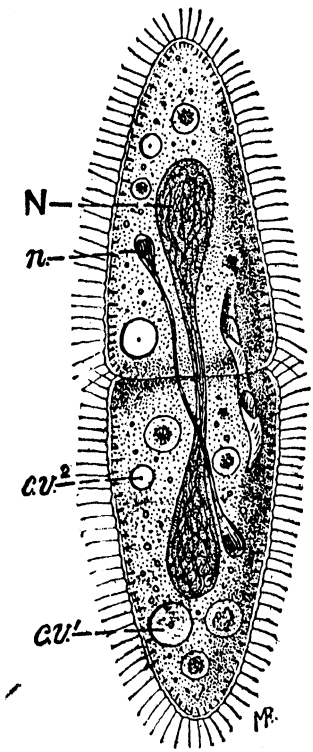


FIG. 78.—*Paramecium caudatum* showing binary fission. The macronucleus (*N*) divides by amitosis and the micronucleus (*n.*) mitotically; *c.v.*¹, original and *c.v.*², new contractile vacuole in one of the daughter individuals. (From Minchin, after Bütschli and Schewiakoff.)

It will be noticed that, in the present instance (see also p. 211), conjugation is not a process of multiplica-

tion: it has been ascertained that during the time two individuals are conjugating each might have produced a very large number of offspring by continuing to undergo fission at the usual rate. The importance of the process lies in the exchange of nuclear material between the two conjugating individuals, which exercises a stimulating function.

Parasitic Ciliates.—It will be interesting to compare Paramecium with a ciliate infusor which lives in the intestine of *Rana tigrina*, and is known as *Opalina coracoidea*.[1]

Opalina has a flattened body with an oval outline,

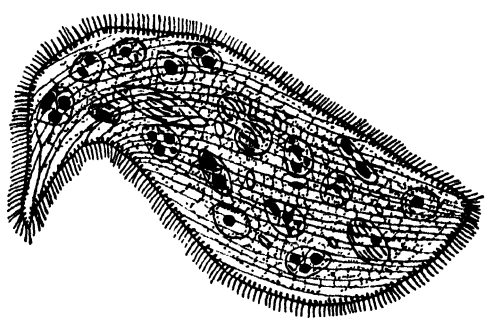


FIG. 79.—*Opalina coracoidea.*
Note the numerous nuclei scattered in the cytoplasm.
(After Bhatia and Gulati from *Fauna of British India.*

and full-sized specimens may be as much as 1 mm. in length. The protoplasm is divided into cortex and medulla, and is covered with a cuticle; the cilia are equal-sized and uniformly arranged in longitudinal rows over the whole surface.

On a first examination no nucleus is apparent, but after staining, a large number of globular nuclei can be

[1] Certain other parasitic ciliates, *e.g.*, *Nyctotherus* and *Balanatidium*, are also commonly found in the rectum of *Rana tigrina*.

seen; these nuclei multiply within the body of the infusor.

There is no contractile vacuole, and no trace of either mouth or gullet, so that the ingestion of solid food is impossible. The creature lives, as already stated, in the intestine of the frog: it is therefore an *internal parasite*, or *endoparasite*, having the frog as its *host*. The intestine contains the partially-digested food of the frog, and it is by the absorption of this that the Opalina is nourished. Having no mouth it feeds solely by imbibition: it simply absorbs food ready digested by its host, upon which it is dependent for a constant supply of soluble and diffusible nutriment.

VORTICELLA

Vorticella.—The next organism we have to consider is a ciliate infusor, even commoner than Paramecium. It is hardly possible to examine the water of a pond with any care without finding in it, sometimes attached to weeds, sometimes to the legs of water-fleas, sometimes to the sticks and stones at the bottom, numbers of exquisitely beautiful little creatures, each like an inverted bell with a very long handle, or a wine-glass with a very long stem. These are the well-known "bell-animalcules," the commonest among them belonging to various species of the genus *Vorticella*.

Form and Structure.—The first thing that strikes one about Vorticella (Fig. 80, A) is the fact that it is permanently fixed, like a plant, the proximal or near end of the stalk being always firmly fixed to some aquatic object, while to the distal or far end the body proper of the animalcule is attached.

But in spite of its peculiar form it presents certain very obvious points of resemblance to Paramecium. The protoplasm is divided into cortex (C, *cort*) and

due to the successive contraction of all the cilia in the same direction, and is analogous to that produced by a strong wind on a field of corn or long grass. The bending down of successive blades of grass produces a series of waves travelling across the field in the direction of the wind. If instead of a field we had a large circle of grass, and if this were acted upon by a cyclone, the wave would travel round the circle, which would then appear to revolve.

Nutrition.—Naturally the movement of the circlet of cilia produces a small whirlpool in the neighbourhood of the Vorticella, as can be seen by introducing finely-powdered carmine into the water. It is through the agency of this whirlpool that food particles are swept into the mouth, surrounded, as in Paramecium, by a globule of water: the food-vacuoles (C) thus constituted circulate in the medullary protoplasm and the non-nutritive parts are finally egested at an anal spot (*an*) situated near the base of the gullet.

Contractility and Irritability.—The stalk (A, *st*) consists of a very delicate, transparent, outer substance, which is continuous with the cuticle of the body and contains a delicate *axial fibre* (*ax. f*) running along it from end to end in a somewhat spiral direction. This fibre is a prolongation of the cortex of the body (C): under a very high power it appears granular or delicately striated, the striæ being continued into the cortex of the proximal part of the body.

A striking characteristic of Vorticella is its extreme irritability, *i.e.*, the readiness with which it responds to any external stimulus. The slightest jar of the microscope, the contact of some other organism, or even a current of water produced by some free-swimming form like Paramecium, is felt directly by the bell-animalcule, and is followed by an instantaneous change in the

relative position of its parts. The stalk becomes coiled into a close spiral so as to have a mere fraction of its original length, and the body from being bell-shaped becomes globular, the disc being withdrawn and the peristome closed over it (D[1], D[2]).

The coiling of the stalk leads us to the consideration of the particular form of contractility called *muscular*, which is met with in multicellular animals, *e.g.*, the frog (p. 58). It was mentioned above that while the stalk in its fully expanded condition is straight, the axial fibre is not straight, but forms a very open spiral, *i.e.*, it does not lie in the centre of the stalk, but at any transverse section is nearer the surface at one spot than elsewhere, and this point as we ascend the stalk is directed successively to all points of the compass.

Now suppose that the axial fibre undergoes a sudden contraction, that is to say, a decrease in length accompanied by an increase in diameter, since, as we have already seen, there is no decrease in volume in protoplasmic contraction. There will naturally follow a corresponding shortening of the elastic cuticular substance which forms the outer layer of the stalk. If the axial fibre were entirely towards one side of the stalk, the result of the contraction would be a flexure of the stalk towards that side, but, as its direction is spiral, the stalk is bent successively in every direction, that is, is thrown into a close, spiral coil.

The axial fibre is therefore a portion of the protoplasm which possesses the property of contractility in a special degree; in which, moreover, contraction takes place in a definite direction—the direction of the length of the fibre—so that its inevitable result is to shorten the fibre and consequently to bring its two ends nearer together. This is the essential characteristic of a muscular contraction, and the axial fibre in the stalk of Vorticella is

therefore to be looked upon as the first instance of a clearly differentiated *muscle* which has come under our notice amongst unicellular animals.

Reproduction.—There are some interesting features in the reproduction of Vorticella. It multiplies by binary fission, dividing through the long axis of the body (E^1, E^2). Hence it is generally said that fission is longitudinal, not transverse, as in Paramecium. But on the theory (p. 238) that the peristome and disc are ventral and the attached end dorsal, fission is really transverse in this case also.

It will be seen from the figures that the process takes place by a cleft appearing at the distal end (E^1) and gradually deepening until there are produced two complete and full-size individuals upon a single stalk (E^2). This state of things does not last long: one of the two daughter-cells takes on a nearly cylindrical form, keeps its disc and peristome retracted, and acquires a new circlet of cilia near its proximal end (E^3): it then detaches itself from the stalk, which it leaves in the sole possession of its sister-cell, and swims about freely for a time. Sooner or later it settles down, becomes attached by its proximal end, loses its basal circlet of cilia, and develops a stalk, which ultimately attains the normal length.

The object of this arrangement is obvious. If, when a Vorticella divided, the plane of fission extended down the stalk until two ordinary fixed forms were produced side by side, the constant repetition of the process would so increase the numbers of the species in a given spot that the food-supply would inevitably run short. This is prevented by one of the two sister-cells produced by fission leading a free existence long enough to enable it to emigrate and settle in a new locality, where the competition with its fellows will be less keen. The

production of these free-swimming zooids is therefore a *means of dispersal*: contrivances having this object in view are a very general characteristic of fixed organisms.

Conjugation occasionally takes place, and presents certain peculiarities. A Vorticella divides either into two unequal parts (F^2) or into two equal halves, one of which divides again into from two to eight daughter-cells (F^1). There are thus produced from one to eight *microzooids* which resemble the barrel-shaped form (E^3) in all but size, and, like it, become detached and swim freely by means of a basal circlet of cilia. After swimming about for a time, one of these microzooids comes in contact with an ordinary form or *macrozooid*, when it attaches itself to it near the proximal end (G^1), and undergoes gradual absorption (G^2), the macro- and micro-zooids becoming completely and permanently fused to form a *zygote* (p. 177).

Notice that in this case the conjugating bodies or gametes are not of equal size and similar character; but one, which is conveniently distinguished as the *microgamete* (= microzooid), is relatively small and active, while the other or *macrogamete* (= macrozooid, or ordinary individual) is relatively large and passive. As we have seen in the case of the frog (pp. 174 and 176), this differentiation of the gametes is precisely what we get in the higher animals, and, in fact, in almost all organisms with two sexes: the microgamete being the male, the macrogamete the female conjugating body (p. 177).

The result of conjugation is somewhat different in the two cases just studied: in Paramecium no zygote is formed, conjugation being a mere temporary union (p. 234): in Vorticella the zygote is an actively moving and feeding body, indistinguishable from an ordinary individual of the species.

Vorticella sometimes encysts itself (Fig. 80, H^1), and

the nucleus of the encysted cell has been observed to break up into a number of separate masses, each doubtless surrounded by a layer of protoplasm. After a time the cyst bursts, and a number of small bodies or *spores* (H^2) emerge from it, each containing one of the products of division of the nucleus. These acquire a circlet of cilia (H^3), by means of which they swim freely, and they are sometimes found to multiply by simple fission (H^4). Finally, they settle down (H^5) by the end at which the cilia are situated, the attached end begins to elongate into a stalk (H^6), this increases in length, the basal circlet of cilia is lost, and a ciliated peristome and disc are formed at the free end (H^7). In this way the ordinary form is assumed by a process of progressive differentiation or *development* (p. 10); and, moreover, the free-swimming young (H^3), to which the spores formed by division of the encysted protoplasm give rise, differ strikingly in form and habits from the adult. This is expressed by saying that development is in this case accompanied by a *metamorphosis*, this word, literally meaning simply a change, being always used in zoology to express a striking and fundamental difference in form and habit between the young and the adult; as, for instance, between the tadpole and the frog, or between the caterpillar and the butterfly. It is obvious that in the present instance metamorphosis is another means of ensuring dispersal.

In Vorticella, as we have seen, fission results not in the production of equal and similar daughter-cells, but of one stalked and one free-swimming form. It is, however, quite possible to conceive of a Vorticella-like organism in which the parent-cell divides into two equal and similar products, each retaining its connection with the stalk. If this process were repeated again and again, and if, further, the plane of fission were extended down-

wards so as to include the distal end of the stalk, the result would be a branched, tree-like stem with a Vorticella-like body at the end of every branch.

Colonial Forms.—As a matter of fact, this process takes place not in Vorticella itself, but in some nearly allied infusors, such as *Carchesium* and *Epistylis*. Each of these forms consists of a main stem attached by its proximal end and giving off at its distal end several

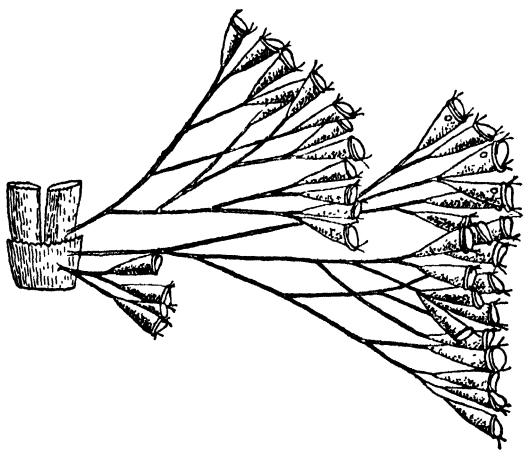


FIG. 81.—*Epistylis anastatica*. (After Kent, from *Fauna of British India*.)

branches, on each of which numerous bell-animalcules with short stalks are borne (Fig. 81).

As in Vorticella, the stem of Carchesium consists of a cuticular sheath with an axial muscle-fibre which, at the distal end of the main stem, branches like the stem itself, a prolongation of it being traceable to each zooid; so that the muscular system is common to the whole colony, and any shock causes a general contraction of all the zooids. The stalk of Epistylis, on the other hand, is non-contractile.

We see, then, that Carchesium and Epistylis differ from all our previous types in being *compound organisms*. The entire "tree" is called a *colony* or *stock*, and each separate bell-animalcule borne thereon is an *individual* or *zooid*, morphologically equivalent to a single Vorticella or Paramecium. The colony is therefore an *individual of a higher grade* than the zooid; and such a multicellular animal as a frog, the cells of which differ markedly in structure and function, is an individual of a higher grade still.

Class Ciliata.—This class includes all Protozoa in which the body has a definite form on account of being covered by a cuticle, and possesses cilia as the organs of locomotion. The arrangement of the cilia differs in different organisms. With the exception of Opalina and its allies, the organisms included in this class show a nuclear differentiation, there being a larger vegetative macronucleus and a smaller reproductive micronucleus. Reproduction takes place by transverse binary fission or by conjugation. Most of them are free-living aquatic forms, but many are parasitic.

Biogenesis and Abiogenesis.—The study of the foregoing living things, and especially of Bacteria, the smallest and probably the simplest of all known organisms naturally leads us to the consideration of one of the most important problems of Biology—the problem of the origin of life.

In all the higher organisms we know that each individual arises in some way or other from a pre-existing individual: no one doubts that every bird now living arose by a process of development from an egg formed in the body of a parent-bird, and that every tree now growing took its origin either from a seed or from a bud produced by a parent-plant. But there have always—until quite recently, at any rate—been upholders

of the view that the lower forms of life, Bacteria, Monads, and the like, may under certain circumstances originate independently of pre-existing organisms: that, for instance, in a flask of some organic infusion boiled so as to kill any living things present in it, fresh forms of life may arise *de novo*—may in fact be created then and there.

We have therefore two theories of the origin of the lower organisms: the theory of *Biogenesis*, according to which each living thing, however simple, arises by a natural process of budding, fission, spore-formation, or what not, from a parent organism; and the theory of *Abiogenesis*, or as it is sometimes called *Spontaneous Generation*, according to which fully-formed living organisms sometimes arise from not-living matter.

In former times the occurrence of abiogenesis was universally believed in. The expression that a piece of meat has "bred maggots"; the opinion that parasites such as the gall-insects of plants or the tape-worms in the intestines of animals originate where they are found; the belief still held in some rural districts that frogs would spring up in large numbers if a dead and dried-up frog was pounded and the powder sprinkled over water, or scorpions would be formed if cow-dung and curd were kept in an earthen pot—all indicate a survival of this belief.

As accurate enquiries into these matters were made, the number of cases in which spontaneous generation was supposed to occur was rapidly diminished. It was not surprising, however, considering the rapidity with which Bacteria and Monads were found to make their appearance in organic substances and infusions, that many men of science imagined them to be produced abiogenetically. The rapid multiplication of these forms means, of course, that a certain amount of fresh living protoplasm has been formed out of the constituents of

the hay-infusion, through the agency in the first instance of a single living Bacterium. The question naturally arises, Why may not the formation of protoplasm take place independently of this insignificant speck of living matter?

It must not be thought that this question is in any way a vain or absurd one. That living protoplasm has at some period of the world's history originated from not-living matter seems a necessary corollary of the doctrine of evolution, and is obviously the very essence of the doctrine of special creation (p. 198); and there is no *a priori* reason why it should be impossible to imitate the unknown conditions under which the process took place. But at present we are quite unable to solve this fundamental problem.

Experiments conducted with proper precautions, however, all tell the same tale: they prove conclusively that in putrescible infusions that have been properly *sterilized* —*i.e.*, thoroughly boiled so as to kill any organisms they may contain—and adequately protected from the entrance of atmospheric germs, no micro-organisms ever make their appearance. So that the last argument for abiogenesis has been proved to be fallacious, and the doctrine of biogenesis shown, as conclusively as observation and experiment can show it, to be of universal application as far as existing conditions known to us are concerned. It is also necessary to add that the presence of microbes in considerable quantities in our atmosphere has been proved experimentally.

CHAPTER IV

PHYLUM PROTOZOA—*continued*

MALARIAL PARASITES—CLASS SPOROZOA—CLASSIFICATION OF THE PROTOZOA

In another class of the Protozoa known as the *Sporozoa* parasitism occurs without exception, and the relation between parasites and host is much more intimate than in the case of parasitic forms referred to in previous chapters: instead of living within the enteric canal and merely absorbing the contained products of digestion, these penetrate into the tissues of the host, even passing into the interior of its cells, from the contents of which they absorb fluid nutriment. As is the rule in parasites, they are able to multiply very rapidly.

Sporozoan parasites occur in most classes of animals: many seem to be comparatively innocuous, so that even when infested with large numbers, the host apparently suffers no harm. In other cases they, like some other parasitic Protozoa (*e.g.*, the flagellate *Trypanosoma* in "sleeping sickness") and certain Bacteria, may cause dangerous diseases and epidemics. One of the dangerous and extremely widespread diseases is malaria, from which in India alone millions of people die every year; and millions more who escape death are weakened and injured by this disease. The symptoms of the disease are unfortunately too well known to need any description. Practically everyone in this country has had an attack of malarial fever, and has experienced for himself the

chill and the shaking of the body which mark the onset of the attack, the rise of temperature (fever), which is succeeded by the sweating stage, in which the body perspires freely, the temperature comes down to the normal, and the person is apparently healthy, but subject to subsequent attacks, unless remedial measures are adopted. The disease came to be called malaria, as it was formerly supposed to be due to the effect of bad air (Italian *mala*, bad; *aria*, air) in marshy districts or other places where collections of stagnant water abound after the rains. But it is now definitely known to be due to the existence of a Protozoan parasite in the blood.

Malarial Parasite.—This parasite has two hosts, viz., man and mosquito. In man, the parasite lives in the red blood-corpuscles. There are several types of malarial fever, and these are probably due to different species of the parasite. Three chief forms are generally recognized: *Plasmodium vivax*, found in tertian fever, the attacks of which recur every other day, *Plasmodium malariæ*, found in quartan fever, and *Plasmodium falciparum* (placed by some in a separate genus and then known as *Laverania malariæ*), which causes malignant tertian, or sometimes an irregular or quotidian fever. The three differ from each other in certain structural details and the time they take to complete their asexual reproduction, but otherwise the life-histories are quite similar.

Schizogony.—A certain number of minute parasites, in a condition in which they are known as *sporozoites*, are introduced into human blood by the bite of a mosquito of the genus *Anopheles*. The sporozoites are slender curved bodies, pointed at either end and with a thicker central portion containing the nucleus. Each sporozoite makes its way into a red blood-corpuscle, and once within the corpuscle it becomes rounded and

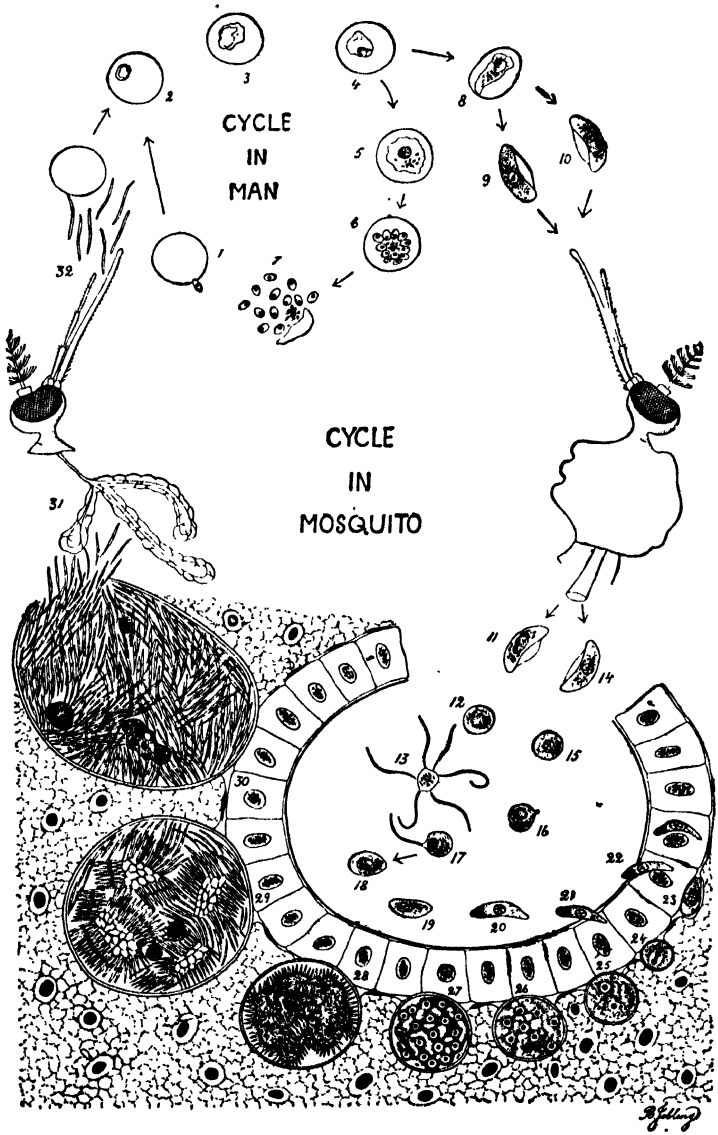


FIG. 82.—Life cycle of Malarial Parasite, *Plasmodium falciparum* in Man and the Mosquito. (After Wenyon.)

grows at the expense of the corpuscle. In the early stages, each has a large space in its body, probably caused by a vacuole which gives it a signet-ring appearance (Fig. 82, *3*) in fixed and stained preparations. As the parasite grows, the ring-like form is less evident; it becomes more compact and amœboid, and is known as the *trophozoite*. When full-grown, the trophozoite is spherical and almost as large as the corpuscle and proceeds to divide by a process of multiple fission known as *schizogony*. The nucelus divides into a number of nuclei which come to the surface, and the protoplasm constricts round these daughter nuclei to form a rosette (Fig. 82, *6*) of smaller parasites called *merozoites* surrounding the residual unused part of the schizont which contains all the pigment granules. The enfeebled blood-corpuscle can resist no longer and breaks up, and the merozoites are set free into the blood-stream. These enter as many uninfected corpuscles, develop into trophozoites, become schizonts, and repeat the rosette-formation.

The generic name *Plasmodium* given to these parasites is a very inappropriate one, as in no phase of their life-cycle do they become what is ordinarily understood in zoology by the term plasmodium (a multinucleate mass of protoplasm formed by a number of amœboid organisms coalescing together). Owing to the characteristic amœboid phase, the parasites are generally referred to as Hæmamœbæ (*haima*, blood), but it is unfortunate that the name plasmodium cannot be replaced by a more appropriate one. When first introduced, the number of parasites is small and no inconvenience is caused to the host (the man harbouring them in his blood). For about ten days this schizogonous multiplication goes on, till the number of infected corpuscles becomes so large that, on their breaking up,

toxic products are set free in the blood which cause an attack of fever. This period which elapses between the first introduction of the parasites into blood by the bite of a mosquito and their multiplication to such a degree as to be able to make their existence felt by the host and to cause the disease in him is called the incubation period. After the first attack of fever, there are successive attacks at each period of merozoite formation. The period for a schizogonous cycle for *P. vivax* is forty-eight hours, and for *P. malariæ* seventy-two hours, and relapses occur every other day in the case of "tertian" and every third day in the case of "quartan" fever. By repeated schizogony the number of parasites increases in a geometrical progression until a very large number of corpuscles are destroyed, the only natural check being the action of the leucocytes which destroy the merozoites. The well-known drug quinine also destroys the merozoites when they escape from the corpuscles and before they have safely ensconced themselves inside other corpuscles.

Conjugation.—After a number of asexual generations, some of the trophozoites develop into gametocytes—that is, cells which will give rise to gametes. In *P. falciparum* the gametocytes are elongated oval and slightly curved bodies, exceeding in length the diameter of the corpuscle, the remans of which are seen in the hollow of the gametocytes (Fig. 82, 9 and 10). These are familiarly known as "crescents," and are characteristic of pernicious malaria. The male progenitors or microgametocytes have a larger nucleus and lightly-staining cytoplasm, while the female progenitors, or macrogametocytes, have a smaller nucleus and dark-staining cytoplasm. The crescents appear to originate in the spleen and bone-marrow, but when fully developed are found in the superficial blood-vessels. Having freed

themselves from the remains of blood-corpuscles, they become oval and afterwards spherical. They do not get beyond the spherical stage in the human blood, and may be transferred to the stomach of the mosquito as crescents, ovals, or spheres. Unless these sexual forms are taken in by a mosquito they perish. If an anopheline mosquito sucks the blood of a malarious patient, the gametocytes persist and develop further. Should a gnat (*Culex*) suck infected human blood, the parasites in all their forms get digested.

The further development of the gametocytes and the process of conjugation take place in the stomach of the mosquito. In the male gametocyte the nucelus divides rapidly into four to six parts, which move to the surface of the parent cell. Then suddenly and with explosive violence the nuclei elongate, and with a small quantity of protoplasm form long, slender, motile bodies, the microgametes (Fig. 82, *13*). These microgametes move rapidly here and there, till they reach the female gamete. In the macrogametocyte the nucleus remains undivided, but gives off a small portion of its chromatin. The macrogametocyte thus gives rise to a single female gamete, which forms a small superficial protuberance or cone of attraction to receive one of the microgametes (Fig. 82, *16*). After the latter has entered into the substance of the macrogamete, its chromatin is seen to form a male pronucleus. The two pronuclei now unite, and as the result of the conjugation of two gametes, a zygote is formed (Fig. 82, *17*, *18*).

Sporogony.—The zygote becomes elongated and shows extraordinary activity. It moves actively over the inner surface of the stomach, and on account of its worm-like, gliding movements is designated a vermicule or *ookinete*. Gradually it bores its way through the epithelium of the stomach, and, reaching the tissue

outside the epithelium, becomes rounded and motionless, and secretes a cyst, but continues to grow in size. These cysts are seen forming small rounded projections on the external surface of the stomach of an infected mosquito (Fig. 83). The nucleus of the encysted zygote begins to divide, and division is repeated a great number of

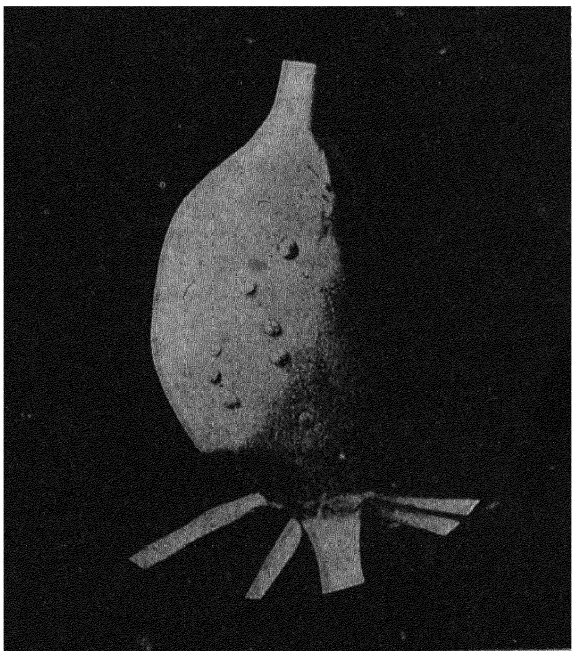


FIG. 83.—Stomach of an Infected Mosquito.

times. The cytoplasm develops vacuoles, till it becomes a sponge-like mass (Fig. 82, *26* and *27*). The minute nuclei pass to the surface, and in this way the cytoplasm becomes studded with protrusions. The nuceli undergo rapid and repeated divisions and finally produce an enormous number of slender. sickle-shaped bodies, which

when fully developed separate from the mass within (Fig. 82, *29*). Each tiny body so formed is called a *sporozoite*, and the cyst may contain thousands of these minute sporozoites, together with the rest of the cytoplasm and, in addition, a blackish pigment (melanin). Ultimately the cyst bursts and liberates the contained sporozoites into the body-cavity of the mosquito. The sporozoites travel in the body-fluids until they reach the salivary glands. The mosquito is now infective. Only the female mosquito sucks blood, as blood is required by it to furnish energy for propagation. When a female mosquito with sporozoites in its salivary glands pierces the skin of a human being, it injects into the puncture a drop of saliva containing numbers of sporozoites. Thus the mosquito not only sucks blood, but also spits into the wound, and to add injury to this insult further introduces the sporozoites of the malarial parasites. It takes about ten days for the cycle to be completed in the mosquito.

It will have been seen from the foregoing account of the life-history of the malarial parasite that it lives in the body of two hosts, firstly man, in whose blood it multiplies by schizogony, and secondly the mosquito, in whose body sexual forms are differentiated and conjugation is followed by sporogony. Of these two hosts, man is the intermediate host, and the mosquito the final or definitive host, since it is in this latter that the parasite undergoes sexual differentiation. At no period of its life does the parasite have a free existence. From mosquito to man and man to mosquito goes on the cycle.

History of the Discovery.—The complicated life-history of the parasite has been fully worked out through the combined labours of a large number of distinguished workers. In 1880, Laveran, a French army surgeon, discovered the parasites while examining the blood of a

malarial patient. Further search proved that these were always to be found in the blood of persons suffering from malaria, and the discovery of the parasites was confirmed by Golgi and other workers. Sir Patrick Manson had previously found the embryos of a parasitic worm known as *Filaria* in the tissues of the mosquito. So he made the suggestion that possibly in malaria also the parasites are introduced into the human body by the bite of a mosquito. Following his suggestion, Sir Ronald Ross (then Major in the Indian Medical Service, working at Secunderabad in Southern India) fed all the different kinds of mosquito procurable on blood of malarial patients, and then dissected and examined every part of their bodies to see if there was any trace of the parasites. Hundreds of mosquitoes were examined, but for two years (1895–97) no clue could be obtained. In 1897 he discovered pigmented cysts on the stomach of an Anopheline mosquito which had been fed on human blood containing crescents, and a year later, working with bird malaria, succeeded in elucidating the life-cycle of those parasites in Culex mosquitoes. The same year (1898) Grassi and his co-workers studied the complete development of the human parasite in an Anopheline mosquito, and they also succeeded in infecting a man with malaria by means of Anopheline mosquitoes. Manson (1900) also succeeded in infecting a man in London with malaria by means of anopheles imported from Italy. Last of all, to demonstrate that a bite from infected mosquitoes was the only source of infection, a party of two medical men with two other companions went and lived for four months in mosquito-proof houses in one of the most malarious districts in Italy and did not catch the infection, while practically every one in the neighbourhood was getting it.

Prevention of Malaria.—The problem of effectively

dealing with malaria is a great national problem in India, and the student who has acquainted himself with the life-cycle of the malarial parasite should feel interested to know the general principles on which all preventive measures are based. These are :—

(1) To kill the mosquitoes in all stages of their development (Chapter VII).

(2) To save ourselves from being bitten by the mosquitoes.

(3) To destroy the malarial parasites existing in the blood or other parts of the body of persons suffering from the disease.

(4) To kill the parasites that may happen to find their way into the blood of healthy individuals, and thus prevent their subsequent development and multiplication.

Class Sporozoa.—As mentioned before, the class Sporozoa includes organisms which are entirely parasitic —that is, can only live within the body of other animals. There are no free living forms among them. Like parasites belonging to other groups of the animal kingdom, they are degenerate, and have lost their organs of locomotion and food-capture. They absorb food in a liquid form only from the cells or tissues of their host, and neither food-vacuoles nor contractile vacuoles are present. They possess the power of prolific multiplication as a necessary adaptation for the maintenance of the species. Both asexual and sexual methods occur, and, as a rule, regularly recur, thus showing alternation of generations during the course of a more or less complicated life-history. The transference of the parasite from one host to another is effected by means of *spores*, which are thick-walled resistant bodies, containing one or more *sporozoites*, which infect the new host. In the majority of the Sporozoa (Gregarines, Coccidia) the spores are ingested with the food that has been contaminated with

the fæces in which the spores were passed out by an infected host. In other forms, however, as in the Malarial parasites, the asexual part of the life-cycle is passed in the blood of one host, and the sexual part in the body of a widely different host, usually a biting insect, which serves to inoculate or re-introduce the parasites into the blood of a host of the first kind. In such cases, sporozoites are not enclosed within a thick-walled cyst, as they are not subjected to the vicissitudes of the outside world.

Classification of the Protozoa.—Each of the organisms which we have studied in this and the three previous chapters consists of a single cell—or in the case of Volvox or Carchesium and Epistylis of a colony of cells to a large extent independent of one another. They are therefore placed in the lowest primary division of the animal kingdom—the phylum **Protozoa** (p. 197). This phylum is subdivided into a number of *classes*, examples of most of which we have examined.

Class **Sarcodina.** Protozoa devoid of cuticle and possessing pseudopodia. Amœboid form predominant. *Amœba, Entamœba.*

Class **Flagellata.** Protozoa covered with a cuticle and possessing one or more whip-like processes, called flagella. *Euglena, Volvox, Trypanosoma.*

Class **Ciliata.** Protozoa covered with a cuticle and possessing cilia.

Those wholly covered with cilia. *Paramecium, Opalina.*

Those with a single band of cilia. *Vorticella, Carchesium*, etc.

Class **Sporozoa.** Endoparasitic Protozoa devoid of cilia or flagella, in which spore-formation is the usual mode of reproduction. *Plasmodium.*

are in the form of little heaps of small, rounded pellets or balls, each distinct from the others, while those of *Eutyphœus* are large, tower-like structures. In this way a quantity of finely divided earth, mixed with the fæces of the worms, is constantly being spread out on the surface of the soil, and Darwin calculated that on an average a layer of earth about one-fifth inch in thickness, or about ten tons an acre, is thus brought to the surface in the course of a year. Earthworms are therefore good friends to the gardener and agriculturist, as they are continually ploughing and manuring the soil, and in doing so they gradually cover up stones and other objects lying on the surface.

Earthworms are generally nocturnal in habit, coming out at night to feed and conjugate, but retreating into their burrows during the day-time. *Pheretima* is a confirmed burrower, and is seldom seen on the surface of the ground. Earthworms generally inhabit a surface layer of twelve to eighteen inches of the earth, which is rich in organic matter, but in the summer descend deeper in search of moisture. Ordinarily they have to be dug out of the ground, but during the rains they come out of their burrows and are found creeping over the surface in large numbers.

External Features.—The body of the earthworm is long and narrow, approximately cylindrical in shape, and bilaterally symmetrical (p. 261), the form being well adapted to its burrowing habit. A full-grown specimen of *P. posthuma* is usually found to be four to six inches in length, and less than a quarter of an inch in diameter. Anterior end is pointed, posterior end more or less blunt, and its greatest diameter is reached a little way behind the anterior end. In the ordinary creeping movements of the animal, which are effected by the alternate contraction and extension of its body, the

anterior end is directed forwards. The colour is brown in most species, and is paler on the lower or ventral than on the upper or dorsal side which is further clearly recognizable by a dark median line running throughout the length of the body. The worms belonging to the genus Pheretima are very active, and some have the curious habit of protruding their buccal cavity beyond the anterior end of the worm.

The surface of the body is distinctly marked by transverse annular grooves into *body-segments* or *metameres* (Fig. 94, A), the number of which is about 100–120, more or less. This external segmentation corresponds with an internal segmentation of the body; but some of the anterior segments show a secondary annulation appearing bi- or even tri-annulate owing to superficial furrows. At the extreme anterior end is a conical fleshy lobe, the *prostomium*, which overhangs the *mouth*, situated on the antero-ventral surface of the first segment, which is therefore called the *peristomium*. The *anus* is a circular opening at the posterior end of the last or *anal segment*. The earthworm is thus a *metamerically segmented* animal, and the segments are serially homologous with one another (p. 34).

The whole of the body is invested with a delicate, iridescent membrane or *cuticle* (p. 279), formed as a secretion of the *epidermis* or outer epithelial layer of the body (p. 114). Every segment, except the first and the last, is provided with a large number (about 100) of very small cuticular bristles or *setæ* (Fig. 94, C)—slightly curved bodies with tapering ends, composed of a horn-like substance called *chitin* (compare p. 206)—each of which is developed in a small sac formed as an involution of the epidermis and is provided with muscles by means of which it can be protruded and retracted. These setæ are arranged on a distinct ridge encircling the middle of

each segment and form a continuous series round the segment. As the tips of these setæ point backwards a distinct roughness can be felt if a worm is drawn between

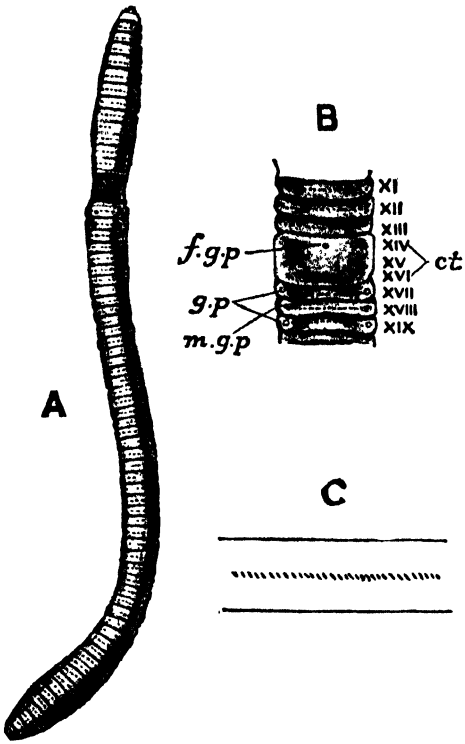


FIG. 94.—*Pheretima posthuma*, external characters. B.I.B.
A, ventral view of the entire animal; *B*, genital area of the ventral surface (further enlarged); *C*, skin of single segment spread out and seen under the microscope, showing the setæ arranged in an unbroken series.
ct. clitellum; *f. g. p.* female genital pore; *g. p.* genital papillæ; *m. g. p.* male genital pore. Roman numerals indicate the respective segments.

the fingers from the tail to the head end. They serve to prevent the animal from slipping backwards as it moves along on the surface of the ground or in its burrows.

In adult worms a prominent band of thickened and glandular skin encircles the body like a girdle and extends

over three segments, viz., fourteenth to sixteenth; this is known as the *clitellum* (Fig. 94, B, *ct*), and, as we shall see, it is important in the process of impregnation and in forming a case or *cocoon* for the eggs. The clitellum is not very different from the rest of the body in the living animal, but becomes very distinct in spirit-preserved specimens. The clitellum is quite smooth, since it is without setæ; in young specimens, however, three distinct rows of setæ can be seen on the clitellar segments also.

On the ventral surface of the segments following the clitellum are seen three pairs of papillæ in a series. Those on the eighteenth segment bear the *male genital pores* (Fig. 94, B, *m. g. p.*). The other pairs situated on the seventeenth and the nineteenth segments in a line with the male pores, are simply cup-shaped depressions of the body-wall known as *genital papillæ* (*g. p.*). The *female genital pore* (*f. g. p.*) is a small median opening situated on the ventral surface of the first clitellar segment. In addition to the openings mentioned above may be seen four pairs of small *spermathecal pores* situated ventro-laterally in the furrows between the fifth and sixth, sixth and seventh, seventh and eighth, and eighth and ninth segments. These are openings of sperm-sacs (see p. 319) into which spermatozoa are passed during copulation. The occurrence and arrangement of genital papillæ, and the number of spermathecæ, differ widely in different species of Pheretima. Situated in the middle dorsal line, in the grooves between all the segments except the first twelve, are a series of *dorsal pores*, by which the body-cavity communicates with the outside. Scattered irregularly all over the surface of the body are very minute openings of the excretory tubules or nephridia, known as *nephridiopores*, which can only be seen in thin sections examined under the microscope.

General Plan of Structure.—We have seen that the earthworm takes in its food, together with quan-

cellular *cuticle* (*c.*). Next comes the *epidermis* (*ep.*) which consists of different kinds of epithelial cells, including gland-cells for secreting mucus which keeps the skin moist. Within this a very thin connective-tissue layer and a double layer of *muscle-fibres* by means of which the movements of the body are produced—an outer, in which the fibres extend transversely round the body (*c. m.*), and a much thicker inner layer consisting of longitudinal fibres, in section seen as bundles of fibres which have been cut across (*l. m.*). Finally, within the muscular layer and lining the cœlome is a thin layer of cells, the parietal layer of the *cœlomic epithelium.*

A transverse section of the intestine shows an inner layer of columnar *intestinal epithelium* (*i. ep.*) (compare p. 117), a very thin middle layer composed of muscle-fibres and connective-tissue, and an outer layer of cells forming the visceral layer of cœlomic epithelium. These cells are believed to take up excretory substances from the blood-capillaries of the gut and store them as yellow granules. They are therefore known as *yellow cells.* When full, the cells fall off into the cœlome and the excretory matter is got rid of through the nephridia or the dorsal pores.

We are now in a better position to compare the transverse section of the Hydra and the earthworm. The epidermis of the earthworm being the outermost cell-layer is to be compared with the ectoderm of Hydra, and its cuticle with the layer of the same name which, though absent in Hydra, is present in the stem of hydroid polypes, such as Obelia (viz., the perisarc). The intestinal epithelium of the earthworm, bounding as it does the digestive cavity, is clearly comparable with the endoderm of Hydra. So that we have the two layers of muscle-fibres and the two layers of cœlomic epithelium not represented in Hydra, in which their

muscle-fibres are not of the striped kind, like those in the corresponding position in the frog (p. 118).

But it will be remembered that in Medusæ there is sometimes found a layer of separate muscle-fibres between the ectoderm and the mesoglœa, and it was pointed out (p. 277) that such fibres represented a rudimentary intermediate cell-layer or mesoderm. We may therefore consider the muscular layer and the cœlomic epithelium of the earthworm as mesoderm, and we may say that in this animal, as in the frog (p. 182, and Fig. 67), the mesoderm is divisible into an outer or *parietal layer*, and an inner or *visceral layer*.

The parietal layer is in contact with the ectoderm, and with it forms the body-wall; the visceral layer is in contact with the endoderm or intestinal epithelium, and with it forms the alimentary canal. The cœlome separates the parietal and visceral layers from one another, and is lined throughout by cœlomic epithelium.

The relation between the diploblastic polype and the triploblastic worm may therefore be expressed in a tabular form as follows:

Hydroid.		*Earthworm.*[1]
Cuticle		Cuticle.
Ectoderm		Epidermis.
Mesoderm (rudimentary)	Parietal layer	Connective-tissue and muscle-fibres.
		Cœlomic epithelium (parietal layer).
	Visceral layer	Cœlomic epithelium (visceral layer).
		Connective-tissue and muscle-fibres.
Endoderm		Intestinal epithelium.

[1] It will be seen that the relations of these layers in the earthworm and frog are similar, except that in the latter the cuticle is wanting (compare Figs. 6, 41, and 42).

Strictly speaking this comparison does not hold good of the anterior and posterior ends of the worm: at both mouth and anus the epidermis passes insensibly into the enteric epithelium, and the study of development shows that the cells lining both the anterior and posterior ends of the canal are ectodermal (compare pp. 180 and 183).

It is important that you should, before reading further, understand clearly the general composition of a triploblastic animal as typified by the earthworm, which may be summarized as follows. It consists of two tubes formed of epithelial cells, one within and parallel to the other, the two being continuous at either end of the body where the inner tube (enteric epithelium) is in free communication with the exterior; the outer tube (epidermis) is lined by a layer of connective-tissue, muscle-fibres, and cœlomic epithelium, all these together forming the body-wall; the inner tube (enteric epithelium) is covered externally by a layer of muscle-fibres, connective-tissue and a thin cœlomic epithelium, which form with it the wall of the alimentary canal; lastly, the body-wall and alimentary canal are separated by a considerable space, the cœlome.

Cœlome.—The alimentary canal is not, as might be supposed from the foregoing description, connected with the body-wall only at the mouth and anus, but is supported in a peculiar way. There is no dorsal mesentery as in the frog (p. 25), but a series of transverse vertical partitions or *septa* (Fig. 96) extends right across the body-cavity, each being perforated by the canal. The septa are regularly arranged and correspond in position with the external grooves by which the body is divided into metameres. Thus the transverse or metameric segmentation affects the cœlome as well as the body-wall, the former being divided up into a series of chambers,

which, however, communicate with each other ventrally by an aperture surrounding the nerve-cord. The septum between the fourteenth and the fifteenth segments and all the following septa are also riddled with numerous minute apertures (Fig. 100, *s. a.*) which are surrounded by sphincter muscles, by closing which the cœlomic fluid can be restricted to particular segments, making those segments turgid in order to secure a firm leverage of the setæ on the soil to help locomotion. There are no septa in the first segments; the first definite septum, thin and membranous, is between the fourth and fifth segments. The next five septa, *i.e.*, between the fifth and sixth, sixth and seventh, seventh and eighth, eighth and ninth *or* ninth and tenth, and tenth and eleventh, are thickened and muscular. One of the septa, either between the eighth and ninth or between the ninth and tenth segments, is absent. These six anterior septa are not transverse, but oblique, forming six cones, one within the other, with their apices directed backwards. Each septum is composed of a sheet of connective-tissue and muscle-fibres, and is covered on both sides by cœlomic epithelium. The cœlome communicates with the exterior by the dorsal pores.

The cœlome is filled with a colourless transparent *cœlomic fluid* in which are suspended amœboid corpuscles or phagocytes, circular non-granular cells, elongated mucous-secreting cells, and yellow cells in various stages of degeneration. The function of this cœlomic fluid is phagocytic and excretory. The worm ejects the fluid through the dorsal pores and kills off myriads of bacteria of the soil which would otherwise settle and grow upon its body. The degenerating yellow-cells and other products of excretion are carried to the mouths of the nephridia, or got rid of directly by the flow of the cœlomic fluid through the dorsal pores. The fluid also

serves to keep the skin moist and thus help in respiratory exchange.

There is a series of small whitish bodies, known as *lymph-glands* (Fig. 96, *ly. gl.*), lying upon the intestine on either side of and close to the dorsal vessel, a pair in the twenty-sixth and every succeeding segment.

Each consists of lobules containing masses of phagocytes and a few yellow cells, etc. The phagocytes of the cœlomic fluid are believed to originate in these glands and also return to them from the cœlomic cavity.

Digestive System.—The digestive canal is not a simple tube of even calibre throughout, but is divisible into several portions. The mouth lies in the first or buccal segment ventral to the prostomium and leads into a small thin-walled *buccal sac* which communicates with a thick-

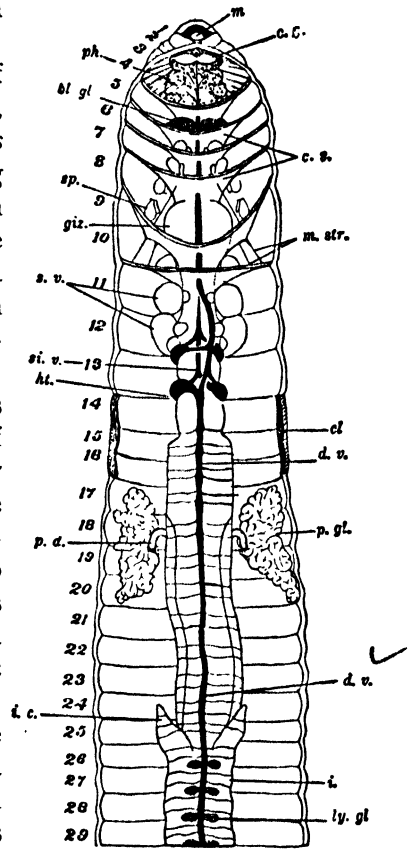


FIG. 96.—*Pheretima posthuma*, dissection of the anterior region of the body.

bl. gl. blood glands; *c. g.* cerebral ganglia; *cl.* clitellum; *c. s.* cone-shaped septa; *d. v.* dorsal vessel; *giz.* gizzard; *ht.* heart; *i.* intestine; *i. c.* intestinal coeca; *ly. gl.* lymph glands; *m.* mouth; *m. str.* muscular strand; *p. d.* prostatic duct; *ph.* pharnyx; *p. gl.* prostate gland; *s. v.* seminal vesicles; *si. v.* supra-intestinal vessel; *sp.* spermatheca. (After Karm Narayan Bahl.)

walled *pharynx* (*ph.*) extending slightly beyond the fourth segment, and connected with the body-wall by a number of radially arranged muscle-fibres, the septa being absent in this region. When the worm feeds, the buccal chamber is everted, and the muscles serve to draw it and the pharynx back again, as well as to dilate the pharynx. The buccal chamber is marked off from the pharynx by a groove in which the supra-pharyngeal nerve ganglia (*c. g.*) lie dorsally. The pharynx is compressed dorso-ventrally owing to the presence dorsally of the *pharyngeal mass*. This pharyngeal mass consists of peculiar, irregularly-shaped deeply-staining glandular cells penetrating for some distance between crossing and interlacing muscular fibres which form the main portion of the mass. The glandular portion of the pharyngeal mass secretes a salivary secretion which is conducted into the lumen of the pharynx. The pharynx is followed by a narrow *gullet* or *œsophagus* extending through the fifth, sixth, and seventh segments, and becoming enlarged into a round body with thick muscular walls called the *gizzard*; this is placed in the eighth segment, or occupies both the eighth and ninth segments in those specimens in which the septum between the two segments is wanting. From the gizzard the œsophagus is continued back to the fourteenth segment, where it passes into a wider tube, the *intestine* (*i*), which runs in a straight line to the anus. The soft portion of the œsophagus as well as the intestine is constricted where it passes through the septa. In the twenty-sixth segment a pair of conical pouches, known as *intestinal cœca* (*i. c.*), are given off from the intestine and extend forwards through three or four segments. Extending from the twenty-sixth segment to twenty-three or twenty-five segments in front of the anus, the dorsal wall of the intestine is folded inwards

so as to produce a longitudinal ridge or *typhlosole* (Fig. 95, *ty*), which serves to increase the absorptive surface. The surface of the intestine is covered over by the *chloragogen* or *yellow cells*, which are considered to perform an excretory function.

A large quantity of earth has to be swallowed to provide the necessary amount of organic matter. The salivary secretion poured into the pharynx lubricates the food and the contained ferment starts the digestion of the proteins. The food is ground down to a fine state of division in the gizzard. Certain of the cells lining the intestine, and especially those along the typhlosole, secrete a digestive juice containing several kinds of ferments, one of which converts proteins into peptones, another converts starch into sugar, and a third splits fats. The digested food is absorbed by the intestinal epithelium and passes into the blood. The process is purely extra-cellular or enteric, the food being dissolved and rendered diffusible entirely in the cavity of the canal (p. 271). By the movements of the canal—caused partly by the general movements of the body and partly by the contraction of the muscles of the canal and septa—the contents are gradually forced backwards, and the earth and other indigestible matters expelled at the anus.

Vascular System.—The earthworm, like the frog, possesses a series of *blood-vessels*, containing red blood, the whole of which form a single closed vascular system, there being no communication between them and any of the other cavities of the body. The main trunks have a longitudinal direction, the chief ones being a large *dorsal vessel* (Figs. 97 and 98, *d. v.*), running along the dorsal surface of the alimentary canal, a *ventral* or *sub-intestinal vessel*, below the canal (*v. v.*), and a smaller *sub-neural* (*sn. v.*) running ventral to the nerve-cord, the last named extending from the posterior end of the

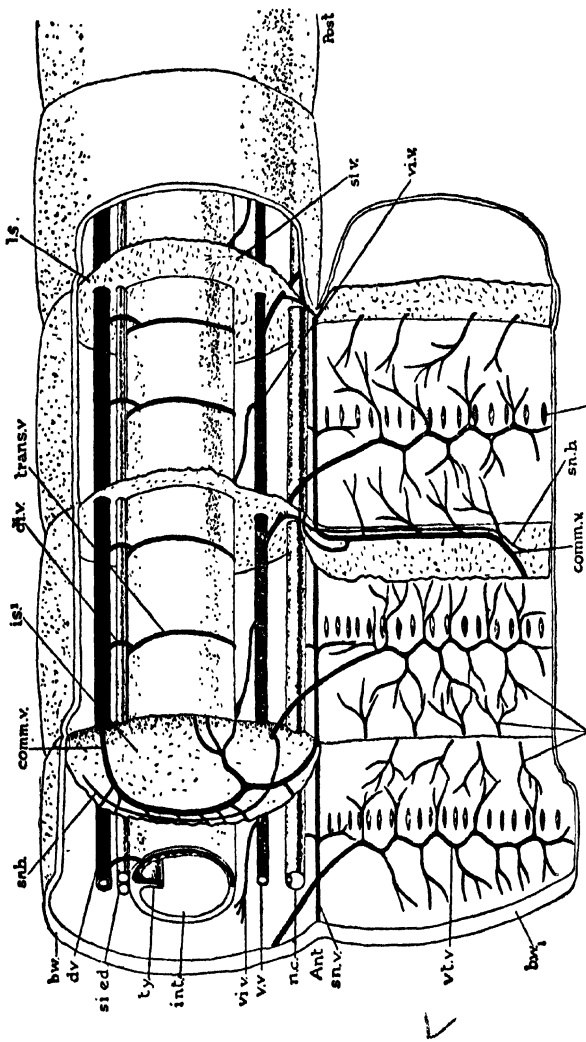


FIG. 97.—A diagrammatic representation of the circulatory system in the region of the body behind the fourteenth segment. Five segments are shown with the greater part of the body-wall on the left side cut and reflected in order to show the blood-vessels, *b.w*, body-wall; *b.w*$_1$ reflected body-wall; *comm. v.* commissural vessel; *d. v.* dorsal vessel; *dt. v.* dorso-intestinal vessel; *int.* intestine; *i. s.*^{1} intersegmental septum; *i. s.* intersegmental septum turned forwards; *int. v.* vessels supplying the body-wall; *n.c.* nerve-cord; *s. d.* supra-intestinal excretory ducts; *si. v.* branches from the commissural to the gut-wall; *sn. v.* subneural vessel; *sn. b.* vessel supplying septal nephridia; *s. s.* setal sac; *ty.* typhlosole; *trans. v.* transverse vessel; *v. v.* ventral vessel; *vi. v.* vessel to the intestine; *vt. v.* vessel to the body-wall. (After Karm

worm to the fourteenth segment anteriorly. All these longitudinal trunks give off branches to the various parts of the body. The subneural is connected with the

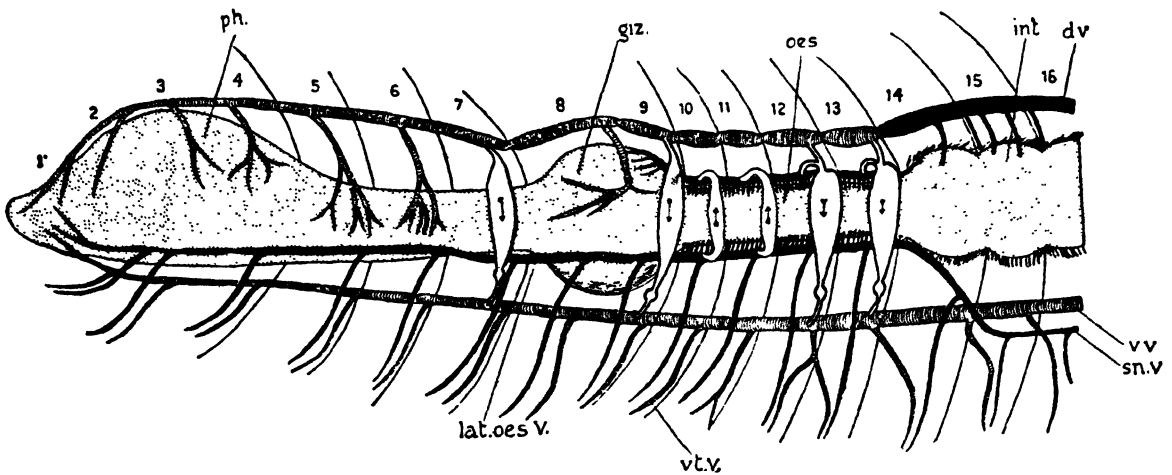


FIG. 98.—A diagrammatic representation of the blood-vessels in the first sixteen segments, *d. v.* dorsal vessel; *giz.* gizzard; *int.* intestine; *lat. œs.* lateral œsophageal vessel; *œs.* œsophagus; *ph.* pharynx; *sn. v.* subneural vessel; *v. v.* ventral vessel; *vt. v.* vessel to the body-wall. Numerals indicate the segments. The "hearts" lie in the seventh, ninth, twelfth and thirteenth segments, and the "anterior loops" in the tenth and eleventh segments. (After Karm Narayan Bahl.)

dorsal by a pair of lateral *commissural vessels* (Fig. 97, *comm. v.*) in each segment, and there are two pairs of *transverse vessels* (*trans. v.*) in each segment which encircle the gut and open into the dorsal vessel by small *dorso-intestinal vessels* (*di. v.*).

The blood flows forwards in the dorsal vessel and backwards in the ventral and subneural vessels. In the region of the body behind the first fourteen segments, the dorsal vessel acts merely as a channel for collecting and propelling the blood forwards. The ventral vessel is the chief distributing channel throughout the body. Its branches supply blood to the body-wall, nephridia and other structures lying in the body-cavity, and by a short unpaired vessel in each segment directly to the wall of the gut. The blood is returned from these parts to the subneural and from that into the commissurals or directly to the commissurals, and thus gets back in either case into the dorsal vessel. The blood from the gut-wall is returned more directly through the dorso-intestinals.

In the first fourteen segments of the body, the circulation of the blood is on different lines from that in the rest of the body. The dorsal vessel, instead of functioning as a receiving channel, here becomes a great distributing trunk. It sends out blood into four pairs of rhythmically contractile " hearts," which are situated in the seventh, ninth, twelfth and thirteenth segments, and pump the blood into the ventral vessel. The dorsal vessel also supplies the blood, by paired branches, to the gizzard, the pharynx and the pharyngeal nephridia. The ventral vessel continues to be a distributing channel and supplies the body-wall, the integumentary nephridia, spermathecæ, seminal vesicles, ovaries, etc. It does not, however, supply blood to the gut, as the latter is in this region supplied by the dorsal vessel. The sub-

neural vessel on entering this region bifurcates into two *lateral œsophageals* (Fig. 98, *lat. œs. v.*) which are running on the right and left of the alimentary canal, and attached to its walls in the region of the œsophagus. The blood from the gut, nephridia and reproductive organs is returned to the lateral œsophageals. These empty into the main stream through the "anterior loops" situated in the tenth and eleventh segments, and the supraœsophageal vessel, which extends from the tenth to the thirteenth segments, and communicates in its turn with the two posterior pairs of "hearts" situated in the twelfth and the thirteenth segments. The blood returned to the lateral œsophageals is thus passed into the ventral vessel, or flows backwards into the subneural and passes through the commissurals into the dorsal vessel, in the region posterior to the fourteenth segment. The blood-vessels thus form a continuous though somewhat complicated circulatory system.

The red colour of the blood is due to *hæmoglobin* (p. 100), which is not, as in the frog, contained in red blood-corpuscles, but is dissolved in the plasma, in which, however, minute colourless corpuscles can be recognized.

Respiration.—In the earthworm, as in many other lower animals, there are no specialized respiratory organs (lungs or gills), the necessary exchange of gases taking place through the skin, which is thin and has a rich blood-supply. The minute branches of the blood-vessels in the body-wall are only separated from the air by the single layer of epidermal cells. Exchange of gases can effectively take place when the skin is moist. The skin is kept moist by contact with damp earth, by the secretion of mucus by its glandular cells, and by the cœlomic fluid which oozes out through the dorsal pores. An earthworm is unable to breathe, and dies after some hours, if its skin dries up.

Excretory System.—In discussing in a previous chapter the differences between plants and animals (p. 222), we found that in the unicellular organisms previously studied the presence of an excretory organ in the form of a contractile vacuole was a characteristic feature of such undoubted animals as Amœba and many other Protozoa. But you will have noticed that Hydra and its allies have no specialized excretory organ, waste-products being apparently discharged from any part of the surface. In the earthworm we meet once more with an animal in which excretory organs are present, although, in correspondence with the complexity of the animal itself, they are very different from the simple contractile vacuoles of Paramecium or

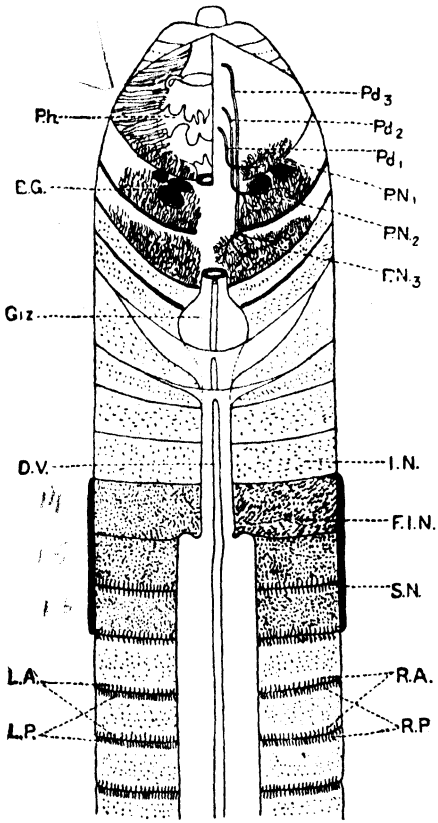


FIG. 99.—The general plan of the nephridial system in *Pheretima posthuma*.
S.N. septal nephridia; R.A., R.P. L.A., L.P. right and left anterior and posterior series of septal nephridia; I.N. integumentary nephridia; F.I.N. "forests" of integumentary nephridia; $P.N._1$, $P.N._2$, $P.N._3$ pharyngeal nephridia of the fourth, fifth, and sixth segments displayed after removing the septa between these segments; Pd_1., Pd_2., Pd_3. ducts of the pharyngeal nephridia; B.G. blood glands; Ph. pharynx; Giz. gizzard; D.V. dorsal vessel. (After Karm Narayan Bahl.)

Vorticella, and are more nearly comparable with those of the frog (p. 129).

The excretory organs in most kinds of earthworms are little tubes called *nephridia*, of which each metamere—with few exceptions—generally possesses a pair, one on either side. You will remember that in the frog all the urinary tubules are connected together to form a pair of kidneys, each with a single duct communicating with the cloaca. In the common European earthworm (*Lumbricus*) and among other genera in *Helodrilus*, which is fairly commonly found in India, the excretory organs are of the *meganephric type*, that is, each nephridium is a long and extremely delicate tube, arranged in three main loops, opening at one end into the cœlome by a *nephrostome* and at the other communicating with the exterior directly.

In Pheretima the excretory organs are of a different type. Instead of two distinct tubes in each segment, there are a large number of extremely fine tubules situated mostly on the septa and the inner surface of the body-wall (Fig. 99). Altogether, there are three different sets, named, according to their position, the *septal* (S.N.), the *pharyngeal* (P.N.$_1$, P.N.$_2$, P.N.$_3$), and the *integumentary* (I.N.). The septal nephridia are attached on both sides (R.A., R.P., L.A., L.P.) of all the septa behind the fourteenth segment. They do not open on the external surface of the earthworm, but communicate, through a pair of septal excretory canals (Fig. 100, *s. e. c.*) situated on each septum, with a pair of supra-intestinal excretory ducts (*si. e. d.*) running longitudinally near the mid-dorsal line below the dorsal blood-vessel. These longitudinal excretory ducts communicate segmentally with the lumen of the gut, through which the excretory products due to the activity of the nephridia would seem to be passed out. The number of

septal nephridia in each cœlomic chamber is from 80 to 100. The pharyngeal nephridia occur in tufts and surround the œsophagus in the fourth, fifth, and sixth segments. These open by long muscular ducts (Fig. 99, Pd_1, Pd_2, Pd_3) into the pharynx and buccal cavity of the worm. The septal and pharyngeal nephridia are

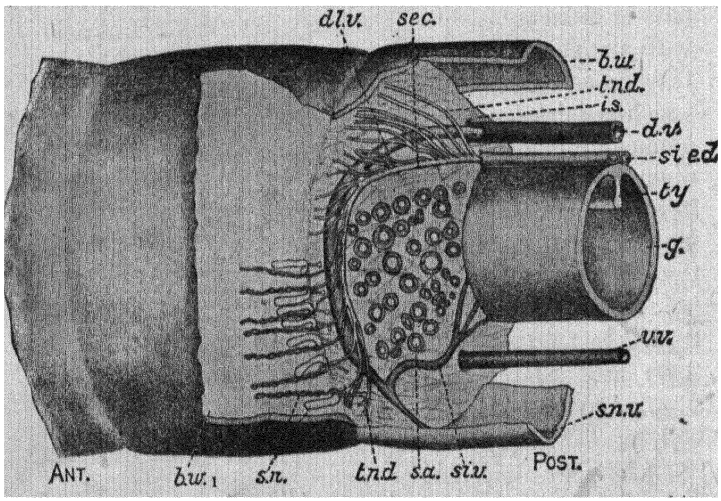


FIG. 100.—A diagrammatic representation of the septal nephridial system and its relative position in *Pheretima posthuma*. Three segments are shown, and part of the skin on the left side of the posterior (third) segment has been cut and reflected forwards so as to lie on the second segment, in order to expose the various structures.

b.w. body-wall; *b.w.*$_1$ body-wall cut and reflected forwards; *i.s.* intersegmental septa; *s. a.* sphincter ed apertures in the septum; *g.* gut; *ty.* typhlosole; *d. v.* dorsal vessel; *dl. v.* dorso-lateral vessel or the "septal loop"; *s. a.* sphinctered apertures; *si. v.* septo-intestinal vessel; *sn. v.* subneural vessel; *v. v.* ventral vessel; *s. n.* septal nephridia; *t. n. d.* terminal nephridial ducts; *s. e. c.* septal excretory canal; *si. e. d.* supra-intestinal excretory ducts. (After Karm Narayan Bahl.)

described as belonging to the *enteronephric type*, as they pour their secretion into the alimentary canal, instead of the exterior. This arrangement is believed to be an adaptation for the conservation of water which would otherwise be lost to the earthworm living in a dry climate. The integumentary nephridia are less than half the size

of the septal, but very much more numerous, and are attached to the inside of the body-wall. They open directly to the exterior by numerous nephridiopores.

Each septal nephridium (Fig. 101) consists of (i) a funnel (F.), followed by a short narrow tube (F.N.T.), which is bent on itself before joining the body of the nephridium, (ii) the main body of the nephridium consisting of a short straight lobe (S.L.) and a long spirally twisted loop (S.T.L.). The straight lobe is rounded at its free end, and is continued at its other into one of the limbs of the long twisted loop, which is more than twice the length of the straight lobe; and (iii) a terminal nephridial duct (T.N.D.), which is a continuation of the other limb of the twisted loop, and leads from the nephridium to the septal excretory

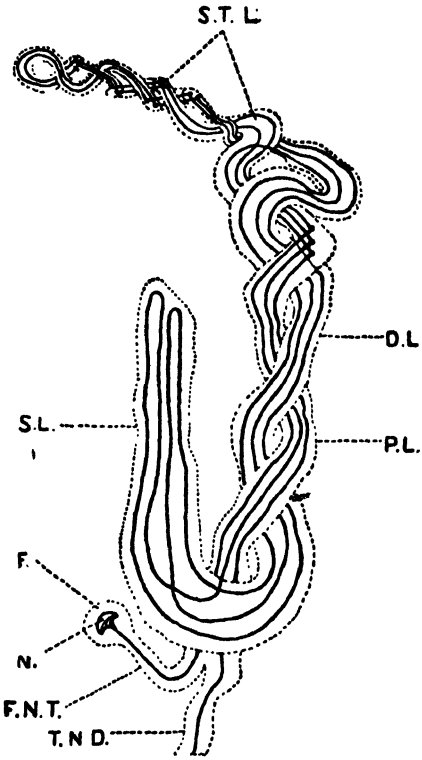


FIG. 101.—A septal nephridium showing the course of the nephridial tube in it (diagrammatic). The dotted line represents the outline of the nephridium and the thick black line the nephridial tube.

F. funnel; F.N.T. the first free part of the nephridial tube; N. nephrostome; S.L. the short straight lobe; S.T.L. the spirally twisted loop; P.L. the proximal limb, and D.L. the distal limb of the twisted loop; T.N.D. the terminal nephridial duct going to the septal excretory canal. (After Karm Narayan Bahl.)

canal (Fig. 100, *s. e. c.*). The whole nephridium, including its funnel, hangs freely in the cœlomic cavity, and is solely attached to the septum near its outer edge by means of the terminal nephridial duct, which runs along the septum obliquely to join the septal excretory canal (Fig. 100).

The nephridia are abundantly supplied with blood-vessels, and are lined in part by gland-cells and in part by cilia which work towards the exterior. Water and nitrogenous waste from all parts of the body pass by diffusion into the blood and are conveyed to the nephridia, the gland-cells of which withdraw the waste products and pass them into the cavities of the tubes, whence they are finally discharged from the body. Waste matter in the cœlomic fluid also passes through the nephrostomes into the nephridia.

Nervous System.—In discussing the hydroid polypes we found that one of the most important points of difference between the locomotive medusa and the fixed polype was the presence in the former of a well-developed nervous system (p. 285) consisting of an arrangement of peculiarly modified cells, to which automatic action was seen to be due. It is natural to expect in such an active and otherwise highly organized animal as the earthworm a nervous system of a considerably higher degree of complexity than that of a medusa.

The central nervous system (Figs. 95, 96, and 102) consists of two parts, the *brain* and the *ventral nerve-cord*. The brain consists of a pair of white pear-shaped swellings known as *cerebral* or *supra-pharyngeal ganglia* (Fig. 102, *c. g.*) situated on the dorsal side of the junction of the buccal sac and the pharynx. The ventral nerve-cord is a longitudinal band extending along the whole middle ventral line of the body, internally to the longitudinal muscular layer, from the third to the anal seg-

ment, and slightly swollen in each segment. The brain is connected with the anterior end of the ventral nerve-cord by a pair of nervous bands, the *circumpharyngeal connectives* (Fig. 102, *comm.*), which pass respectively right and left of the pharynx and thus form a *nerve-collar*. In transverse sections (Fig. 95) the nerve-cord (*v. n. c.*) is seen to be composed of two longitudinal cords surrounded by a common sheath. This is due to the fact that during development there are two distinct laterally situated cords which gradually approach each other and fuse together in the middle line to form the double ventral nerve-cord of the adult.

It is to be noted that one division of the central nervous system—the brain—lies altogether above and in front of the alimentary canal, the other division—the ventral nerve-cord—altogether beneath it; and that, in virtue of the union of the two divisions by the circum-pharyngeal connectives, the alimentary canal perforates the nervous system. Both brain and cord are composed of delicate nerve-fibres and nerve-cells, the latter being situated in the ventral and lateral regions of the cord along its whole length, so that there is here hardly any distinction into ganglia and connectives, although the swellings are often spoken of as ganglia. Along the dorsal side of the cord, as seen in transverse sections, are three transparent tube-like structures, known as *giant-fibres* which are outgrowths of large nerve-cells and serve for the rapid transmission of impulses through the whole length of the cord (Fig. 102). The whole cord is enclosed in a sheath consisting of connective-tissue.

The peripheral nervous system consists of a number of nerves, both sensory and motor (p. 156), which arise from the central nervous system and supply the various parts of the body. From each cerebral ganglion two nerves are given off to the prostomium and the buccal

sac, the first two segments are supplied by nerves from the circumpharyngeal connectives, and the third and fourth by nerves from the sub-pharyngeal ganglia. From each ganglionic enlargement two pairs of nerves can be traced into the body-wall and the vicera.

Comparing the nervous system of the earthworm with that of a medusa, it is important to notice the concentration of the central nervous system in the higher type, and the special concentration at the anterior end of the body to form a brain. When, again, we compare the central nervous system of the earthworm with that of the frog (pp. 26 and 136) several important points of difference are noticeable. In the former it lies freely in the cœlome, and, with the exception of the brain, is situated on the ventral side of the body; while in the frog it is enclosed in a neural canal and is dorsal in position. The brain of the frog is a complicated structure, and the whole nervous system is hollow, there being ventricles in the brain and a central canal in the spinal cord; while in the earthworm the brain consists merely of a pair of cerebral ganglia, and the brain and the ventral cord are both solid.

The whole nervous system is capable of originating automatic action. It is a well-known fact that if the body of an earthworm is cut into several pieces each performs independent movements; in other words, the whole body is not, as in the higher animals, paralysed by removal of the brain (p. 157). There can, however, be little doubt that complete co-ordination, *i.e.*, the regulation of the various movements to a common end, is lost when the brain is removed.

The earthworm is devoid of organs of sight or hearing. It exhibits sensitiveness to bright light, for which special nerve-endings or *receptors* are found in the epidermis, particularly on the prostomium, and the peristomium.

The sense of hearing appears to be absent. A faculty analogous to taste or smell enabling the animal to distinguish between different kinds of food is well developed, and for this purpose there are groups of cells or receptors on the epithelium of the buccal sac. The sense of touch, including the perception of vibrations of the ground, is the most highly developed. Groups of narrow cells, known as tactile receptors, are found in the epidermis all over the body.

There are two matters of general importance in connection with the structure of the earthworm to which special attention must be drawn.

Notice in the first place how in this type, far more than in Hydra, we have, as in the frog, certain definite parts of the body set apart as *organs* (p. 28) for the performance of particular functions: it is clear that differentiation of structure and division of physiological labour play a far more obvious and important part than in any of the lower organisms described in the previous chapters.

Notice in the second place the vastly greater complexity of microscopic structure, the body being divisible into *tissues* (p. 112), each clearly distinguishable from the rest. We have epithelial tissue with its cuticle, muscular tissue, and nervous tissue, as well as blood and cœlomic fluid. One result of this is that, to a far greater extent than in Hydra, we can study the morphology of the earthworm, as we have done that of the frog, under two distinct heads: *anatomy* and *histology* (p. 97).

Regeneration.—Asexual reproduction does not take place normally in the earthworm, but it frequently happens by accident that a worm is cut into two or more parts. When this occurs, each end is able to re-

produce the missing portion: this process is known as *regeneration* (compare p. 272).

Reproductive System.—The earthworm, like Hydra, is hermaphrodite (p. 272), and besides the essential organs of sexual reproduction—ovaries and spermaries—which are, as in the frog, developed from certain parts of the cœlomic epithelium (p. 299), it possesses various accessory organs. The whole reproductive apparatus is situated in segments 6–21.

Female Organs.—The *ovaries* (Fig. 102, *ov*) are a pair of minute bodies about 1 mm. in length, attached by their bases, one on either side, to the posterior face of the septum separating segments 12 and 13, not far from the nerve-cord. Under a microscope the proximal end of each ovary, nearest the stalk, is seen to be composed of a mass of undifferentiated cells of *germinal epithelium* (compare Figs. 64 and 65): nearer its middle certain of these increase in size so as to be recognizable as young ova: while the distal end consists of a number of separate filaments, each of which resembles a string of beads and contains the ripe ova, each enclosed in a vitelline membrane and containing a large nucleus and nucleolus and a number of granules of food-yolk (p. 175). The eggs are discharged into the cœlome and are received into the *oviducts* (Fig. 102, *ovd*)—two short tubes, each with a funnel-like mouth with much-folded margins, placed opposite the corresponding ovary. The oviducts perforate the next following septum (*i.e.*, that between segments 13 and 14) and converge to meet beneath the nerve-cord and open by a single minute aperture on the fourteenth segment in the mid-ventral line

Certain sacs called *spermathecæ* (Figs. 96, *sp*, 102) also belong to the female part of the reproductive apparatus. Of these there are usually four pairs in this species situated in the sixth, seventh, eighth, and ninth segments,

and opening to the exterior on the ventral surface in the grooves between the fifth and sixth, sixth and seventh,

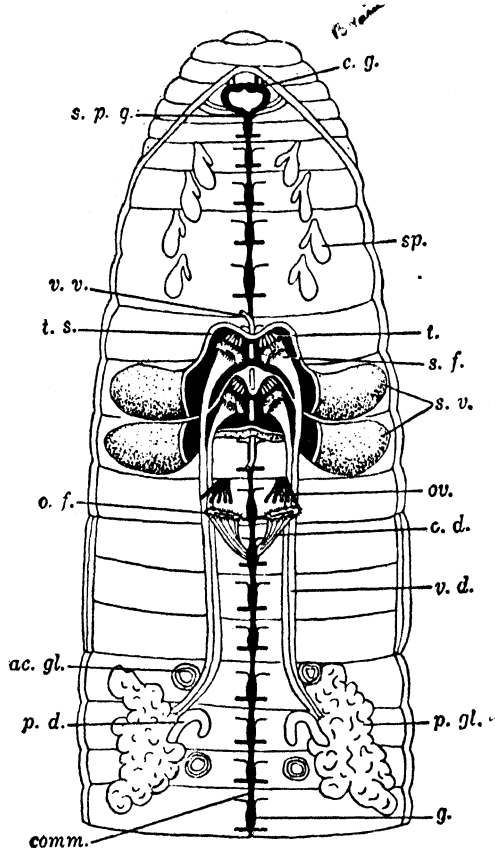


FIG. 102.—*Pheretima posthuma*, dissection of the nervous and reproductive systems. *ac. gl.* accessory gland; *c. g.* cerebral or supra-pharyngeal ganglia; *comm.* the fused commissures and *g.* ganglia of the ventral nerve-cord; *o.d.* oviduct; *o. f.* funnel of oviduct; *ov.* ovary; *p. d.* common prostatic and spermatic duct; *p. gl.* prostate gland; *s. f.* seminal funnel; *s. v.* seminal vesicles; *sp.* spermatheca with its diverticulum; *s.p. g.* sub-pharyngeal ganglia; *t.* testis; *t. s.* testis-sac; *v. d.* vasa deferentia; *v. v.* ventral blood-vessel. (After Karm Narayan Bahl.)

seventh and eighth, and eighth and ninth segments respectively. Each spermatheca consists of a pyriform

sac which is continued into a duct, from which a narrow diverticulum is given off. The spermathecæ store the spermatozoa received from another earthworm during copulation.

Male Organs.—The most prominent portion of the reproductive apparatus are certain large, whitish, sac-like bodies, the *seminal vesicles* (Fig. 102, *s. v.*), situated on both sides of the œsophagus in the eleventh and twelfth segments. Ventral to the œsophagus, and seen on carefully removing the latter, are two pairs of *testis-sacs* (*t.s.*) in the tenth and eleventh segments. The cavities of the testis-sacs in each segment are continuous, and communicate laterally with the seminal vesicles in the segment next behind. The cavities of the testis-sacs are to be looked upon as closed-off portions of the cœlome, while the seminal vesicles are outgrowths of the septa.

The essential organs of reproduction are a pair of *spermaries* or *testes* lying in the testis-sacs, attached to the posterior face of the septum between the ninth and tenth, and tenth and eleventh segments respectively (Fig. 102 *t*). They are recognizable under a lens, only in young worms, becoming atrophied in the adult. Each spermary is made up of a number of finger-shaped processes hanging from a narrow base, and contains mulberry-like masses of sperm mother-cells which are shed into the testis-sacs and pass into the seminal vesicles where they develop further into spermatozoa. Each of these has a rod-like head and a vibratile tail (compare pp. 174 and 273). The mature spermatozoa pass back into the testis-sacs and thence into the seminal funnels. Behind each spermary, in the same segment, and also contained within the testis-sac, is a ciliated *seminal funnel*, produced backwards through the septum next behind into a *spermiduct* or *vas deferens*. The

two ducts of either side meet each other in the twelfth segment, and run backwards side by side in a somewhat irregular course on the body-wall till they reach the seventeenth segment, where they curve outwards to join the prostatic duct just near its origin. The *prostates* or *spermiducal glands* (Figs. 96, 102, *p. gl.*) are a pair of large white glands of an irregular shape lying on either side of the intestine in the sixteenth to twenty-first segments. Each gland has a muscular duct alongside which run the vasa deferentia of its side; and the common prostatic and spermatic ducts of the two sides curve to open externally at the male genital pores on the eighteenth segments (Fig. 94, *m. g. p.*); each male genital pore is really a group of three apertures, a larger prostatic aperture and two smaller apertures of the two vasa deferentia, and thus the prostatic and the seminal secretions are carried independently to the exterior. In segments 17 and 19 are two pairs of accessory glands corresponding in position with the genital papillæ seen externally on these segments in series with the male genital pores. The secretion of the accessory glands is carried outside by minute ductules opening at the genital papillæ and assists in copulation.

It is well known that many flowers (the reproductive organs of higher plants) contain the generative cells of both sexes, enclosed within the ovules and anthers respectively; yet in very many cases self-fertilization does not occur owing to contrivances of various kinds for its prevention. It has been proved in numerous instances that cross-fertilization—*i.e.*, the impregnation of the ovum in one individual by the male cell of another—is of great importance in keeping up the strength and vigour of the plant from generation to generation. The same is true amongst animals; and though in some

hermaphrodite forms, such as the Hydra, there is no special arrangement for the prevention of self-impregnation if the male and female gametes of the same individual ripen at the same time, in others, such as the earthworm, the ova are always fertilized by the sperms from another individual.

The process of copulation has not yet been observed in *Pheretima*, as it probably takes place underground. It is effected in other earthworms in the following way. Two individuals, their anterior ends pointing in opposite directions, become applied together by their ventral surfaces and attached to one another in this position by a viscid secretion from the clitellum. The sperms are then passed from the male apertures of one into the spermathecæ of the other individual, and the two worms afterwards separate. The clitellum then secretes a membranous girdle round the body in this region, which is gradually slipped forwards by the worm wriggling back out of it. As it passes over the apertures of the oviducts and spermathecæ, ova and sperms (the latter derived from the other individual) are passed into it, as well as albumen secreted by certain glands present in this region. When the worm has entirely withdrawn itself from the girdle, the latter closes up at the ends in virtue of its elasticity, forming the *cocoon*, and the contained eggs, after fertilization, undergo segmentation. Cocoon formation takes place in *Pheretima* throughout the summer months, especially during and after the monsoon.

The cells of the polyplast soon became differentiated into an outer ectoderm, and an inner endoderm enclosing the enteron, which communicates with the exterior by the blastopore (compare p. 180). A mesoderm (pp. 181 and 288) is then developed, and each layer gradually gives rise to the corresponding parts in the adult animal,

some small living animal or fragment of animal matter, which is thus seized and swallowed.

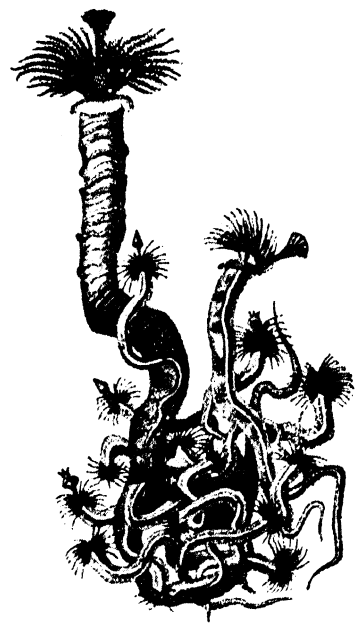
In correspondence with its different mode of life, Nereis is much better provided with sense-organs than is the earthworm. The tentacles and palps, as well as the cirri, are probably organs of touch; and as we have already seen, four eyes are present on the prostomium.

Almost without exception, the Polychæta further differ from the Oligochæta in having their sexes distinct, and in passing through a metamorphosis. The segmented oosperm gives rise to a minute, more or less oval larva known as a *trochosphere*, which swims by means of cilia arranged in circles round the body, and gradually undergoes metamorphosis into the adult.

Classification. — The phylum **Annelida** consists of the following classes :—

Class **Chætopoda.** Annelids provided with bristles or setæ.

Sub-class **Polychæta.** Those with definite bristle stumps or parapodia, each usually bearing many long bristles. A definite head is present, bearing eyes and tentacles. Special filamentous gills are often developed. Chiefly marine forms, including many that are sedentary and dwelling in tubes. *Nereis*, *Serpula* (Fig. 106).



G. 106.—*Serpulæ* with their tubes. (After Quatrefages.)

Sub-class **Oligochæta.** Those with no parapodia, but with only scattered bristles on each segment. No distinct head. Chiefly land or fresh-water forms. *Pheretima.*

Class **Hirudinea.** Annelids in which the external rings of the body are more numerous than the metameres, and the setæ are absent. Each end of the body bears a sucker, and the animals progress by looping movements. They are all hermaphrodite. The class includes the leeches which usually live in ponds and sluggish streams, where they suck blood from fishes and frogs. *Hirudo, Hirudinaria* (Fig. 107).

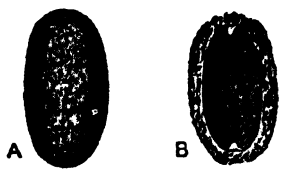


FIG. 107.—The cocoon of *Hirudo*. *A*, entire; *B*, in section. (After Leuckart.

The body of an Insect, like that of a Crustacean, is segmented, and bears a series of pairs of jointed appendages. The surface is covered with a chitinous cuticle, forming an exoskeleton. Like the body of the Crustacean, that of the Insect is divisible into certain regions. In the Insecta these regions are always three in number, *viz.*, head, thorax, and abdomen. The head does not show any trace of segmentation in the adult, and bears a pair of *antennæ*, a pair of *mandibles*, and two pairs of

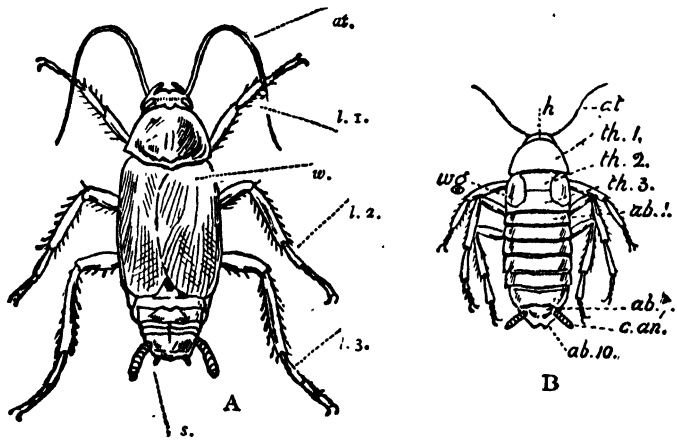


FIG. 113.—*Stylopyga orientalis*; dorsal view. A. male; B. female. *at.* antenna; *ab.* 1 to *ab.* 10, abdominal terga; 8 and 9 are concealed by 7 in the female, but are visible, though small, in the male; *c. an.* anal cerci; *l.* 1 to *l.* 3 thoracic legs; *s.* styles; *th.* 1 prothoracic tergum; *th.* 2 mesothoracic tergum; *th.* 3 metathoracic tergum; *w.* anterior wing; *wg.* vestige of the anterior wing in the female. (A. after Shipley and Macbride, B. after Borradaille.)

maxillæ. The thorax consists of three enlarged segments, each of which bears on the ventral surface a pair of legs, and each of the last two bear on the dorsal surface a pair of wings. The abdomen consists of a varying number of segments. It bears no appendages except at the posterior end, where a pair of jointed feeler-like processes are found.

As a type of this class we shall study the common

Cockroach, known as *Stylopyga orientalis*, which is said to have been originally a native of tropical Asia. It is not quite so common, however, in many places in India, though specimens can generally be found inhabiting the vegetable markets. Specimens of a closely allied form, known as *Periplanata americana*, are also found. In the former species the wings and wing-covers of the female are rudimentary, and in the male do not reach to the end of the abdomen. In *P. americana* both sexes are winged, and the wings and wing-covers are longer than the body. Both are nocturnal animals, and are often found in human dwellings, but hide themselves in corners and crevices during the daytime.

Head.—The Cockroach is divided into regions and bears the appendages as mentioned above. The head is flattened and placed at right angles to the axis of the body. Looked at from the front, it has a pear-shaped outline, with the narrow end directed downwards towards the mouth. The front and sides of the head are covered over by strong chitinous plates, *viz.*, two *epicranial plates* above (Fig. 114, *ep.*), a *clypeus* (*clp.*) forming the lower part of the face, and two *genæ* at the sides below the eyes. Hinged on the lower edge of the clypeus is a movable flap, the *labrum* or upper lip. Embryological and other evidence shows that the head was originally composed of six segments, no traces of which are now discernible except in the four pairs of appendages, viz., the antennæ and the three pairs of mouth-parts which are homologous with the thoracic legs and abdominal appendages of the lower forms. On each side of the head is a large *compound eye* (*E*) which appears as a black reniform area, the surface of which is marked off into a great number of minute hexagonal facets. The antennæ (*ant.*) are a pair of long, slender, many-jointed, whip-like structures, arising close to the

inner curve of each eye, on the front of the head. During life they are stretched downwards as if to try the ground on which the creature moves, or held aloft as if to test the air. To the inner and upper side of each antenna is a small circular area of white colour, covered by soft cuticle. These areas are called the *fenestræ* (*fe.*). The mouth is situated on the lower edge of the head covered

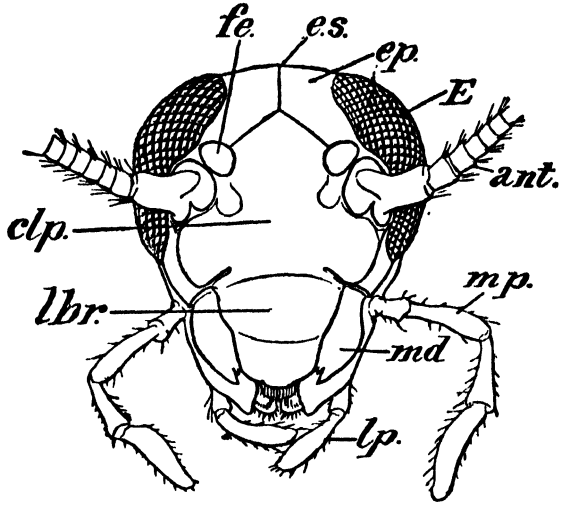


FIG. 114.—Head of *Stylopyga orientalis* seen from the front.
ant. antenna; *clp.* clypeus; *E.* eye; *ep.* epicranium; *es.* epicranial suture; *fe.* fenestra; *lbr.* labrum; *lp.* labial palp; *md.* mandible; *mp.* maxillary palp. (After Bourne.)

in front by the labrum. At the sides of the mouth are situated the first and second pairs of mouth appendages, known as the mandibles and the first maxillæ, and a third pair fused together in the middle line forms a plate called the labium, and completes the boundaries of the mouth behind. Each *mandible* (Fig. 115, *A*) is a stout, single-jointed structure with no palp, and with a toothed inner margin which bites against the corre-

sponding part of its fellow. The *first maxilla* (*B*) consists of a protopodite of two joints known as the cardo (*ca.*) and stipes (*st.*), a five-jointed exopodite known as the maxillary palp (*p. p.*), and a double endopodite consisting of an inner pointed *lacinia* (*la.*) and an outer softer *galæ* (*ga.*). The *second* pair of *maxillæ* are constructed on the same plan as the first, but the protopodites and the endopodites are fused together. The first joint of the fused protopodite is called *submentum* (*sm.*), the second is the *mentum* (*m.*), and the third is the *prementum* (*pm.*), which bears the *palps* and the partially fused endopodites forming the *ligula*. Each half of the ligula consists of an inner *lacinia* (*la.*), and an outer *paraglossa* (*ga.*) corresponding to the galea of the first maxilla. The exopodites or *labial palps* (*p. p.*) are three-jointed, and are raised on a projection of the mentum.

The head is joined to the thorax by a slender *neck* covered with a soft cuticle in which are developed a number of hard, chitinous plates or sclerites.

Thorax.—The three segments of the thorax are known as *prothorax*, *mesothorax*, and *metathorax*, and each of these is covered by a dorsal *tergum* and a ventral *sternum*. The tergum of the first is the largest, and projects forwards to conceal the neck. Each segment bears a pair of legs (Fig. 115, *D*) consisting of a stout basal joint, the *coxa* (*cx.*), a very small *trochanter* (*tr.*), an elongated stout *femur* (*fe.*), a more slender *tibia* (*tb.*), and a *tarsus* (*ta.*) composed of five short joints terminating in a very small movable piece which bears a pair of claws. The tibia and tarsus bear numerous bristles which are used in cleaning the body, and the terminal claws are used in climbing. The names of the various joints were given as the result of fanciful and misleading comparison with the parts of the vertebrate limb, with which, however,

they are not homologous. The mesothorax and metathorax bear each a pair of wings jointed to the anterior corners of their respective terga. The wings are membranous expansions of the skin strengthened by a net-

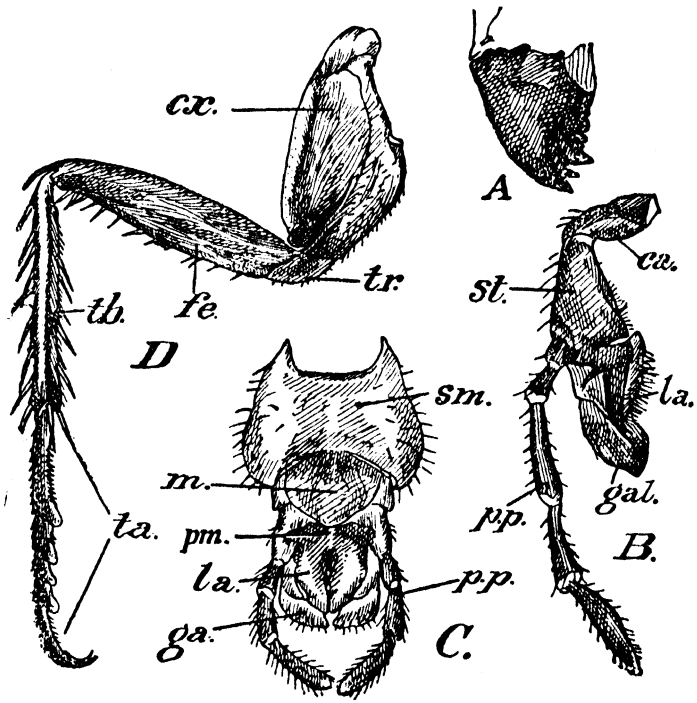


FIG. 115.—*A*. *B*. *C*. Mouth and appendages of *Stylopyga*. Magnified. *D*. Second thoracic leg, drawn to a smaller scale than the mouth-parts.
A. Mandible; *B*. first maxilla; *ca*. cardo; *st*. stipes; *la*. lacinia; *gal*. galæ; *p.p*. maxillary palp; *C*. fused second maxillæ or labium; *sm*. submentum; *m*. mentum; *pm*. prementum; *ga*. paraglossa, corresponding to the galea; *la*. lacinia; *p. p*. labial palp; *D*. second thoracic leg; *cx*. coxa; *tr*. trochanter; *fe*. femur; *tb*. tibia; *ta*. tarsus. (After Bourne.)

work of ridges or nervures. The anterior pair are dark-coloured and horny, and in a state of rest conceal the dorsal surface of the animal behind the prothorax. One of them slightly overlaps the other, and the two together

form a protective cover to the more delicate posterior wings; hence they are generally known as wing-covers or elytra. The posterior pair of wings are thin and membranous, and constitute the effective organs in the rare flight of the Cockroach. At rest they are folded like a fan and concealed by the elytra.

Abdomen.—The abdomen consists of ten segments, each with a tergum and a sternum joined at the sides by soft cuticle. The eighth and the ninth terga are narrow and tucked under the seventh and are not readily seen unless the animal is artificially stretched. In the male *Stylopyga orientalis*, however, portions of these terga remain uncovered, and are generally visible from the surface without disturbing the adjacent parts (Fig. 113, *A*). The tenth tergum projects backwards beyond the extremity of the body and is cleft into two lobes. The abdomen is broader in the female than in the male, and the seventh sternum is boat-shaped and projects backwards, completely concealing the eighth and ninth sterna and forming the floor of a roomy pouch or cavity in which the egg-case is formed. In the male also the eighth and the ninth sterna are largely concealed by the seventh. A pair of many-jointed, tapering *anal cerci* (*c. an.*), probably homologous with other appendages, emerge below the tenth tergum in each sex, and, in the male, the ninth sternum bears a pair of slender unjointed *anal styles* (Fig. 113, *A*, *s.*).

In the soft tissue between the tenth tergum and the last visible sternum, at the posterior end of the body, is situated the anus, and, below it, the single genital-pore. The anus is supported by a pair of thickened plates, called the *podical plates*, and the genital orifice is surrounded by a complicated set of processes known as the *gonapophyses*, which are concerned with the process of copulation and egg-laying.

On the sides situated in the soft membrane connecting the terga and sterna are ten pairs of *stigmata* or openings leading to the respiratory tubes. Two of these are larger and situated on the sides of the thorax, one between the prothorax and mesothorax and the other between the mesothorax and metathorax, and the remaining eight are situated between the lateral margins of the tergum and the sternum, at the anterior end of each of the first eight abdominal segments.

Digestive Organs.—On removing the skin from the dorsal surface, a body-cavity is exposed which is not a cœlome, but a hæmocœle, as the blood does not remain within a system of closed tubes but flows out into spaces existing between the various organs contained within the cavity. The cavity is largely filled by a loose white tissue known as the fat body, which surrounds the various internal organs. The alimentary canal (Fig. 116) is remarkable for the great extent of the stomodæum (fore-gut) and protodæum (hind-gut) which are formed as invaginations of the anterior and the posterior ends of the embryo respectively, and are therefore lined by cuticle, and the small extent of the mesenteron or mid-gut which alone is formed from the primitive alimentary tract of the embryo. The fore-gut consists of a *buccal cavity*, the posterior wall of which is raised into a conical fleshy tongue or *lingua*, leading into a narrow *gullet* passing through the neck, and expanding into a large thin-walled pyriform sac, the *crop* (*cr.*), which extends through the thorax and partly into the abdomen, and is followed by a short *gizzard* (*giz.*) with thick muscular walls. The inner lining of the gizzard is raised up into six prominent longitudinal folds covered by chitinous plates which can be approximated in the middle line and act as a grinding apparatus. Behind these cuticular teeth are six small elevations covered with setæ which

act as a strainer, and allow only finely divided particles of food to proceed further. The chitinous lining of the gizzard projects backwards in a spout-like form into the mid-gut. The mid-gut or *mesenteron* (*m.g.*) is short and narrow, and is lined by endoderm, being thus the only part of the alimentary canal where absorption can take place. The mid-gut is produced at its anterior end into seven or eight finger-like *hepatic cæca* (*hp. c.*)

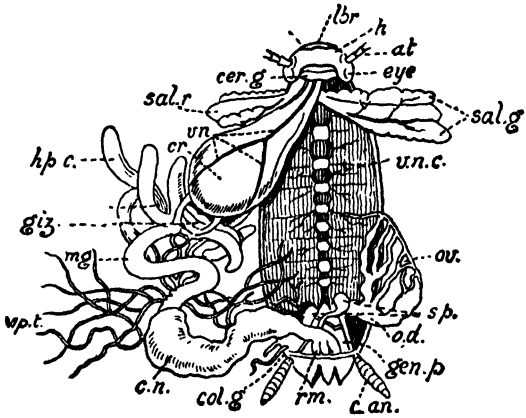


FIG. 116.—A female Cockroach, *Stylopyga*, dissected from the dorsal side. (After Shipley and Macbride.)

at. antenna; *c. an.* anal cerci; *cer. g.* cerebral ganglia; *cn.* colon; *col. g.* colleterial gland; *cr.* crop; *eye*, eye; *gen. p.* genital pouch; *giz.* gizzard; *h.* head; *hp. c.* hepatic cæca; *lbr.* labrum.; *m.g.* mesenteron; *Mp. t.* Malpighian tubules; *od.* oviduct; *ov.* ovary; *rm.* rectum; *sal. g.* salivary gland; *sal. r.* salivary receptacle; *sp.* spermatheca; *vn.* visceral nerves; *v. n. c.* ventral nerve cord.

which secrete a digestive fluid. The mesenteron, the limit of which is marked by the insertion of the *Malpighian tubules*, is succeeded by the hind-gut or proctodæum, a long, coiled tube, which is divisible into a narrow *ileum*, a wider *colon* (*cn.*), and a sac-like *rectum* (*rm.*) which opens to the exterior by the anus.

Lying along the crop on each side are a pair of diffuse *salivary glands* (*sal. g.*) and between each pair a bladder-

like *salivary receptacle* (*sal. r.*). The ducts of the two glands of each side join, and ducts of both sides unite to form a median duct. This is joined by another median duct formed by the union of the ducts of the receptacles. The common duct so formed opens into the floor of the mouth in the angle between the tongue and the lower lip. The saliva converts starch into sugar. The secretion of the hepatic cæca emulsifies fats and converts proteins into peptones. The products of digestion are passed, after absorption, into the blood, which everywhere bathes the alimentary canal, and through that agency carried to all parts of the body.

Organs of Circulation.—The blood is kept in circulation by a contractile vessel lying in the mid-dorsal line close under the skin, which is known as the *heart*. It extends through the whole length of the thorax and abdomen, and is divided into thirteen chambers corresponding to the number of segments of the body in these regions. Each chamber is narrowed in front, and this narrower portion projects into the chamber next in front and is guarded by a valve which permits the blood to flow in a forward direction only. At the hinder end of each chamber is a pair of ostia or holes through which the blood enters from the pericardium, and valves prevent the blood being forced out of the ostia. The heart lies in a pericardial sinus formed by a horizontal membrane stretched across the body-cavity. This membrane is perforated by a number of small openings through which the blood passes from the hæmocœle to the pericardial sinus. Periodic contraction of certain muscles attached to the sides of the pericardial septum, called the alary muscles, produces a flattening of the septum, thus enlarging the pericardial sinus and causing an inflow of blood into it from the rest of the hæmocœle.

Anteriorly the heart is continued forwards as the aorta, which opens by a trumpet-shaped orifice into the hæmocœle, and the blood pours out of it and bathes all the organs of the body. It thus absorbs the food from the alimentary canal and carries it to all parts of the body, superfluous fat is stored in the fat body, and waste nitrogenous materials are carried from the organs to the Malpighian tubules, by which they are passed out of the body. The blood is colourless and contains amœboid cells. Unlike what is usual in other animals, its respiratory function is at a minimum, air being carried to all organs by a system of respiratory tubes or tracheæ.

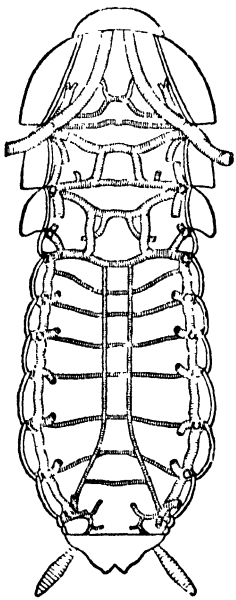


FIG. 117.—View of the arrangement of the principal trunks of tracheal system. (After Miall and Denny.)

Respiratory Organs.—The respiratory system consists of branching tubes or *tracheæ* (Fig. 117), which open to the outer air by ten pairs of stigmata, whose position has been noted before. The tracheæ, being full of air, present a glistening white appearance when the Cockroach is dissected under water. The larger branches have a definite and symmetrical arrangement. There are dorsal arches running up towards the heart and ventral arches descending towards the nerve-cord. These arches are connected with one another by longitudinal trunks. The finer branches become smaller and smaller until they become veritable capillaries which penetrate every tissue. Seen under the microscope (Fig. 118) the tracheæ show a spiral thickening of the chitinous

lining, which helps to prevent them from collapsing. Respiration is effected by the alternate arching up and flattening of the abdomen, which by increase or diminution of its volume secures an alternate inrush and expulsion of air from the tracheæ.

Excretory Organs.—The excretory organs are the Malpighian tubules, which are extremely fine, long blind tubes, 60–80 in number, arranged in six bundles which open into the beginning of the narrow portion of the proctodæum, from which they are outgrowths. They float in the blood, winding about amongst the abdominal viscera (Fig. 116, *Mp.t.*). Their cavities often contain uric acid, which is separated from the blood by the glandular epithelium lining the tubules and passes out of the body through the intestine.

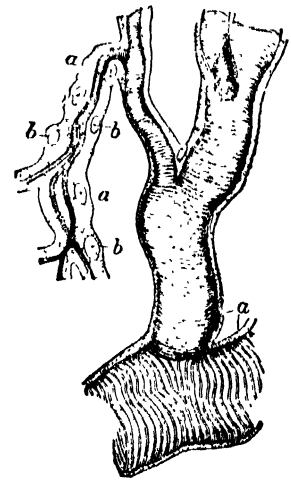


FIG. 118.—Microscopic appearance of a portion of a trachea. *a*, cellular wall; *b*, nuclei. (From Packard, after Leydig.)

Nervous System.—The nervous system is on the same general plan as that of the other segmented Invertebrata which we have considered so far. There is a pair of large *supra-œsophageal ganglia* or *brain* (Fig. 116, *cer. g.*) giving off *commissures*, which encircle the œsophagus and unite below in a *sub-œsophageal ganglion*. Together, these occupy a considerable portion of the cavity of the head. The supra-œsophageal ganglia supply paired nerves to the eyes and to the antennæ, and the sub-œsophageal ganglion supplies the mandibles and both pairs of maxillæ. From it two cords (*v. n. c.*) pass backwards and bear three pairs of ganglia in the thorax and six pairs in the

abdomen, the last of the series being large, and supplying nerves to its own and other posterior segments of the body. The alimentary canal is supplied by a visceral nervous system which receives nerves from the circum-œsophageal commissures and the brain. The principal *visceral ganglion* lies on the dorsal side of the crop.

The sense-organs include the large compound *eyes* (Fig. 114), the antennæ, which are tactile and olfactory, the maxillary palps, and cerci, and various bristles which are all tactile.

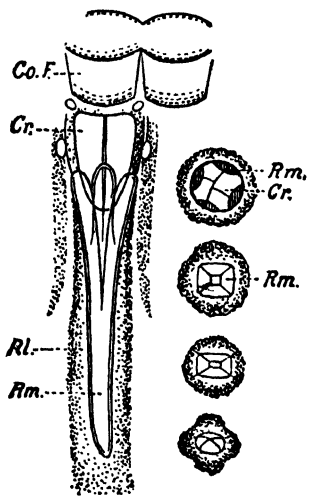


FIG. 119.—One element of the compound eye of the Cockroach ×700. *Co. F.* corneal facets; *Cr.* crystalline cones; *Rm.* nerve-rod (rhabdom); *Rl.* retinula of protoplasmic fibrils. To the right are transverse sections at various levels. (From Miall and Denny, after Grenacher.)

The compound eyes of the Cockroach occupy a large, irregular, oval space on each side of the head (Fig. 114, *E*). Each is marked off into a great number (about 1,800) of minute facets. Each facet is the outermost of a series of parts, some refractive and some sensory, which form one of a mass of radiating rods or fibres. The facets are transparent, biconvex, and polygonal, often, but not quite regularly, hexagonal. The facets (Fig. 119, *Co. F.*), taken together, are often described as the cornea. Beneath the cornea we find a layer of crystalline cones (*Cr.*), each of which rests by its base upon the inner surface of a facet, while its apex is directed inwards towards the brain. The crystalline cones are transparent, refractive, and coated with dark pigment.

Behind each cone is a nerve-rod (rhabdom) (*Rm.*),

which, though outwardly single for the greater part of its length, is found on cross-section to consist of four components (rhabdomeres); these diverge in front and receive the tip of a cone, which is wedged in between them. The rhabdom is invested by a protoplasmic sheath, which is imperfectly separated into segments (retinulæ) (*Rl.*), corresponding in number with the rhabdomeres. To the hinder end of the retinulæ are attached the fibres of the optic nerve. As to the way in which the compound eye renders distinct vision possible, it is generally believed that each element of the compound eye transmits a single impression of greater or less brightness, and the brain combines these impressions nto some kind of picture, a picture like that which could be produced by stippling—that is to say, there is " mosaic vision."

Organs of Reproduction.—The sexes are separate. In the male, the paired *testes* are no longer functional in the adult condition, and as they become reduced in size, it is with difficulty that they can be recognized from the fat body in which they are imbedded. In the young males, however, they can be readily found as two small bunches of small spherical vesicles of a transparent appearance (Fig. 120, B, *t.*), lying beneath the fifth and sixth abdominal terga, one on each side of the body, and discharging their contents into two narrow *vasa deferentia*. These vasa deferentia lead backwards to a conspicuous organ, the so-called *mushroom-shaped gland*, which consists of two short saccular vesiculæ seminales (*v. s.*) lying side by side and bearing at their anterior ends a dense tuft of finger-shaped diverticula. Posteriorly the seminal vesicles unite to form a tube, the *ductus ejaculatorius*, which opens into the genital pouch by the male pore. A gland of doubtful function, known as the conglobate gland (*cl. g.*), lies below the ductus

ejaculatorius and opens into it. The complex apparatus of hooks and plates surrounding the genital pore has been referred to already.

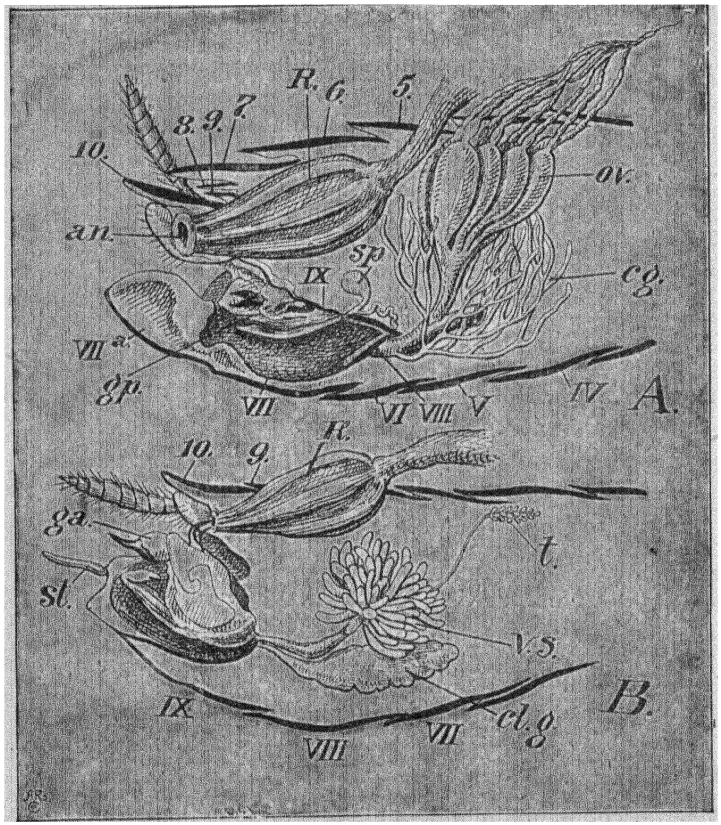


FIG. 120.—Reproductive [illegible] seen in dissection [illegible] right side. The corresponding organs of the right side have been removed.
A, Female; B, Male.
A, Female, *an.* anus; *cg.* colleterial gland; *gp.* gonapophyses; *ov.* ovary; *R.* rectum; *sp.* spermatheca; 5-10, terga; *IV–IX*, sterna.
B, Male, *cl. g.* conglobate gland; *ga.* gonapophyses; *R.* rectum; *st.* anal styles; *t.* testis; *v. s.* vesicula seminalis; 9–10, terga; *VII–IX* sterna. (After Bourne.)

In the female, there are a pair of *ovaries* (Figs. 116 and 120, A, *ov.*) situated in the hinder part of the abdomen.

Each consists of eight tubes, which show swellings caused by a row of ova, and at its anterior end the tapering tubes unite to form a thread which passes forwards till it gets lost in the fat body. Posteriorly the ovaries communicate by short and rather wide *oviducts* with a very short median uterus, which opens into the genital pouch by a slit-like aperture through the eighth abdominal sternum. On its under side the uterus receives the duct of a much-branched *colleterial gland* (Fig. 116, *col. g.*, and Fig. 120, A, *cg.*), and just above the opening of the uterus into the genital pouch is the opening of a small tubular *spermatheca* (*sp.*) which is filled with spermatozoa received from the male during copulation. During their descent the ova increase very much in size, being distended with food-yolk, and bulge out the walls of the ovarian tubes so that the latter look like strings of beads.

After they are laid in the genital pouch they are fertilised by spermatozoa poured out from the spermatheca, and these fertilized eggs are surrounded by the secretion of the colleterial glands, which hardens into the egg-capsule or *cocoon*. Sixteen ova, corresponding to the number of the ovarian tubes in the two ovaries, are packed together in an egg-capsule, which is carried about for some days by the female, half protruding from its genital pouch, and finally deposited in some sheltered place, preferably near some convenient supply of food for the young when hatched out.

When the young ones come out of the cocoon they are white in colour and bear dark eyes, but the integument soon thickens and becomes dark. They have no wings, but in other respects they resemble the adult, and thus there is no metamorphosis such as occurs in the butterflies and many other insects. The casting of the skin or

ecdysis takes place a number of times, and wings appear at the last moult.

Metamorphosis.—Metamorphosis is a very characteristic feature in the life-history of many insects. From the egg hatches out a creature which differs markedly from the adult of the species and lives an independent life. This is known as a *larva*. We have already come across an instance of a larva in the tadpole of frog. The larvæ of insects are specially unlike the adult in those cases in which the food and habits of the two are different. In such cases the larval form, which is always wingless, and may also be legless, as in the grubs of bees or maggots of flies, is retained until growth is complete, the growth being accompanied by a series of skin moults. Then the full-grown larva may enter upon a resting, quiescent stage, known as the *pupal stage*. In this stage the creature is generally motionless and ceases to feed, while certain important changes take place, leading to the perfecting of the special organs. When this is complete, the skin is cast off for the last time, and the winged adult creature, or *imago*, emerges. Such a series of changes, including a quiescent pupal stage, is known as a *complete metamorphosis*.

Life-history of a Gnat.—Metamorphosis which does not occur in the Cockroach can be readily noticed in the case of the common gnat, *Culex pipiens*. After mating, the female makes her way to water, in a ditch or rain-water tub, perhaps, and there lays her eggs on the surface, two or three hundred of them. As they are laid she arranges them with her hind legs and glues them

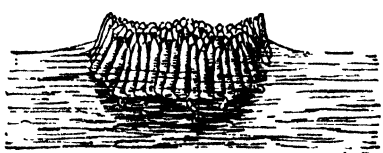


FIG. 121.—The Gnat (*Culex pipiens*). Raft of eggs floating in the water. (After Lulham.)

together, side by side, making a little floating "raft" of eggs (Fig. 121).

After two or three days, the eggs hatch, and from each emerges a small, transparent larva, which at once begins to swim actively in the water. After the rains, myriads of these larvæ are found in practically every roadside ditch or other collection of rain-water, and the further life-history can be easily watched if a small quantity of water containing some of these larvæ is brought home in a glass bottle or jar. These larvæ, though able to swim so rapidly, when undisturbed will remain for a long time floating motionless in a vertical position, head downwards, at the surface of the water (Fig. 124), with a small respiratory tube (Fig. 122, *r.*) projecting obliquely upwards to the surface, from near the posterior end.

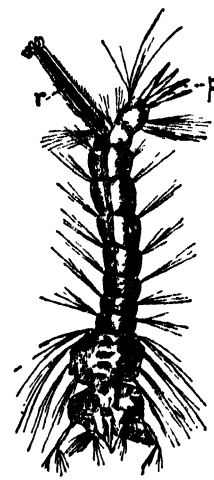


FIG. 122.—Larva of *Culex pipiens*. *r.* respiratory tube; *p.* swimming organ. (After Lulham.)

In a fortnight or so, the larva moults its skin for the third or fourth time, and at the last moult changes its shape completely, and becomes a *pupa*. In this condition it floats with its head upwards, and the rudiments of the eyes, wings, and appendages are clearly visible through the pupal skin which covers the big rounded mass at the front end. The head end being uppermost, the pupa breathes through two little trumpet-shaped tubes (Fig. 123, *r.*) on its head. The pupa does not feed, but, unlike the pupæ of most other insects, it is not always quiescent. If disturbed, it at once darts down in the water, and rises to the surface again soon after. The tail is provided with a pair of flaps which are used

in swimming. After a few days, when the body of the imago has been perfected within, the skin splits along the back between the two air trumpets, and the perfect insect begins to emerge. The head and thorax push up first into the air, and then the legs and wings are carefully withdrawn.

It has been mentioned in a previous chapter (Part II, Chap. IV) that the common gnat, or *Culex*, does not convey the parasites of malaria from man to man, but that the spotted winged mosquito belonging to the genus *Anopheles* is responsible for carrying on that nefarious trade. It is of some importance therefore to be able to recognize the latter from the former.

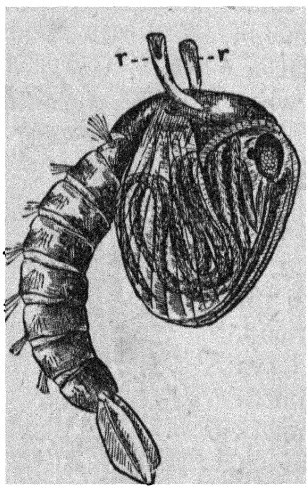


FIG. 123.—Pupa of *Culex pipiens*. *r*. respiratory tubes. (After Lulham.)

The *eggs* (Fig. 124) of Anopheles can be recognized by the fact that they are not laid in raft-like masses, are spindle-shaped, and lie separately and horizontally on the water. The *larvæ* (Fig. 124) also lie horizontally on the surface, and have a very short forked air tube. The pupæ are very similar to those of Culex.

In the adult stage they are easily recognizable from one another by their characteristic posture when at rest. Culex has both the anterior and posterior ends of its body near the wall or the object on which it is resting and has thus earned the appellation of being "hunch-backed," while Anopheles sits with the posterior end of its body directed away from the wall (Fig. 124); further-

more, it does not hold its posterior pair of legs so high in the air, and on closer examination shows a number of dark spots on each wing.

The female mosquito pierces the skin and sucks the blood. The mouth-parts are consequently adapted for piercing and sucking purposes (Fig. 125). The labrum

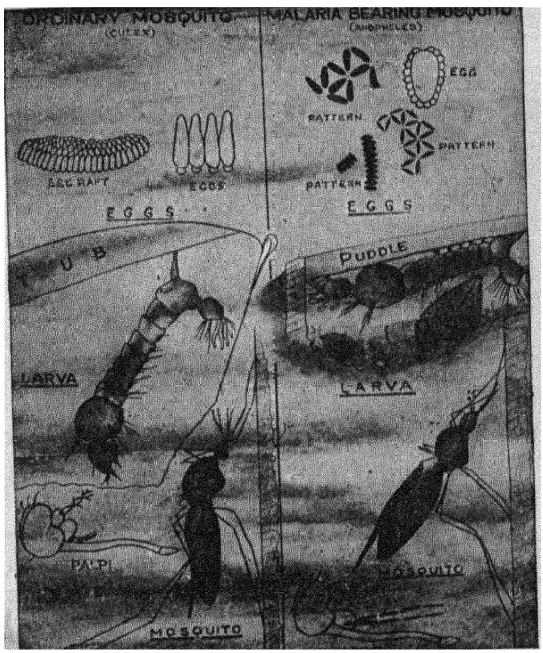


FIG. 124.—Stages in the life-history of *Culex* and *Anopheles* compared.

(*labr.*), two mandibles (*mnd.*) and the two maxillæ (*mx.*) are all very long and pointed, and serve as lancets to cause the puncture. These lancets are protected by a grooved sheath formed by the labium (*lab.*). The labrum is grooved on its under side and along with the hypopharynx (*hypo.*) which is applied to it forms a tube along which the blood is sucked.

Life-history of the House Fly.—Another instructive life-history that can readily be studied is that of the house fly. A fly usually lays its eggs (Fig. 126, A) in horse manure, or in any other animal or plant refuse. An individual lays as many as 120 eggs, and the eggs hatch in six to eight hours, forming larvæ. The larvæ (B) are small, whitish, worm-like wriggling creatures, popularly known as maggots. They feed upon the refuse for four or five days, and then become quiescent and change into *pupæ* (*C*). After five or six days more the pupæ transform into adult flies. Thus in ten days or so a progeny of 120 flies may spring up from a single pair. In a few days these flies in their turn lay eggs giving rise to a new generation. Thus countless numbers will be produced from a single pair within the summer months.

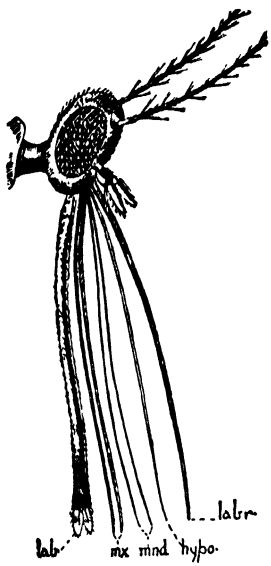


FIG. 125.—Mouth-parts of a female mosquito. *hypo.* hypopharynx; *labr.* labrum-epipharynx; *lab.* labium; *mx.* maxillæ; *mnd.* mandible. (After Lulham.)

The part played by the house fly in transmitting various diseases like cholera, dysentery, and typhoid fever is too well known to need any description. The bacteria causing these diseases occur in the human and other animal refuse, and are carried by flies and deposited upon solid food or in milk or water, with which they gain entrance to the human body. The rough and hairy surface of the body of the fly is well adapted to carrying bacteria from refuse to articles of food or drink.

Life-history of the Silk Moth.—One of the products

of a particular insect which is of great economic importance is silk. The fibre is obtained from the cocoon covering of the silk moth, and it would be instructive to study the life-history of this moth. The eggs (Fig. 127, A) are popularly known as the seed, and hatch out into larvæ in a few days. The larvæ popularly designated as **caterpillars** (B, C, D) are of a creamy white colour and feed on the fresh leaves of mulberry. They grow rapidly and move about in a characteristic looping manner, which has won for them the popular appellation

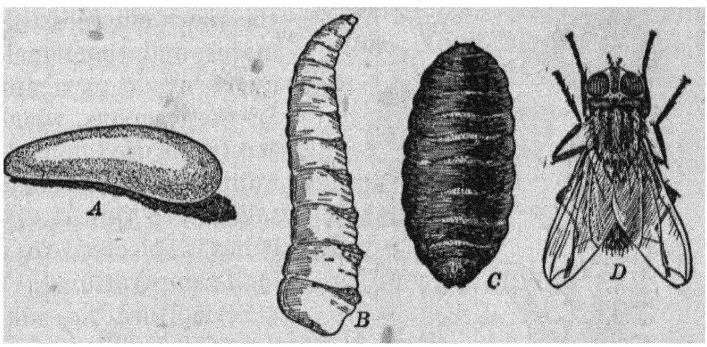


FIG. 126.—Life-history of the House Fly.
A, egg; *B*, larva; *C*, pupa; *D*, adult fly.

of silk-worms. Three pairs of jointed legs arise from the thoracic segments, and several pairs of unsegmented stumpy legs are borne by the abdominal segments. Below the mouth are the openings of the silk glands which spin out a sticky substance which hardens into the silk fibre and forms a covering round the body of the caterpillar known as the *cocoon* (*E*, *F*). Inside the cocoon, the imprisoned caterpillar changes into the quiescent *pupa* or the **chrysallis** stage (G). The latter while within the cocoon undergoes profound structural changes. The unsegmented prolegs dis-

appear and two pairs of wings appear on the thoracic segments. This adult moth, or **imago** as it is called, comes out of the cocoon and flies about. The wings are of a cream colour and about one and a half inches across in the expanded condition. From the hatching of the egg to the completion of the cocoon takes about a month and a half. In five or six days after the completion of the cocoon the caterpillar turns into a chrysalis; and about two weeks later the moth emerges. It mates, and the female moth lays eggs again. In the cocoons which are to be used for obtaining silk the chrysalids are killed by being subjected to a high temperature.

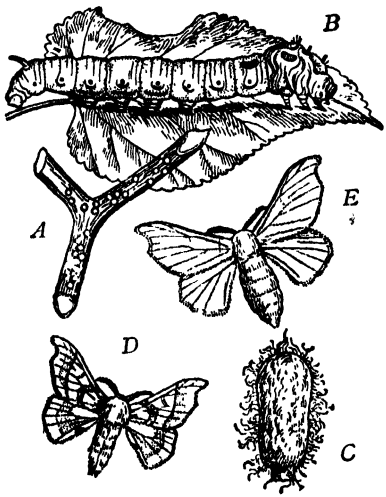


FIG. 127.—Life-history of the Silk Moth. A, eggs; B, caterpillar; C, silken cocoon; D and E, male and female imago or moth. (Natural size.)

Sericulture or silkworm breeding is an important cottage industry in Japan and various other countries, hundreds of thousands of tons of cocoons worth crores of rupees being raised. They are produced by the villagers and sold out to the factories, where silk is spun out of them. This industry can be developed in India to a much greater extent than at present.

Honey-bees.—Another insect of great economic importance is the honey-bee, as we obtain honey and wax from it. The honey-bees are also of great interest to the student of zoology as an example of Social Insects.

They live as a community in the bee-hive, showing division of labour and great skill in organization. There are three forms in every hive, *viz.* the queen, the drones or males, and the workers or imperfectly developed females. The workers are the most numerous, and do all the work of the colony, bringing in nectar and pollen from the flowers, repairing old cells, and making new ones in the honeycomb, and later laying in a store of honey, to supply food during winter when the honey-bees lie close together in the hive to tide over the cold. The drones are larger than the workers, are reared in larger cells, and are relatively few in number. They occur only in the early summer, spend their time in flying about outside the hive, and are expelled from the hive or killed by the workers after the swarming season is over. The drones are developed pathenogenetically—that is, from eggs which have not been fertilized. The queen bee is much larger than the worker, and has a long, pointed body. She is developed in a special cell which is bigger than the ordinary cells, and a specially nutritious food is provided for her by the workers. The queen is always walking about on the comb, and the workers make way for her and attend to her. To perform her maternal duties, a young queen takes a nuptial flight only once in her life, and is mated by a drone. The queen returns to the hive and starts laying the eggs. If in laying a particular egg, the queen fertilizes it by a sperm from the store which she received from a drone, the fertilized egg will develop into a worker or into a queen, according as it is laid in a smaller or



FIG. 128.—The Honey-bee.

larger cell and fed upon the ordinary or the special food. The queen can lay as many as three thousand eggs in a day, so the population increases rapidly. An egg develops into a larva in about three days, and into a fully developed worker in twenty-one days. In an ordinary hive two to three thousand workers can emerge every day when the weather is very warm.

When the population is large and vigorous, it is time to start new colonies. The workers by enlarging the cells, and feeding the grubs on the " royal jelly," enable more queens to develop. The new queens are defended by the workers from the old queen, who with many of her subjects forms a swarm, and goes off to start a new colony. Apiculture or the rearing of honey-bees is a useful industry, and well worth developing in this country.

Other Insect Products.—Another insect product of importance is *lac*, which is required for various purposes. It is used as shellac for making varnish for wood, and as a stiffening for felt in making hats, as an insulating varnish in electrical work, also in the manufacture of lithographer's ink, sealing-wax, and gramophone records. The *lac* insect is confined to India, and thus we practically hold the monopoly for supplying *lac* to the world. As no satisfactory substitute has yet been found, there is room for expanding *lac*-rearing as a subsidiary industry in the country-side.

The cochineal, another insect, furnishes a beautiful red dye, which was formerly used in large quantities. Its economic importance has declined since the introduction of aniline dyes.

Destructive Insects.—We are all familiar with the damage done by insects to the stored food, clothing, and furniture. This loss, considerable as it is, is insignificant as compared with the damage done by various insects to our important crops.

Sugar-cane borers belonging to various species collectively cause a loss of at least 10 per cent. of the crop in India. The greatest damage is done by the borers in early stages of growth of the sugar-cane, when the season is hot and dry. The incidence of borers in October and in ratoon crops (new shoots springing from sugar-cane root after cropping) is much higher than in February plantings. The October and ratoon crops also act as a source of infestation for the ensuing spring plantings. According to Fletcher, the sugar-cane pests alone cause an annual loss of 30 crores of rupees in this country. The measures advocated to prevent this enormous loss include prompt removal and destruction of trash and stubbles, avoidance of ratooning, early planting, spraying the young crop with a stomach poison to kill the first brood of young borers feeding on tender leaves, and the collection and destruction of egg-masses.

Cotton is attacked by the pink boll-worm and the spotted boll-worms in all parts of India. The larvæ of these moths bore into the shoots, flower-buds, and bolls, and reduce the formation of healthy bolls and cause deterioration in the quality of the lint by staining.

Locusts are migratory insects that visit periodically. They come in swarms, settle down in their thousands, and eat away practically every green leaf available. In order to fight them successfully concerted measures have to be taken. Collection and destruction of pairing locusts and their egg-masses are useful measures of control. When the hoppers have come out, trenches should be dug, and they should be driven into them and buried therein.

The most important fruit pests are the Codling moth, San José scale, Apricot chalcid, and the fruit flies. The Codling moth is a notorious pest of apples and other fruits in several parts of the world, and has been

recently found to occur in Baluchistan and the North-Western Frontier Province. The San José scale is another serious pest which has come to India recently, and has been found infesting the fruit trees in Kashmir. The Apricot chalcid damages stones of apricot fruits. The fruit flies do considerable damage to peach, guava, pear, and other fruits in various parts of India.

Importance of Entomology.—The study of Insect life in all its aspects is so important that it is regarded as a special branch of Zoology, and goes by the name of Entomology. The insects form the largest group of animals both as regards the total number of different species and the number of individuals. More than 300,000 different species of insects have already been described, which is well over four-fifths of the total number of different species of animals known to science. The insects are thus the dominant creatures on the earth to-day. Their immense numbers are due to their varied structure, which enables them to live under all possible conditions. The larvæ of many species are adapted to a life in water, others bore in various parts of plants, some are subterranean, while still others inhabit the bodies of domestic animals or other insects. The possession of wings by the adults confers on them the power of conquest over fresh fields and pastures new. The insects exhibit the highest degree of intelligence among the invertebrate animals. The wisdom of the ant and the industry and wonderful organization of the bee are proverbial.

Sufficient has been said in the preceding pages to impress upon the student the part which the insects play in transmitting diseases of man and domestic animals, and the injury done by insects to crops, and household and stored goods. According to M. Afzal Husain, the annual loss to India caused by insects may

be computed at 200 crores of rupees and over a million and a half human lives. To quote him, "It is a truism that insects have been responsible for destruction of more property and loss of life than caused by all wars, floods, earthquakes, fires and famines in human history, and the losses caused by them are on the increase."

Nor can we afford to overlook the usefulness of certain insects in adding to the economic wealth of mankind, to which aspect also brief reference has already been made. The insects play an important rôle in bringing about the pollination of flowers. A large number of tiny insects prey upon or live within the bodies of other insects, and serve as the most important factor in the natural control of injurious species. Thus it will be clear that for tackling all the problems connected with insects and human welfare, a large number of trained entomologists is necessary, and perhaps nowhere more urgently than in India to-day.

Classification.—The phylum **Arthropoda** consists of the following classes among others :—

Class Crustacea.—Arthropods possessing two pairs of feelers (antennules and antennæ) and three pairs of jaws. These as well as other limbs are typically biramous. With few exceptions they are aquatic creatures breathing by means of gills or through the general surface of the body.

The class includes such animals as water-fleas, barnacles, wood-lice, prawns, lobsters, crayfish, hermit-crabs, crabs, etc. (Figs. 129–134).

Class **Myriopoda.**—Arthropods, in which there is a distinct head bearing antennæ, eyes, and jaws, and the body consists of similar segments, each bearing one or two pairs of legs. They are terrestrial creatures breathing by a system of air-tubes or tracheæ, as in the insects. The class includes the Centipedes and the Milipedes (Figs. 135–136).

Class **Insecta.**—Arthropods, in which the body is divided into three distinct regions, viz., head, thorax, and abdomen. The head bears one pair of antennæ and three pairs of jaws. The thorax consists of three

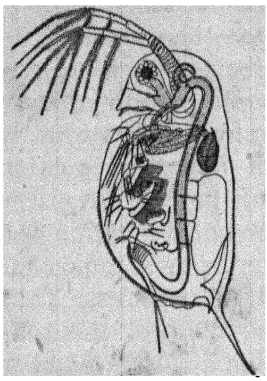


FIG. 129.—*Daphnia*, one of the "water-fleas," a small crustacean found in stagnant water, as seen under the microscope.

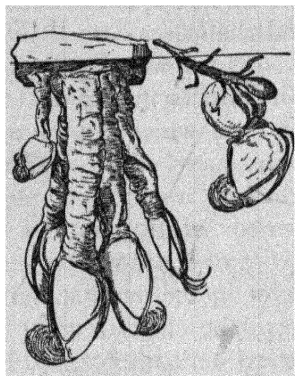


FIG. 130.—*Lepas*, one of the ship barnacles attached as adults to floating-logs and even to ships, showing flexible stalks and curled limbs. (After Thomson.)

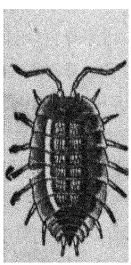


FIG. 131.—*Oniscus*, one of the "wood-lice," common in woods.

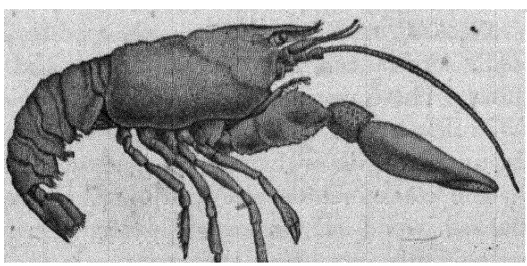


FIG. 132.—*Astacus*, the fresh-water crayfish, common in streams and rivers in Europe.

segments and bears three pairs of legs and usually two pairs of wings. Breathing is carried on by air tubes or tracheæ. The class is divided into a large number of orders, distinguished from each other by the number

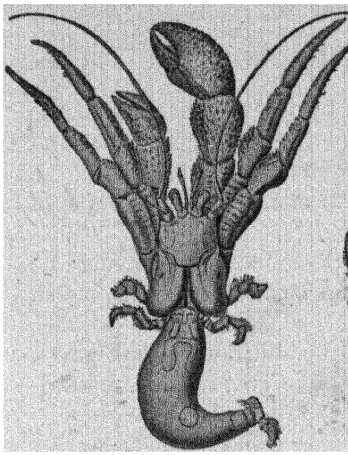


FIG. 133.—*Pagurus*, one of the hermit-crabs, sea-shore animals found inhabiting the empty shells of Gastropods.

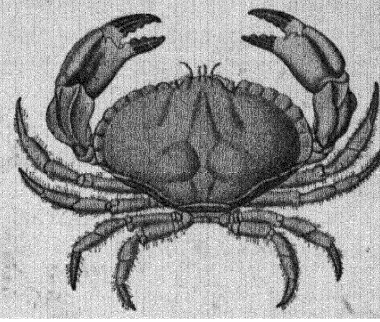


FIG. 134.—*Cancer*, one of the true crabs, which frequent rocky ground under the sea. Young ones are often found in shore pools along with those of the shore-crab.

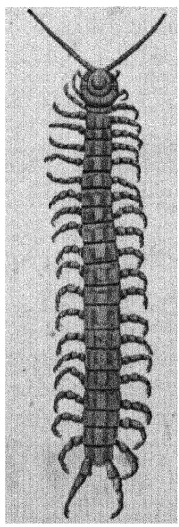


FIG. 135.—*Scolopendra*, a centipede. Head bears four pairs of jaws, including a pair of poison jaws. Each segment bears a single pair of legs.

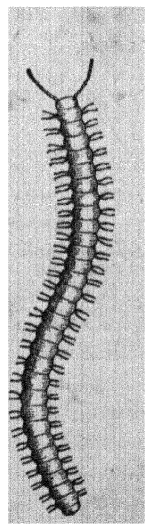


FIG. 136.—A Millipede. No poison jaws. Each segment except the first three bears two pairs of legs.

and the texture of the wings, by the modification of the mouth-parts, by the nature of the metamorphosis, and by the form and habits of the larva and pupa.

The more important of these orders or groups of orders are :—

1. *Aptera.*—Primitive wingless insects showing no metamorphosis. Including Spring-tails and Silver-fish (Fig. 137).

2. *Orthoptera.*—Insects with biting mouth-parts. Fore-wings are firmer and forming covers for the hind-

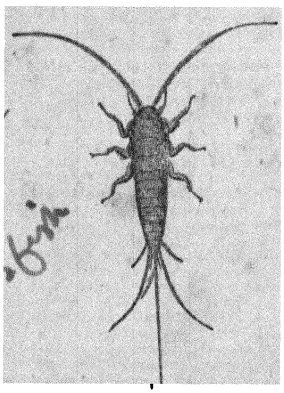


FIG. 137.—*Lepisma.* (After Guérin and Percheron.)

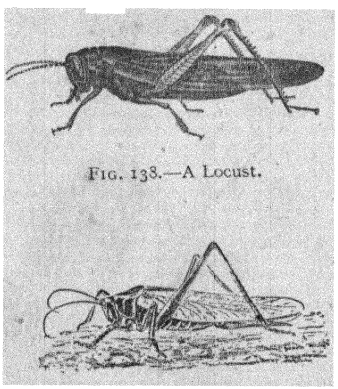


FIG. 138.—A Locust.

FIG. 139.—A Grasshopper.

wings which are membranous and folded like a fan. Metamorphosis is incomplete. Including cockroaches, locusts, grasshoppers, crickets, leaf-insects, and stick-insects (Figs. 138–141). The latter are well-known for their close resemblance to leaves and dry twigs respectively.

3. *Neuroptera.*—Insects with both pairs of wings membranous. The larvæ live in water. The insects formerly included under this head are now divided into several distinct orders. Including May-flies (Fig. 142), Dragonflies (Fig. 143), etc.

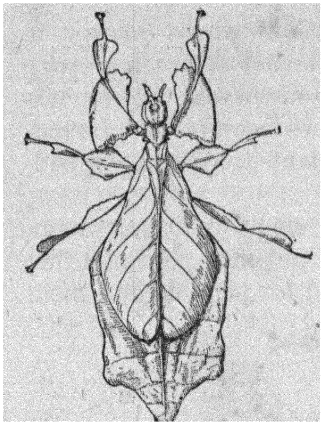


FIG. 140.—Leaf-insect.

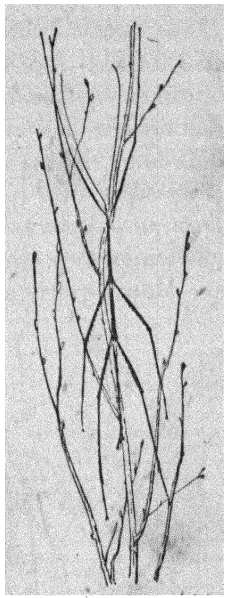


FIG. 141.—Walking stick insect among twigs.

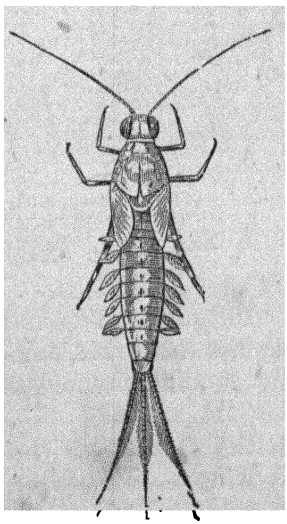


FIG. 142.—Young May-fly or Ephemerid, showing tracheal gills and wings on segments in front of them. (From Thomson's *Outlines of Zoology*. After Eaton.)

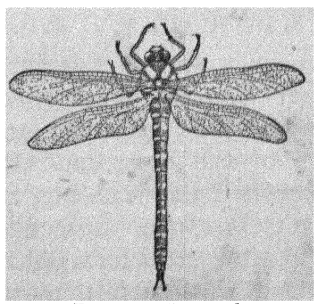


FIG. 143.—Dragon-fly.

4. *Hemiptera.*—Insects with four wings, except in parasitic forms; fore-wings thickened at the base with membranous tips or both pairs membranous; mouth-parts suctorial. Metamorphosis is incomplete. Including plant-bugs, lice (Fig. 144), plant-lice (Fig 145), bed-bugs (Fig. 146), etc.

5. *Diptera.*—Insects with a single pair of membranous wings representing the anterior pair of other orders. Mouth-parts are adapted for piercing and suck-

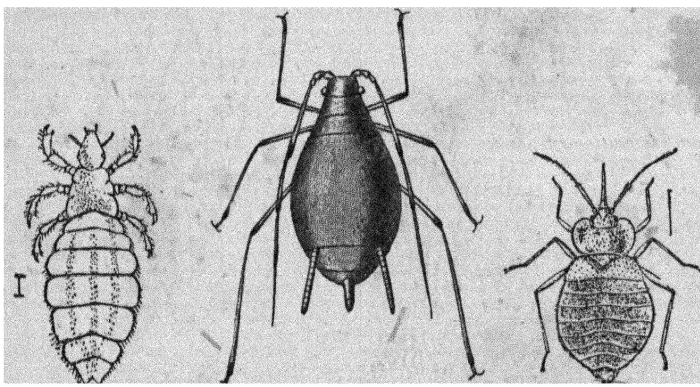


FIG. 144.—Louse, affecting man.

FIG. 145.—Plant-louse, affecting rose.

FIG. 146.—Bed-bug. (From Sanderson and Jackson's *Elementary Entomology*. (Ginn).)

(All greatly enlarged.)

ing. Metamorphosis is complete. Including gnats and mosquitoes (Figs. 124, 125), house-flies (Fig. 126), bot-fly of the horse, and the greatly modified, wingless parasites, the fleas (Fig. 147).

6. *Coleoptera.*—Insects in which the anterior pair of wings takes the form of hard, horny wing-covers (*elytra*), which, when at rest, meet in a straight line along the back, covering the membranous posterior wings. Jaws adapted for biting and chewing. The metamorphosis is complete. Including the true Beetles. (Fig. 148).

7. *Lepidoptera.*—Insects in which the body and both pairs of wings are covered with scales. The first maxillæ are modified to form an elongated sucking-tube, which can be rolled spirally. The mandibles are vestigial or absent. The metamorphosis is complete. The larvæ (caterpillars) possess strong biting-jaws. The pupæ (chrysalids) are enclosed in firm protective cases.

The order includes Butterflies and Moths (Fig. 127).

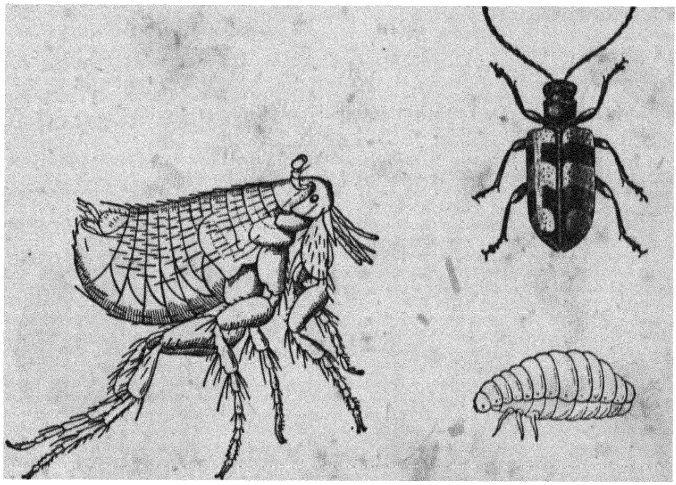


FIG. 147.—Rat-flea. (Greatly enlarged.)

FIG. 148.—A beetle with its larva.

The butterflies are day fliers, and when at rest hold their wings in a vertical position over their back. The antennæ are thread-like and distinctly enlarged at the tip. The moths fly by night and are attracted to lights. When at rest the wings are folded around the abdomen. The antennæ are thread-like or feathered, but never enlarged at the tip.

The caterpillars of most moths spin silken cocoons, which are thin and flimsy in some, while in others, as

in the silk moth, they are firm and contain a large amount of silk, forming a warm home for the hibernating pupæ. The caterpillars of butterflies do not spin any cocoons, and the pupæ (chrysallids) are hanging from

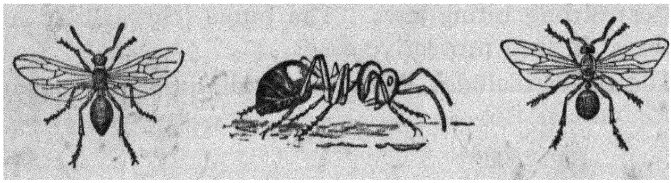


FIG. 149.—Red Ant; male, worker and female.

the food-plant or other near-by object by a strand of silk.

8. *Hymenoptera.*—Insects in which both pairs of wings

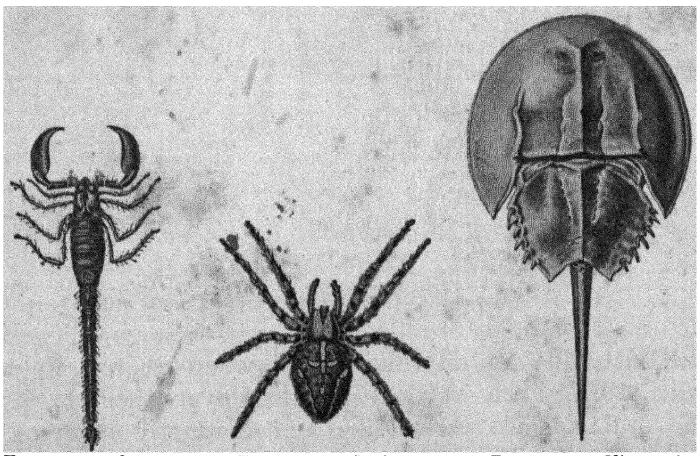


FIG. 150.—A Scorpion. FIG. 151.—A Spider. FIG. 152.—A King-crab.

are membranous, the fore-wings being larger. The mouth-parts are adapted both for biting and sucking or lapping. The first segment of the abdomen is united with the segments of the thorax and the narrow waist is the con-

differentiated into a muscular foot, on each side of which there is a gill or ctenidium.

(2) Class **Gastropoda,** including snails and slugs which are terrestrial, and whelks and periwinkles which are marine. In these molluscs, the mantle is not divided into two lateral folds, and consequently the shell is univalve or composed of a single piece (Fig. 156, *Sch*). The body is flattened from above downwards, and the visceral hump is twisted, thus disturbing the bilateral symmetry. There is a well-developed ventral foot (*F*), usually with a broad, flat surface on which the animal creeps. A head region bears eyes and tentacles. Plume like ctenidia are usually present. In the buccal cavity there is a characteristic organ known as radula bearing numerous minute horny teeth.

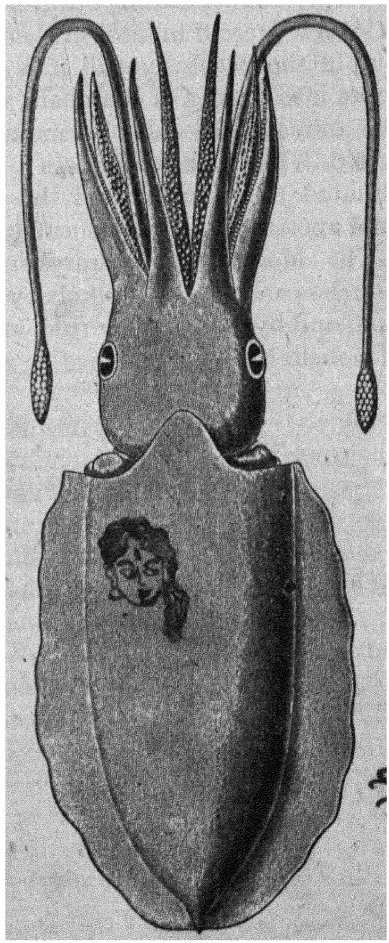


FIG 157.—A Cuttle-fish, viewed from the antero-dorsal aspect. (From Parker and Haswell's *Zoology*.)

(3) Class **Cephalopoda,** including the cuttle-fishes, squids and pearly nautili, are all marine. They have a definitely

formed head, bearing a pair of highly developed eyes, and surrounded by the anterior portion of the foot modified into arms and tentacles. The body is bilaterally symmetrical. The posterior part of the foot is modified to form a funnel leading out from the large mantle-cavity. A shell is present in most of them, and is usually internal; but in the pearly nautili it is external and divided by septa into a series of chambers, which contain the body of the animal. The visceral mass is symmetrical, and not coiled. The mantle encloses a large cavity in which are situated the ctenidia and the renal, reproductive, and anal apertures. There is a radula in the buccal cavity.

The Mollusca are sharply distinguished from the Annelids and the Arthropods by the absence of segmentation, and by having, as a rule, an exoskeleton in the form of a shell.

CHAPTER IX

BRIEF SURVEY OF THE OTHER PHYLA

WE have so far studied one or more types and surveyed the general organization of the following chief divisions of the animal kingdom :—

Protozoa, Cœlenterata, Annelida, Arthropoda, Mollusca, and Chordata (Sub-phylum Vertebrata).[1]

Besides these, there are a number of other important phyla, and our survey of the animal kingdom will be very incomplete without a brief reference to some of them.

Phylum **Porifera** (Sponges).—In sponges, the body consists of many cells lying in close contact with one another, and usually forming a yellowish, asymmetrical mass of varying size, generally attached to a rock or a seaweed and practically motionless like a plant organism. The surface of a sponge is dotted over with minute pores, and one or more larger openings known as *oscula* (Fig. 158, *O.*) also occur. Sponges live always submerged in water, and if a few grains of carmine or some other pigment are dropped in the water near them, it is seen that the grains are drawn *into* the minute " inhalent " pores, and also that they are *driven away* from the larger " oscula." This current of water is produced by the lashing of the protoplasmic threads or flagella possessed by certain of the cells within the body (see Fig. 159, A, *c.*), and it

[1] The frog has been studied in Part I, as a type of one class of the Vertebrata. Types of other classes of the Chordata will be described in the succeeding chapters.

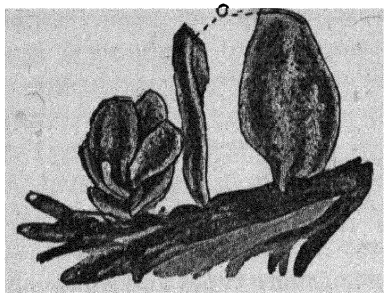


FIG. 158.—The Purse Sponge (*Grantia compressa*), natural size, attached to a branch of seaweed. O. oscula. (After Lulham.)

carries into the body both the oxygen necessary for respiration and also the decaying organic matter which probably serves as food.

The tough texture of the sponges is due to the spicules, which are of a calcareous or siliceous nature, and are embedded in the mesoglœa. They are of very varied shapes in different sponges, and under the microscope are marvels of beauty and symmetry. The spicules may occur alone or combined with a network of horny or silky threads of a substance called *spongin*. In the common Bath Sponges the spongin alone is present, forming the tough supporting skeleton which is sold as a sponge.

These sponges live in deep water, whence they are obtained by divers, or are speared from boats by means of long-handled pronged forks. The living sponges are covered and penetrated throughout by the slimy living tissues, and it is only after these have decayed and the horny skeleton has been washed free from them that the sponge is ready for household use.



FIG. 159.—A. Diagrammatic representation of a longitudinal section through a Sponge of a simple type. *c.* collared cells; *e.* ectoderm; *i.* inhalent pores; *o.* osculum; B. one flagellated collared cell, enlarged. (After Lulham.)

Phylum **Platyhelminthes** (Flatworms) consists of small, worm-

like creatures, with a soft, flattened, bilaterally symmetrical body, which is either unsegmented or consists of a number of similar segments having very little connection with each other.

The flat-worms are more highly organized than the Cœlenterata and are distinctly triploblastic, but, unlike the Annelids, they have no body-cavity or cœlom outside the alimentary canal. The mesoderm forms a kind of connective tissue filling up the space between the alimentary canal and the skin, and several important systems of organs, viz., the muscles, the excretory system, and the reproductive ducts, originate from this layer. There is no circulatory sytem, and the food is carried directly to the tissues through the much-branched digestive tract, which serves, as in the Cœlenterata, as a gastrovascular cavity. There is no anus. The phylum includes the fresh-water planarians, and the parasitic liver-flukes and tape-worms.



FIG. 160.—The Liver-fluke; *excr.* excretory pore; *mo.* mouth; *repr.* reproductive aperture; *sckr.* ventral sucker.

In the liver-flukes the body is provided with suckers (Fig. 160, *sckr.*) by which the parasite clings to the host inside the body of which it lives. The liver-fluke of the sheep (*Fasciola hepatica*) has an extraordinary life-history, passing the adult phase of its life inside the liver of a sheep, and the earlier stages within the body of a water-snail (*Limnæa truncatula*) or of a land-snail (*Helix*). It passes out from the snail on to the grass, and is then swallowed by the sheep when it eats the grass.

The tape-worms (Fig. 162) have a long, ribbon-like, segmented body with no alimentary canal. The seg-

ments are very little dependent on each other; each is capable of reproduction, and separates from the rest when ripe, leaving the body of its host and passing the second phase of its life in another host. *Tænia saginata*

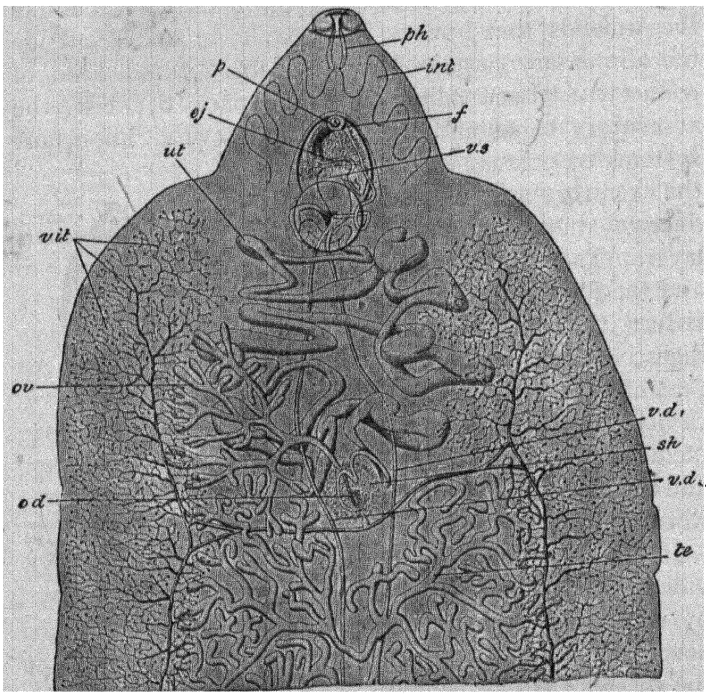


FIG. [illegible] the **Liver-fluke** (***Fasciola hepatica***). General view of the anterior portion of the body, as seen under the microscope.
ej. ejaculatory duct; *f.* female reproductive aperture; *int.* anterior portion of the intestine (the rest is not shown); *od.* commencement of the oviduct; *ov.* ovary; *p.* cirrus; *ph.* pharynx; *sh.* shell-gland; *ts.* testes; *ut.* uterus; *vd.* seminal vesicle. (After Sommer.)

and *T solium* are found as parasites in the human alimentary canal, and pass the second phase of their life in the body respectively of an ox or a pig, and then again infect man if the flesh of these animals is eaten without

being cooked sufficiently to kill the worms. A tape-worm is very commonly found as a parasite of the

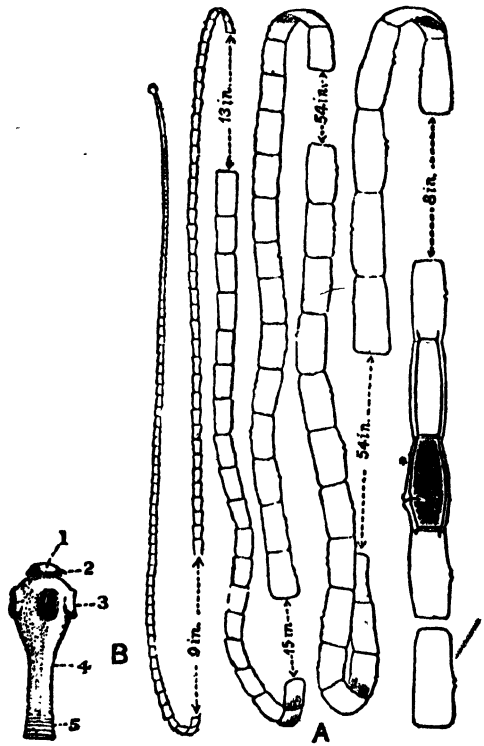


FIG. 162.—The Tape-worm.
A. entire animal; the approximate lengths of the portions omitted in the drawing are given. At * the branched uterus and longitudinal and transverse excretory vessels are shown. B. head or scolex greatly enlarged. 1 rostellum, 2 hooks, 3 suckers, 4 neck, 5 commencement of region after which the body is regularly segmented. (A. from the *Cambridge Natural History*; B. from Shipley and Macbride.)

pigeon, and can readily be obtained for practical study by slitting open the intestines of that bird.

Phylum **Nematoda** (Round worms or Thread worms):—These are bilaterally symmetrical, triploblastic animals

with an elongated cylindrical body, showing no sign of external or internal segmentation. The alimentary canal has a mouth opening at the anterior end and an anal opening on the ventral surface near the posterior end, and lies in a body-cavity or cœlome. Sexes are separate. They are usually small forms, though some of them reach the length of five or six feet. They move with wriggling motion. Most of them are parasites.

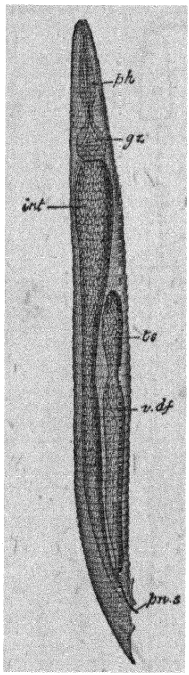


FIG. 163.—The thread-worm (*Oxyuris*), as seen under a microscope. *gz.* gizzard; *int.* intestine; *ph.* pharynx; *pn. s*, penial setæ; *ts.* testis; *v. df.* vas deferens. (From Shipley, after Galeb.)

Oxyuris vermicularis (Fig. 163) is the common thread-worm, which is only about half an inch long, and is often found in the human rectum, more particularly in young children. *Ascaris lumbricoides* is the common round worm parasitic in the intestine of man, which may reach a length of a foot or even more. *Trichina spiralis* is another parasite, at first living in the intestine of man, and then in his muscles, causing a deadly disease known as " trichiniasis." In another phase of its life-history it is parasitic in pig, producing what is known as " measly " pork.

Phylum **Rotifera** (Wheel Animalcules). —Rotifers are microscopic but multicellular forms, very commonly found in the water from ponds and ditches. They are bilaterally symmetrical. The head bears a disc provided with cilia which aid in locomotion and draw food into the mouth. At the opposite end of the body is a tail or foot which is often jointed, and is more or less retractile. The animal is able to fix itself temporarily to any support

in water by means of a secretion from a cement gland in the tail. Although of a microscopic size, the animals show a complicated internal structure. They have a

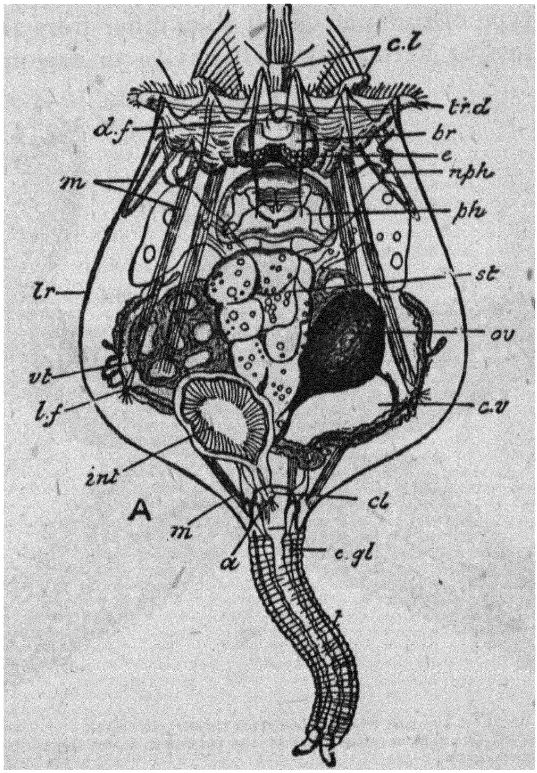


FIG. 164.—A Rotifer (*Brachionus rubens*) as seen under a microscope. *a.* anus; *br.* brain; *d. f.* dorsal feeler; *c. gl.* cement gland; *cl.* cloaca; *c. l.* ciliary lobes; *c.v.* contractile vesicle; *e.* eye-spot; *int.* intestine; *lr.* lorica; *l.f.* lateral feeler; *m.* muscular bands; *nph.* nephridial tubes; *ov.* germarium; *ph.* pharynx; *st.* stomach; *t.* tail; *tr. d.* trochal disc; *vt.* vitellarium. (After Hudson and Gosse.)

body-cavity (cœlome) distinct from the alimentary canal, and also excretory, reproductive, and nervous systems, the brain being relatively large, though the sense-organs are very simple. The sexes are separate.

Most of them are inhabitants of fresh water, but some are marine and a few parasitic.

Phylum **Echinodermata.**—The Echinoderms are multicellular animals which, like the Cœlenterates, show a radial type of symmetry, but they differ from the latter in possessing a distinct body-cavity or cœlome lying

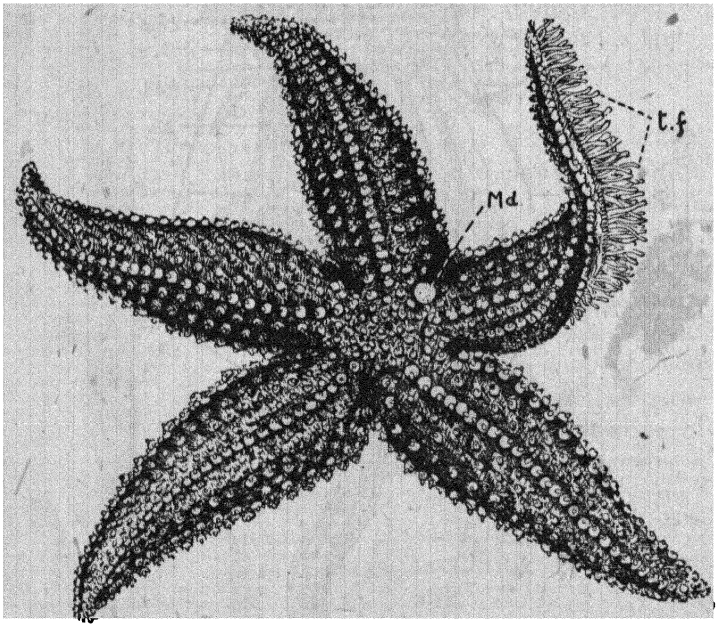


FIG. 165.—A Starfish (*Asterias rubens*) (life size).
Dorsal view: one arm is raised to show the tube-feet, *tf.* on the ventral surface; *md.* madreporite.

outside the alimentary canal and containing various organs in it.

They are usually five-rayed forms, and the skin is hardened by small calcareous plates and spines. A special peculiarity of the members of this phylum is the presence of a peculiar water-vascular system, by means of which water can be taken into the body through an

opening known as the madreporite (Fig. 165, *md.*) and pumped into the tube-feet (*tf.*), which in many of them are the chief organs of locomotion. There is no well-defined blood-vascular or excretory system. The sexes are separate. The phylum is large and varied, and includes such forms as starfishes, sea-urchins, sea-cucumbers, all of which are marine.

CHAPTER X

SURVEY OF THE PHYLUM CHORDATA.

Phylum **Chordata.**—The phylum Chordata (Lat. *Chordatus*, having a chord) includes the vertebrate animals (mammals, birds, reptiles, amphibians, fishes) and certain marine forms that are not generally known except to zoologists. All of them are characterized at some period of their lives by the possession of (1) a skeletal axis, the *notochord* (Gk. *noton*, back) (p. 182), (2) *paired slits* connecting the pharynx with the exterior, and (3) a central *nerve-cord* placed *dorsal to the alimentary canal* and containing a cavity or system of cavities, the neurocœle. In many, some of these features though present during early development are lost in the adult, as the adult frog has lost the notochord and gill-clefts which are present in the tadpole. In many respects the Chordates differ widely from one another, and are usually divided into four sub-phyla, viz., Hemichorda, Cephalochorda, Urochorda, and Vertebrata.

Sub-phylum **Hemichorda.**—This group includes a certain number of worm-like marine animals which possess gill-slits opening from the anterior part of the alimentary canal to the outside world, and for that reason are sometimes known as *Enteropneusts* (Gk. *enteron*, gut; *pneusts*, breathers). Along the mid-dorsal line they possess a slender nerve-cord, which, however, is connected, by a ring round the pharynx, with a ventral nerve-cord. The body is divided into three regions: (*a*) a pre-oral proboscis (PR) used for burrowing in the

sand or mud, (*b*) a collar region (C) behind the mouth (M), and (*c*) the trunk, with gill-slits (GS) in the anterior region. Extending forwards from the anterior end of the alimentary canal into the proboscis is a short rod which is regarded as homologous with the notochord of the other Chordates.

A typical example of the group is *Balanoglossus* (Fig. 166). The creature burrows in the sand and mud, usually in shallow seas. *Balanoglossus* and its allies must be regarded as survivors of primitive forms that diverged from near the origin of the Chordate stock.

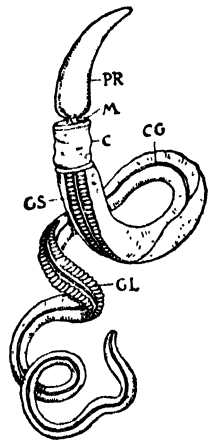


FIG. 166.—*Balanoglossus*. PR. proboscis; M. mouth; C. collar; CG. ciliated groove along mid dorsal line; GS. gill-slits; GL. glandular sacculations from the alimentary canal, shining through the skin. (After Thomson.)

Sub-phylum **Urochorda.** — The group includes the common marine animals, popularly known as sea-squirts or ascidians. They are found from shallow water of the sea-shore to great depths in the ocean. The larval stages are pelagic, but after these are passed, most of them are sedentary, though some continue throughout life as free swimmers. Like other Chordates, they show, at least in the larval condition, a dorsal tubular nervous system, a simple notochord confined to the tail region (hence the name Urochorda, from Gk. *oura*, tail), and gill-slits opening from the pharynx to the outside. The body is enclosed in a test consisting largely of cellulose. The majority of them undergo a regressive metamorphosis during the life-history, and many of them form colonies. A typical adult Ascidian does not appear to be related to other Chordates, but the study of the life-history shows a close resemblance to them.

Sub-phylum **Cephalochorda.**—In various parts of the world, certain small fish-like animals called lancelets are found, the commonest species of which is known as *Amphioxus lanceolatus* (Fig. 169). This animal, which possesses a median fin like that of the tadpole (p. 186), is not more than a couple of inches in length, and lives



FIG. 167.—External appearance of an Ascidian or Sea-squirt, fixed to a rock. Note the mouth at the anterior end, and the exhalant aperture on one side of the test. (After Herdman.)

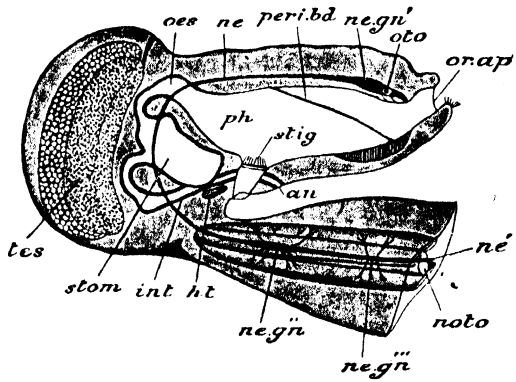


FIG. 168.—Diagram of *Appendicularia*, a free-swimming adult. Note that the notochord is confined to the tail.
an. anus; *ne.* nerve-cord; *noto.* notochord; *or. ap.* oral aperture; *stig.* one of the stigmata. (After Herdman.)

in the sea near the shore, burrowing in the sand; it is especially interesting owing to the fact that it presents certain characteristics indicating a near relationship to the primitive ancestors of Vertebrates. It possesses a notochord, a dorsal hollow nervous system, a pharynx perforated by gill-slits, a hollow outgrowth of the

intestine representing a simple liver, with a hepatic portal system, and a series of nephridia. But it differs from all the Vertebrates in the following important points.

The epidermis consists of a single-layer of cells. There is no distinct head and no skull; the persistent notochord (Fig. 169, *nch*) extends to the anterior end of the animal, and there are no paired limbs. A brain (*br*) can hardly be said to be present, and there are no paired olfactory, optic, or auditory organs. The pharynx is relatively very large, and is perforated by very numerous oblique gill-slits (Fig. 170, *br. cl*) which do not open on the exterior directly, but are surrounded by a chamber, the *atrium* (Fig. 170, *atr*); this opens externally by a pore (Figs. 169 and 170, *atrp*), and though differing in its mode of development from the branchial chamber of the tadpole (p. 187), has somewhat similar relations. There is no heart, and the colourless blood apparently contains no corpuscles of any kind. The nephridia remain distinct, not being united into a single kidney on either side: they are situated anteriorly, in the neighbourhood of the pharynx (Fig. 170, *nph*); the gonads (Figs. 169 and 170, *gon*) are metamerically arranged, and have no ducts.

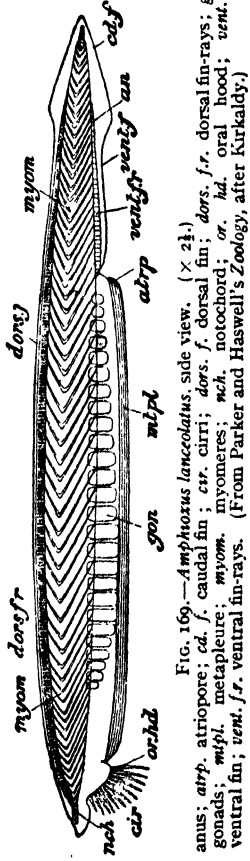


FIG. 169.—*Amphioxus lanceolatus*, side view. (× 2½.)
an. anus; *atrp.* atriopore; *cd. f.* caudal fin; *cir.* cirri; *dors. f.* dorsal fin; *dors. f.r.* dorsal fin-rays; *gon.* gonads; *mtpl.* metapleure; *myom.* myomeres; *nch.* notochord; *or. hd.* oral hood; *vent. f.* ventral fin; *vent. f.r.* ventral fin-rays. (From Parker and Haswell's *Zoology*, after Kirkaldy.)

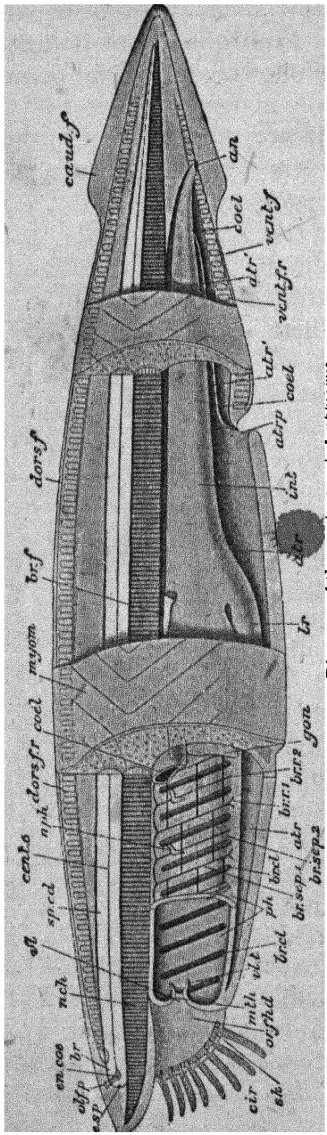


FIG. 170.—Diagram of the anatomy of *Amphioxus*.

an. anus; *atr.* atrium; *atr'.* its posterior prolongation; *atrp.* atriopore; *br.* "brain"; *br. cl.* branchial clefts; *br. f.* "atrio-coelomic funnel"; *br. sep.* 1, primary; *br. sep.* 2, secondary branchial bar; *br. r.* 1, primary; *br. r.* 2, secondary branchial rod; *caud. f.* caudal fin; *cent. c.* central canal; *cir.* cirri; *cœl.* cœlome; *dors. f.* dorsal fin; *dors. fr.* dorsal fin-rays; *ey. coe.* cerebral ventricle; *e. sp.* eye-spot; *gon.* gonad; *int.* intestine; *lr.* "liver"; *mth.* mouth; *myom.* myomeres; *nch.* notochord; *nph.* nephridia; *olf. p.* olfactory pit; *or. f.* *hd.* oral hood; *ph.* pharynx; *sk.* skeleton of oral hood and cirri (dotted); *sp. cd.* spinal cord; *vent. f.* ventral fin; *vent. f. r.* ventral fin-rays; *vl.* velum; *vl. t.* velar tentacles. (From Parker and Haswell's *Zoology*, reduced.)

These numerous and marked differences between the lancelet and the Vertebrata make it necessary to place it in a separate subphylum called Cephalochorda (Gk. *Kephale*, head; *chorde*, chord), the name being given on account of the notochord extending to the anterior end of the body.

Sub-phylum **Vertebrata.**—From your study of the frog you have learnt something about a vertebrate animal, and in this and the next chapters we will examine a few more examples of the sub-phylum Vertebrata, which as we have seen (p. 196), includes several classes, the *Pisces*. *Amphibia*.

CHAPTER XI

CLASS MAMMALIA

THE RABBIT AS A TYPE OF MAMMALIA—CHARACTERS OF THE CLASS—CLASSIFICATION

Class **Mammalia.**—Before examining a rabbit, as an example of the highest class of Vertebrates—the *Mammalia*, it will be well to recall the characters in which the frog, taken as an example of the class Amphibia, differs from a fish and resembles the reptiles, birds, and mammals (see p. 411), as also the points which these three classes have in common and in which they differ from a frog (see p. 196). The Mammal, again, differs from all other vertebrates in many important respects, some of the more obvious of which are:—the presence of an *epidermal* exoskeleton consisting of *hairs*; the high temperature of the blood, which remains almost uniformly within a few degrees of 100° Fahr., and does not vary to any appreciable extent with the temperature of the air; the presence of *mammary glands* beneath the skin in the female which secrete milk for nourishing the young. In the large majority of Mammals, the teeth are differentiated into front-teeth for biting or seizing the food and cheek-teeth or grinders, and their succession is limited to two functional sets; an external ear or *pinna* is present; there is no cloaca, the anus and urinogenital apertures opening separately on the exterior. The other important characters will be summed up after we have examined the structure of the rabbit in detail.

External Characters.—The rabbit (*Lepus cuniculus*) is a very abundant and widely distributed animal which in the wild state makes burrows in the earth, and the practically hairless young are born in these or in special nests. There are a number of varieties, the habits and general appearance of which have been modified by domestication (compare p. 610).

In addition to *head*, *trunk*, and short *tail*, the rabbit possesses a distinct *neck*, and the whole animal, including the limbs and even the soles of the feet, is covered with

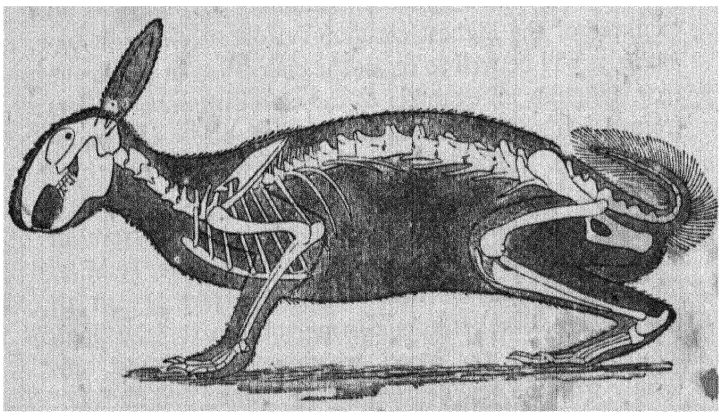


FIG. 185.—Lateral view of skeleton of Rabbit with outline of body. (× ½.)
(From Parker and Haswell's *Zoology*.)

a soft fur consisting of *hairs* (Fig. 186). In the wild rabbit, the fur is of a brownish colour, lighter below, and white under the tail: in the many domesticated varieties the colour is very varied.

The hairs are derived from modified epidermal cells which become converted into a horny material; they are developed in tube-like involutions of the epidermis called *hair-sacs*, into the swollen base of each of which a mesodermal *hair-papilla* projects, the substance of the hair, with its *cortex* and *medulla*, being formed from the epidermal cells covering the papilla (Fig. 186). Into the hair-sacs open the ducts of the *sebaceous glands* (D) the secretion of which serves to lubri-

cate the hairs. Embedded in the dermis are coiled tubular masses, the *sweat-glands* (SD), the ducts of which open on the surface of the skin and pour out the sweat.

There are five digits in the hand or *manus*, and four in the foot or *pes*, each terminated by a pointed and curved horny *claw*, developed, like the hairs, from the

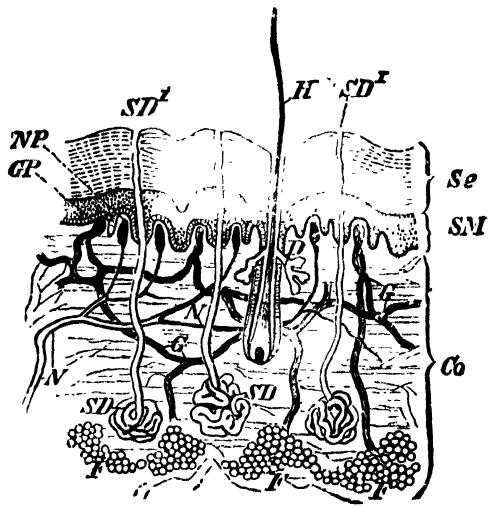


FIG. 186.—Section through the Human Skin.
Co. derm; *F.* subcutaneous fat; *GP.* vascular papillæ; *H.* hair with sebaceous glands (*D*); *N* and *G.* nerves; *NP.* sensory papillæ; *Se.* stratum corneum; *SD.* sweat-glands, with their ducts (*SD*¹); *SM.* stratum Malpighii. (After Weidersheim.)

epidermis. Along the ventral surface of the body in the female are four or five pairs of papillæ—the *teats*, on which open the ducts of the milk-glands, which correspond to modified integumentary glands. The various parts of the skeleton (Fig. 185) can be felt through the skin, and it will be noticed that the anterior part of the trunk, or *thorax*, is surroundered by *ribs*, many of which meet below with a breast-bone or *sternum*, and which are absent in the posterior part of the trunk, or *abdomen*.

Beneath the anterior end of the snout is the transverse

mouth, which has a narrow gape and is bounded by upper and lower *lips*: the upper lip is divided by a longitudinal cleft which is continuous with the oblique, slit-like *external nostrils*. Just inside the lips are the upper and lower front teeth or *incisors*, which are chisel-shaped, and behind them the hairy integument is continued on either side into the cavity of the mouth. The *eyes* are protected by movable hairy *upper* and *lower eyelids*, as well as by a hairless third eyelid or *nictitating membrane* (compare p. 428), supported by cartilage and situated in the anterior corner of the eye, over which it can be partly drawn: it corresponds to the little red lump in the inner corner of the human eye. On the upper lip and above and below the eye are certain very long and stiff hairs—the "whiskers" or *vibrissæ*, and behind the eyes are a pair of long and movable *external ears* or *pinnæ*: these are supported by cartilage and are somewhat spout-shaped, leading to the external auditory openings.

Below the root of the tail is the *anus*, and in front of this the *urinogenital aperture*, the space between them being known as the *perineum*. On either side of these apertures is a hairless depression of the skin on which open the ducts of the *perineal glands*, the secretion of which has a strong and characteristic odour. In the female the slit-like urinogenital aperture is called the *vulva*; in the male the aperture is smaller and is situated on the conical apex of a cylindrical organ, the *penis*, which can be retracted within a fold of skin, the foreskin or *prepuce*. On either side of the penis is an oval pouch of skin, the *scrotal sac*, not very apparent in young animals, in each of which a *spermary* or *testis* is contained.

Skeleton.—The skeleton of the adult rabbit consists almost entirely of bone, but it must be remembered that,

in addition to certain cartilages described below, all articular surfaces are covered or lined by a thin layer of cartilage, and that the various parts of the skeleton are connected together by ligaments.

In the **skull,** both replacing and investing bones (p. 41) are much more numerous than in the frog, and the structure of the entire skull is far more complicated and highly differentiated. A posterior, relatively large *cranial region,* in the side walls of which the auditory capsules are embedded, can be distinguished from an anterior, somewhat conical *facial region,* constituting the skeleton of the snout (Fig. 187). Just behind the junction of these two regions on either side is a large *orbit,* separated from its fellow by a thin *interorbital septum,* perforated by a foramen for the optic nerve (*opt. fo*).

At the sides of the *foramen magnum* are the two rounded *occipital condyles*; the *auditory apertures* (*aud. me*) are situated at the sides of the posterior part of the cranium, and the *external nostrils* open at the anterior end of the snout. Most of the bones remain more or less distinct throughout life, and are in contact along lines or *sutures,* many of which are wavy or zig-zagged: others, again, become completely fused in the adult, so that their limits are no longer distinguishable.

The *upper jaw* forms part of the facial region, which encloses the olfactory chambers; and the *lower jaw,* consisting of a single bone on either side, articulates directly with the sides of the cranium without the intervention of a hyomandibular as in the dogfish (p. 419) or of a quadrate cartilage as in the frog (p. 41). The rest of the visceral portion of the skull, representing the hyoid and first branchial arch, forms the so-called *hyoid* bone, which is embedded in the base of the tongue (Fig. 198, *b.hy*).

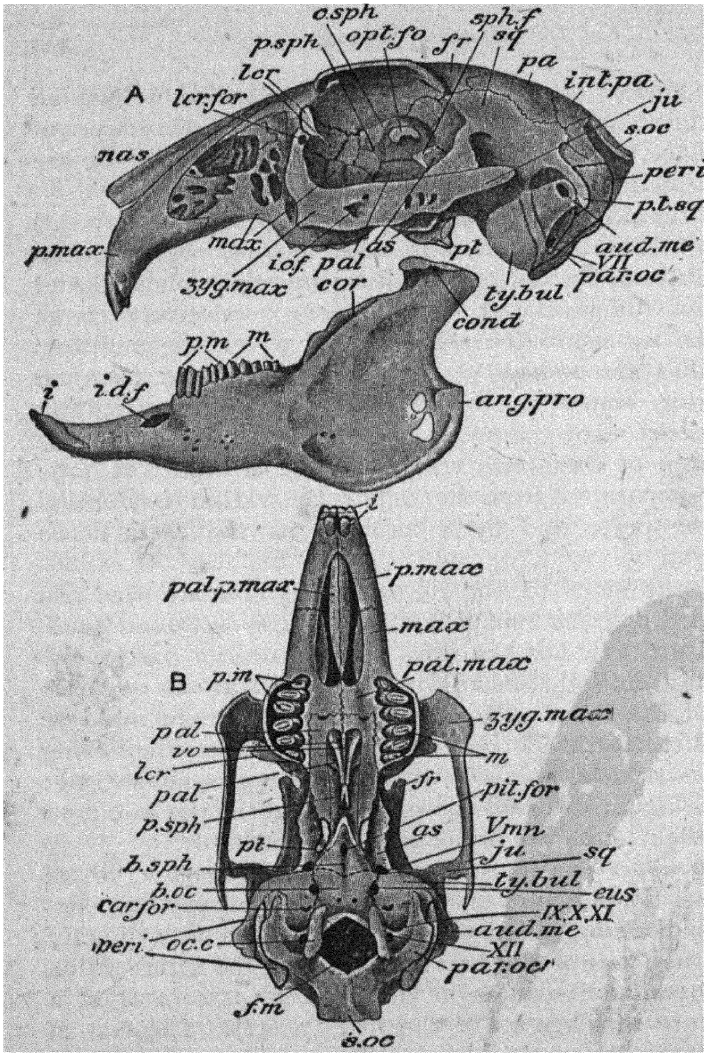


FIG. 187.—Skull of Rabbit. (Nat. size.) A, lateral view with lower jaw; B, ventral view.

ang. proc. angular process of mandible; *as.* alisphenoid (external pterygoid process below); *aud. me.* external auditory aperture in tympanic bone; *b.oc.* basi-occipital; *b.sph.* basisphenoid; *cond.* condyle of lower jaw; *car. for.* foramen for internal carotid artery; *eus.* Eustachian canal; *f. m.* foramen magnum; *cor.* coronoid process; *fr.* frontal; *i.* incisors; *i. d. f.* inferior dental foramen

for passage of the mandibular division of the trigeminal nerve; *int.pa.* interparietal; *s. o. f.* infraorbital foramen for passage of the maxillary division of the trigeminal nerve; *ju.* jugal, *lcr.* lacrymal; *lcr. for.* lacrymal foramen; *m.* molars; *max.* maxilla; *nas.* nasal; *oc. c.* occipital condyle; *opt. fo.* optic foramen; *o. sph.* orbitosphenoid; *pa.* parietal; *pal.* palatine; *pm.* premolars; *pal. max.* palatine process of maxilla; *par.oc.* paroccipital process of exoccipital; *pal. p. max.* palatine process of premaxilla; *p. max.* premaxilla; *peri.* periotic; *pit. for.* pituitary foramen; *p.sph.* presphenoid; *pt.* pterygoid; *p. t. sq.* posttympanic process of squamosal; *s.oc.* supraoccipital; *sph. f.* sphenoidal fissure; *sq.* squamosal; *ty. bul.* tympanic bulla; *vo.* vomer; *zyg. max.* zygomatic process of maxilla; *V. mn.* foramen for mandibular division of trigeminal nerve; *VII.* for facial nerve; *IX. X. XI.* for glossopharyngeal, vagus, and spinal accessory; *XII.* for hypoglossal. (From Parker and Haswell's *Zoology*.)

The bones [1] which form the walls of the **cranium** are arranged in three rings or segments, the middle and posterior of which are separated by the auditory capsules (Figs. 187, A, and 188, *peri*).

The posterior, or *occipital segment*, consists of four bones, which in the adult become completely united with one another. The lower of these is the *basioccipital* (*b. oc*), a flattened bone bounding the foramen magnum below, and forming the hinder part of the base of the skull and the lower part of each occipital condyle (*oc. c*). The two *exoccipitals* (*e. oc*) bound the foramen magnum at the sides, and form the upper part of the occipital condyles: each is produced downwards into a process (*par. oc*) which fits closely against the posterior surface of a swollen bone (*ty. bul*) to be described presently, which is continuous with a tube surrounding the auditory aperture (*aud. me*). The occipital segment is completed above by the *supraoccipital* (*s. oc*), bounding the foramen magnum above; it has a pitted surface and is marked externally by a shield-shaped prominence.

The middle, or *parietal segment*, consists of five bones —a *basisphenoid* (*b. sph*) below, an *alisphenoid* (*a. sph, as*) on either side, and two *parietals* * (*pa*) above. The broad posterior end of the basisphenoid is connected with the basioccipital by a thin plate of cartilage, and

[1] In the following description, the investing bones are distinguished by an asterisk from the replacing bones (see p. 41).

tapers in front to a blunt point: it is perforated at about its middle by an oval foramen, and on its upper surface is hollowed out to form a depression in which the pituitary body lies (*s. t*). The alisphenoids are wing-like bones, directed upwards and outwards, and firmly united with the basisphenoid: each is produced ventrally into a process (*as*), consisting of two laminæ which converge and unite with one another anteriorly. The parietals

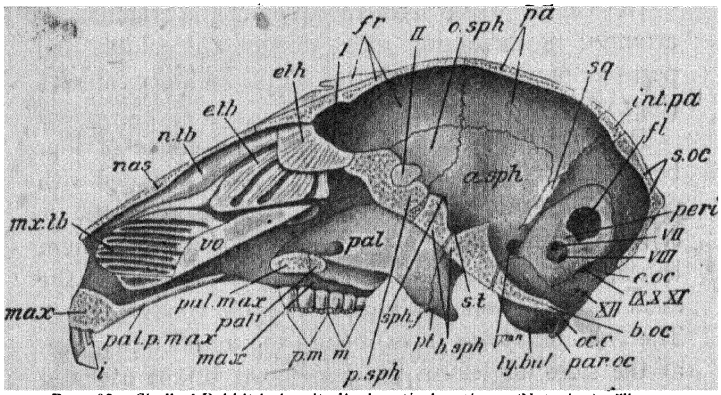


FIG. 188.—Skull of Rabbit in longitudinal vertical section. (Nat. size.) The cartilaginous nasal septum is removed.

a.sph. alisphenoid; *e.oc.* exoccipital; *e.tb.* ethmo-turbinal; *eth.* ethmoid; *fl.* fossa for flocculus of brain; *i.* incisors; *mx.tb.* maxillo-turbinal; *n.tb.* naso-turbinal; *pal'.* palatine portion of the bony palate; *p. sph.* presphenoid; *s. t.* sella turcica, or depression in which the pituitary body lies; I, region at which the olfactory nerves leave the skull; II, optic foramen; V *mn.* foramen for mandibular division of trigeminal; VII, for facial nerve; VIII, for auditory nerve; IX, X, XI, for glossopharyngeal, vagus, and spinal accessory; XII, for hypoglossal. Other letters as in Fig. 150.

are a pair of thin, slightly arched bones forming a considerable part of the roof of the brain-case and united with one another by suture along the middle line; the outer edge of each gives off a thin, ventral process which is covered by the squamosal (*sq*), a bone which will be referred to presently (p. 448) and which separates the parietal from the alisphenoid. Interposed between the parietals and the supraoccipital is a small median *interparietal** (*int. pa*).

The *frontal segment* also consists of five bones—a *presphenoid* (*p. sph*), two *orbitosphenoids* (*o. sph*), and two *frontals** (*fr*). The small presphenoid is laterally compressed and is connected with the basisphenoid by cartilage, so that in the dry skull there is a considerable interval between the two bones; it forms the inferior and anterior boundary of the optic foramen (*opt. fo*, II), which puts the two orbits in communication with one another and both in communication with the cranial cavity. The orbitosphenoids are two wing-like laminæ directed outwards and slightly backwards, and completely fused with the presphenoid; they surround the rest of the optic foramen. The frontals form the roof and side-walls of the anterior part of the brain-case, and are united by suture with one another in the middle line and with the parietals behind; below they meet with one another anteriorly on the floor of the brain-case and unite with the presphenoid by suture; the outer part of each forms a prominent crescentic ridge, the *supra-orbital process*.

The brain-case is closed in anteriorly by a bone riddled with numerous small holes for the passage of the olfactory nerves (I) : this is the sieve-like or *cribriform plate* of the *ethmoid* (*eth*).

It will be remembered that in the frog the occipital region is ossified by exoccipitals only, the parietals and frontals of either side are fused, there are no ali- or orbito-sphenoids, the cartilaginous walls of the anterior part of the cranium are ossified a a sphenethmoid, and that the floor of the skull is supported by an investing bone, the parasphenoid (p. 38).

The auditory capsules are comparatively loosely wedged in laterally between the parietal and occipital segments; in the embryo each is ossified from three centres, instead of one (the pro-otic) as in the frog, but these early unite to form the *periotic bone* (*peri*), as the

ossified auditory capsule is called. The internal or *petrous* portion of this bone (Fig. 188) encloses the membranous labyrinth of the ear and is very dense and hard; posteriorly it is produced outwards as the porous *mastoid* portion, which is visible on the outer side of the skull (Fig. 187, A). Closely applied to the outer surface of each periotic is a bone called the *tympanic*,* consisting of a tubular portion above—the edge of which surrounds the auditory opening (*aud. me*) to which the cartilage of the pinna is attached, and of a swollen portion, or *tympanic bulla* (*ty. bul*), below: this encloses the tympanic cavity, and in it, at the base of the tubular portion, is an incomplete bony ring to which the tympanic membrane is attached (Fig. 187). The tympanic is incomplete on its inner side, where its cavity is closed by the outer wall of the periotic, and between the two, at the antero-inferior angle of the former, is the aperture by which the Eustachian tube leaves the tympanic cavity (compare p. 15). When the tympanic is removed, two small holes are seen on the outer wall of the periotic: the anterior of them is the *fenestra ovalis* and is plugged by the *stapes*—which, together with two small bones, the *malleus* and *incus* (Fig. 210), forms the chain of *auditory ossicles* to be described later in connection with the organ of hearing; the posterior aperture is called the *fenestra rotunda*. On the internal or cranial surface of the periotic is a large depression (*fl*) which lodges the flocculus of the cerebellum (Fig. 207).

The olfactory capsules are roofed in by two long and narrow *nasal bones** (*nas*), which meet together in the middle line and unite by suture with the frontals posteriorly. Their side-walls are formed by the bones which bear the teeth of the upper jaw—the *premaxillæ** (*p. max*) and *maxillæ** (*max*), and in the median line below is a single long and slender bone, deeply grooved

on its upper surface, and formed by the fusion of the two *vomers** (*vo*). The two nasal chambers are separated from one another in the middle line by a median vertical plate of cartilage, the *nasal septum* (Fig. 198), embraced below by the vomers. This cartilage, together with the cribriform plate and a median vertical plate of bone (*eth*) extending forwards from the latter into the septum, constitutes the *mesethmoid*. Within the nasal chambers certain scroll-like folds of the mucous membrane (Fig. 198) are present in order to increase the surface, and in these cartilages are developed. The cartilages become ossified, and the resulting *turbinal bones* unite with certain of the bones enclosing the olfactory organs, and are named accordingly. The *ethmo-turbinals* (Fig. 188, *e. tb*), or true olfactory scrolls, are two complicated, folded bones united to the cribriform plate of the ethmoid, and are covered in the fresh condition by the olfactory epithelium; the *maxillo-turbinals* (*mx. tb*) are similar but more complex bones in the antero-ventral part of the nasal cavities; and the *naso-turbinals* (*n. tb*) are thin, folded bones, much less complex, and fused with the inferior surface of the nasals.

In the front wall of each orbit, fitting comparatively loosely between the frontal and maxilla, is a small bone, the *lacrymal** (Fig. 187, A, *lcr*), with a notch near its outer border through which the naso-lacrymal duct passes (p. 168).

As in the frog, the chief bones of the upper jaw on either side are the *premaxilla** (*p. max*) and the *maxilla** (*max*), and nearer the middle line are the *palatine** (*pal*) and "*pterygoid*"* (*pt*): in the embryo the position of the two last-mentioned bones is taken by cartilage representing the upper jaw of the dogfish (compare Figs. 174 and 10). The premaxillæ, in which the sockets

for the front or incisor teeth are situated, form the anterior boundary of the snout, and articulate with one another in the median line and with the maxilla behind: each gives off a *nasal process* passing backwards between the nasal and maxilla to the frontal, and a *palatine process* (*pal. p. max*) extending backwards along the palate in contact with its fellow of the opposite side. The maxillæ are large and irregular bones, parts of the sides of which are fenestrated, and in which the cheek-teeth are situated. From the inner and inferior edge of each, opposite the first two cheek-teeth, a horizontal *palatine process* (*pal. max*) is given off, which, articulating with its fellow of the opposite side, forms the anterior part of the bony support of the hard palate—this is of much less extent in the rabbit than in most mammals: from its outer side arises a *zygomatic process* (*zyg. max*), which forms the anterior part of the strong *zygomatic arch* extending below and externally to the orbit.

The palatines are thin, nearly vertical, bony laminæ, internal to the maxillæ to which they are attached in front, while above they join the presphenoid and the pterygoid process of the alisphenoid. They bound the passage of the internal nostrils, and from the inner and anterior region of each is given off, opposite the third cheek-tooth, a horizontal, inwardly directed process (*pal*[1]), which, articulating in the middle line with its fellow of the opposite side and in front with the palatine process of the maxilla, forms the posterior part of the bony support of the hard palate. The bones usually known as pterygoids are small irregular plates attached to the posterior edge of the corresponding palatine and the pterygoid process of the alisphenoid; each ends ventrally in a backwardly curved process.

The *squamosals** (*sq*) are a pair of plates which overlap and complete the side-walls of the brain-case (p. 444)

in front of the periotics : they articulate with the frontals, parietals, orbitosphenoids, and alisphenoids. From the outer face of each is given off a strong *zygomatic process*, which bears on its under surface the articular facet for the lower jaw, and further back a slender process (*p. t. sq*) arises which is applied to the outer surface of the periotic.

The zygomatic processes of the squamosal and maxilla respectively are united by a flat bar of bone, the *jugal** (*ju*), which in the adult is fused with the latter. All these three bones therefore take part in forming the zygomatic arch.

Most of the apertures for the transmission of the cerebral nerves have so far not been mentioned : the branches of the olfactory nerve, as we have seen, pass out through the numerous apertures in the cribriform plate (Fig. 188, *eth*, I), and the optic foramen (*opt. fo*, II) is situated between the orbitosphenoid and presphenoid. Behind and below the optic foramen is a vertical aperture—the *sphenoidal fissure* (*sph. f*)—between the basisphenoid and alisphenoid, which transmits the third, fourth, and sixth nerves, as well as the ophthalmic and maxillary divisions of the fifth. Between the periotic and alisphenoid is a large space (V *mn*), through the anterior part of which the mandibular division of the trigeminal leaves the skull.[1] Between the mastoid portion of the periotic and the posterior border of the tympanic, at the junction of the tubular and bulbous portions of the latter bone, is a small aperture—the *stylomastoid foramen*, which transmits the seventh nerve : this and the eighth (VII, VIII) enter the periotic just below the depression for the flocculus of the cerebellum (*fl*). A space (IX, X, XI) between the occipital condyle and tympanic bulla gives exit to the ninth and tenth, as well as to the eleventh—which is not represented as a distinct nerve in the dogfish and frog; and the hypoglossal (p. 143), which in Mammals is counted as the twelfth cerebral nerve, passes out through two small

[1] In many Mammals (*e.g.*, dog, cat) the maxillary division of the trigeminal passes out through a separate foramen, behind the sphenoidal fissure; and the anterior part of the space referred to above is separated off as a distinct foramen for the mandibular division.

apertures (XII) in the exoccipital, just anterior to the condyle. Various other apertures will be noticed in the skull and jaws : through some of these branches of certain of the above-mentioned nerves pass, while others transmit blood-vessels.

The lower jaw or *mandible* (Fig. 187, A) consists of two halves or rami, each corresponding essentially to the dentary of the frog, which unite with one another in front, at the symphysis, by a rough surface, while behind they diverge like the limbs of the letter V. Each ramus is a vertical plate of bone, broad behind and tapering towards the front, where it bears the incisor teeth : further back, on its upper margin, are the sockets for the cheek-teeth, and behind them is an ascending portion which bears the *condyle* (*cond*) for articulation with the facet on the squamosal : in front of the condyle is a curved *coronoid process* (*cor*). The postero-inferior border, which is rounded and inflected, is known as the *angular process* (*ang. pro*).

The *hyoid* is a small bone situated at the root of the tongue, anterior to the larynx. It consists of a stout body or *basi-hyal*, a pair of small anterior horns, representing the ventral ends of the hyoid arch of lower Vertebrates, and a pair of longer, backwardly projecting posterior horns or *thyro-hyals*, attached to the larynx and representing the lower ends of the first branchial arch (compare p. 418).

The **vertebral column** includes about forty-five bony vertebræ, each consisting of a centrum, a neural arch, and various processes (compare pp. 31–32), but becoming simplified towards the end of the tail. The centra have flat anterior and posterior surfaces, and are not connected by synovial articulations, as in the frog, but interposed between them are elastic *intervertebral discs* of fibro-cartilage. In addition to the ossification which gives

rise to the main part of the centrum, a separate flat disc of bone (Fig. 189, *ep*) is formed on the anterior and posterior surface of each. These *epiphyses* are characteristic of the vertebræ of all or nearly all Mammals: they unite comparatively late with the centrum proper, and so in disarticulated skeletons of young animals they often come away from the main mass of the centrum and remain attached to the intervertebral discs.

In correspondence with the differentiation of the parts of the body, the vertebral column is divisible into five regions (Fig. 185): the *cervical* in the neck, including seven vertebræ, the first two of which—called respectively the *atlas* and *axis*—are peculiarly modified in order to allow the skull free movement; the *thoracic* in the thorax, twelve or thirteen in number, and bearing *ribs*; the *lumbar*, seven or six in the abdominal region; the *sacral*, three or four in the sacral region; and the *caudal*, about fifteen or sixteen in the tail.

Examining one of the anterior thoracic vertebræ first (Fig. 189), we see that the *centrum* (*c*) is continuous above with the *neural arch* (*n. a*), the lower part of which, on either side, presents an anterior and a posterior notch (*i. v. n*), so that when the vertebræ are in their natural position, an *intervertebral foramen* is formed for the passage of a spinal nerve. The roof of the arch is continued into a long *neural spine* (*n. sp*) projecting upwards and backwards, and just above the intervertebral notches are a pair of anterior and posterior *articular processes* or *zygapophyses* (*pr. z, pt. z*), which articulate synovially with the vertebræ next in front and behind respectively. The articular surface of each pre-zygapophysis looks upwards and inwards, that of the post-zygapophysis downwards and outwards. Arising laterally from either side of the arch is an outstanding *transverse process* (*t. pr*), on the under surface of which is an articular *tubercular facet* (*t. f*), with which the upper fork of the rib (p. 454) articulates. The lower fork or *head* of the rib articulates with a facet (*c. f*) formed partly by the anterior edge of the corresponding centrum just at the base of the neural arch, and partly by the posterior edge of the centrum next in front, so that each centrum bears half

a *capitular facet*, as it is called, on either side, both anteriorly and posteriorly (*c. f'*, *c. f''*). There are no free ribs in the vertebræ of other regions, in which, however, they are represented in the embryo, but early fuse with the corresponding transverse processes.

The first *cervical* vertebra, or *atlas* (Fig. 190, A), is ring-shaped, and its lower portion is narrow and unlike the other centra. The neural spine is small, and the transverse processes are broad horizontal plates, each perforated at its base by a *vertebrarterial canal* through which the vertebral artery runs. On the anterior face of the lateral parts of the atlas are two concave articular facets for articulation with the occipital condyles of the skull, and on its posterior face are two small facets for articulation with the second vertebra. The second cervical vertebra, or *axis* (Fig. 190, B), has its centrum produced anteriorly into a conical *odontoid process*, which fits into the lower part of the ring of the atlas and is held in its place by a ligament extending transversely across the latter: it is ossified from a distinct centre, which really belongs to the centrum of the atlas. The neural spine of the axis is elongated and compressed, and its transverse processes small and perforated each by a vertebrarterial canal; zygapophyses are present only on the posterior face of the arch. In all the other cervical vertebræ (Fig. 190, C), the transverse processes are also perforated by vertebrarterial canals, and, except in the seventh or last, are divided into dorsal and ventral lamellæ. The zygapophyses resemble those of the thoracic vertebra described above. The seventh cervical vertebra has a longer spine than the others, and bears a pair of half facets on the posterior surface of its centrum with which the first pair of ribs in part articulate.

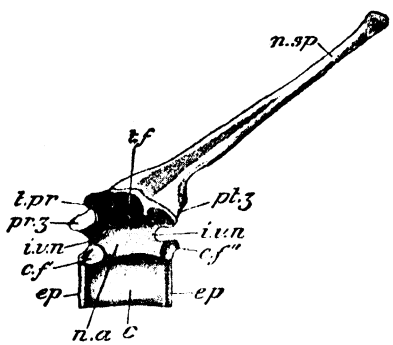


FIG. 189.—Fifth thoracic vertebra of the Rabbit, from the left side. (× 1½.)
c. centrum; *c. f'* capitular half-facet for fifth and *c. f''* for sixth rib; *ep.* epiphysis; *i.v. n.* intervertebral notch; *n. a.* neural arch; *n. sp.* neural spine; *pr. z.* pre-zygapophysis; *pt.z.* post-zygapophysis; *t. f.* tubercular facet for fifth rib; *t. pr.* transverse process.

A typical *thoracic* vertebra has already been described. In the tenth, the neural spine is vertical, and in the remaining two or three, which are larger than the others, it slopes forwards. In the posterior three or four there are no tuber-

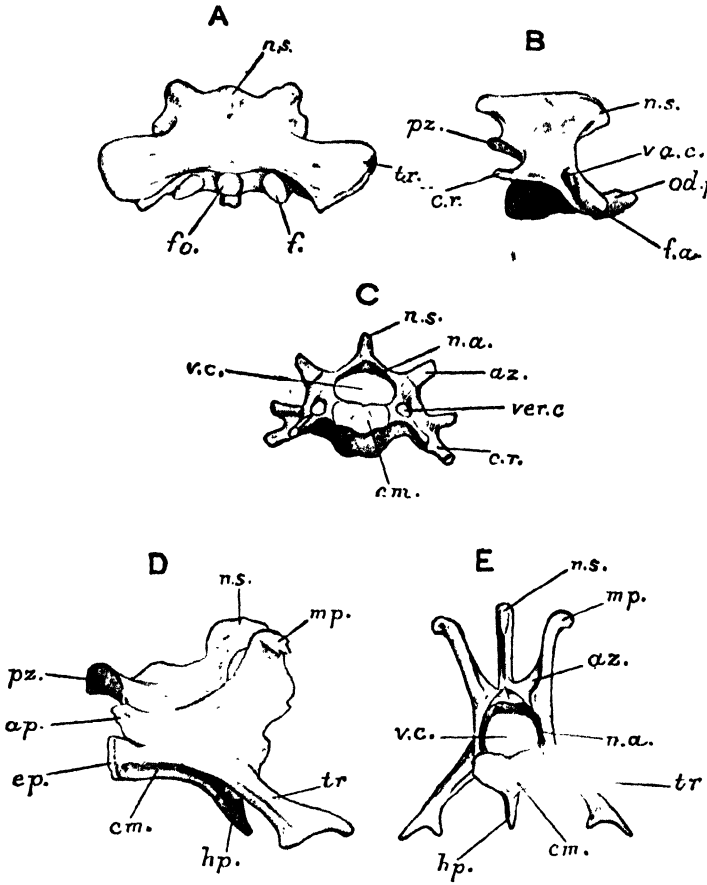


FIG. 190.—Selected vertebræ of Rabbit.

A, Atlas, from the dorsal surface; *B*, Axis, from the right side; *C*, one of the middle cervical vertebræ, anterior aspect; *D*, second lumbar vertebra, from the right side; *E*, the same, anterior aspect; *ap.* anapophysis; *c. r.* cervical rib; *f.* articular surfaces for the axis; *fa.* articular surfaces for the atlas; *fo.* facet for odontoid process; *hp.* hypapophysis; *mp.* metapophysis; *od. p.* odontoid process; *tr.* transverse process; *va. c.* or *ver. c.* vertebrarterial canal. Other letters as in the previous figure.

cular facets, the ribs in this region not being forked; the capitular facets are entire, and are situated on the corresponding centrum only. Additional processes are present above the pre-zygapophyses from the ninth thoracic vertebra onwards.

The *lumbar* vertebræ (Fig. 190, D and E) are relatively large, increasing in size from before backwards, and their various processes are greatly developed. The neural spines are directed upwards and forwards, the transverse processes are large and project outwards, downwards and forwards. As in the posterior thoracic vertebræ, there are stout processes above the pre-zygapophyses (which face *inwards*), and there is also a pair of more slender processes below the post-zygapophyses (which face *outwards*), and a median ventral process projecting downwards from the centrum in the first two.

The *sacral* vertebræ are fused to form the *sacrum* (Fig. 194, *sacr*), which supports the pelvic arch. The first —and to a less extent the second also—has large expanded, transverse processes which articulate with the ilia; these are the sacral vertebræ proper; the others, which decrease in size from before backwards, are really the anterior caudal vertebræ which fuse with the true sacral vertebræ to form a *compound sacrum*.

The more anterior *caudal* vertebræ resemble those of the sacral region, but on passing backwards all the processes are seen to diminish in size, until nothing but the centra are left at the end of the tail.

There are twelve or occasionally thirteen pairs of **ribs**, which have the form of curved rods, situated in the walls of the thorax, and articulating with the thoracic vertebræ above and—in the case of the first seven—with the breast-bone or sternum below: the remaining ribs do not reach the sternum (Fig. 191).

Each rib consists of a bony, dorsal *vertebral portion*, and of a ventral, *sternal portion* consisting of cartilage which is calcified or only incompletely ossified. The dorsal end—the head or *capitulum* of the rib—articulates with the capitular facets on the centra, and the first nine have also a *tubercle*, *a* short distance from the capitulum, which articulates with the tubercular facet; just externally to the tubercle is a short, vertical process.

The **sternum** (Fig. 191), which is developed in the embryo by the fusion of the ventral ends of the ribs (and therefore has a different morphological significance from the sternum of Amphibians, see p. 46), consists of six segments or *sternebræ*, the first of which, or *manu-*

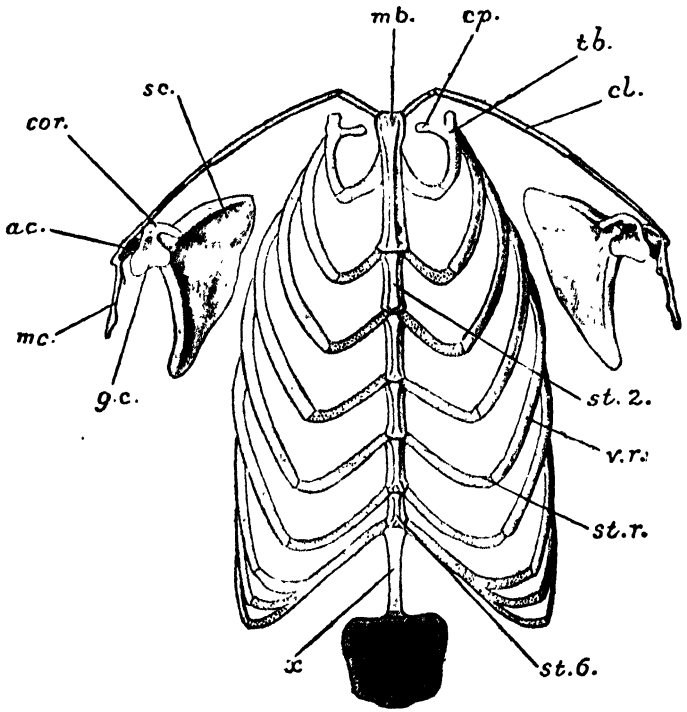


Fig. 191.—Sternum and pectoral arch of Rabbit, ventral aspect. *ac.* acromion; *cl.* clavicle; *cor.* coracoid process; *cp.* capitulum; *g. c.* glenoid cavity; *mb.* manubrium; *mc.* metacromion; *sc.* scapula; *st.* 6. sixth sternebra; *st. r.* sternal portion of a rib; *tb.* tuberculum; *v. r.* vertebral portion of a rib; *x.* xiphisternum with its cartilaginous plate. (After Borradaille.)

brium (*mb*), is larger than the rest, and has a ventral keel. With the last is connected a rounded, horizontal, cartilaginous plate, the *xiphisternum*. The ribs articulate between the successive sternebræ except in the case of

the first pair, the articulations of which are on the manubrium.

The chief bone of the **pectoral arch** is the flat, triangular *scapula* (Fig. 191, *sc*), the coracoid portion (compare p. 45) becoming early fused with it and forming a small, inwardly curved *coracoid process* (*cor*), situated anteriorly to the glenoid cavity at the lower end or apex of the scapula: the apex lies over against the first rib, and the bone inclines upwards and backwards to its dorsal base, which in the fresh condition consists of a strip of cartilage, the *suprascapula*. On its outer surface is a prominent ridge or *spine*, the free ventral edge of which is called the *acromion* (*ac*), from which a process, the *metacromion* (*mc*), projects backwards. The collar-bone or *clavicle* is never strongly developed in Mammals in which the fore-limb only moves in one plane—forwards and backwards: in the rabbit it is a small, curved, rod-like bone, attached by fibrous tissue at one end to the sternum and at the other to the acromion process of the scapula, there being small cartilages at either end of it.

The relative positions of the bones of the **fore-limb** are at first sight somewhat difficult to understand owing to their having become altered in the course of development. In your own fore-arm the bones can be rotated on one another, so that the thumb can be made to point outwards or inwards: while in the rabbit the first digit has permanently the same position, pointing inwards. To understand this, extend your arm outwards with the thumb pointing away from the ground. The back of the hand and arm, continuous with the dorsal surface of the body, or back, is its *dorsal surface*; the palm of the hand, and the surface of the arm continuous with the chest, is its *ventral surface*; the border of the arm and hand continuous with the thumb is the *preaxial border*; and that continuous with the little finger the *postaxial border*. This position is called the position of *supination*; if the fore-arm and hand be now rotated, so that the thumb points inwards, the position is that of *pronation*. While in this position, bend the elbow at right angles and bring

it inwards close to the body; the preaxial border of the hand will now be on the inner side, and an examination of the bones of the fore-arm shows that they cross one another. It is in this position that the bones of the rabbit's fore-limb are permanently fixed (Fig. 185, and compare Fig. 16).

The proximal extremity of the *humerus* (Fig. 192) bears a rounded *head* (*hd*) for articulation with the glenoid cavity, in front of which is a groove for the tendon of the biceps muscle (p. 58); certain *tuberosities* for the attachment of muscles will also be observed. Its distal extremity presents a large, pulley-like surface or *trochlea* (*tr*) for the articulation of the bones of the fore-arm, and a deep depression or *fossa*, perforated by a foramen, on its posterior side, for the reception of the end of the ulna. The *radius* (Fig. 193) is the shorter, inner (preaxial) bone of the fore-arm, and is slightly curved. Its head presents a large double surface for articulation with the trochlea of the humerus, and its distal extremity a pair of slight concavities for the bones of the carpus: the shaft is flattened where it abuts against the corresponding flattened surface of the *ulna* (Fig. 193). Near the proximal end of the last-mentioned bone is a cavity for the articulation of the humerus, and proximally to this, at the elbow, the ulna is produced to form a large *olecranon process* (*o. p.*), which is received into the fossa on the humerus when the limb is extended; its small distal end articulates with the carpus.

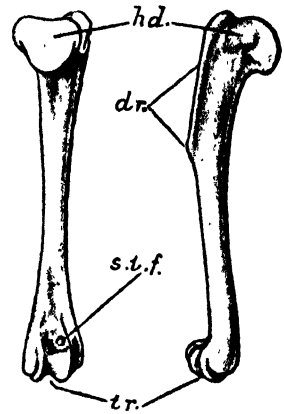


FIG. 192.—Humerus of Rabbit. *d. r.* deltoid ridge; *hd.* head; *s.t. f.* supra-trochlear foramen; *tr.* trochlea.

The skeleton of the hand or *mauus* consists of the *carpus*, the *metacarpus*, and the *phalanges*. The *carpus* (Fig. 193), as in the frog (p. 48), consists of a proximal and a distal row of small, nodular bones, which articulate with one another where they are in contact. The bones of the proximal row, beginning at the inner (preaxial) side, are the *radiale* (*r*) and *intermedium* (*i*) articulating with the radius, and the *ulnare* (*u*), articulating with the ulna. In the distal row are five bones, the middle one of which is distinctly proximal to the other four, so as really to lie in the middle of the carpus: this is the *centrale*, the others constituting a row of *distal carpals*. Of these the first three articulate with the corresponding digits, the fourth, on the outer (postaxial) side, supporting the fourth and fifth digits and really consisting of two carpals fused with one another.

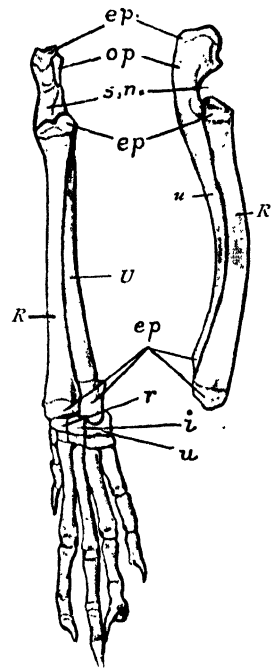


FIG. 193.—Radius and Ulna, Carpals, Metacarpals, and Phalanges of Rabbit.
ep. epiphyses; *i.* intermedium, *o. p.* olecranon process; *R.* radius; *r.* radiale; *s. n.* sigmoid notch; *U.* ulna; *u.* ulnare.

A small bone, the *pisiform*, articulating with the ulna and ulnare on the ventral side, is usually looked upon as a *sesamoid bone*, *i.e.*, an ossification in the tendon of a muscle; but it probably represents the vestige of a sixth digit.

Beyond the carpals (Fig. 193), there are five digits, each made up of a *metacarpal* and *phalanges*, articulating with one another. The innermost (preaxial) digit—the

thumb or *pollex*—is the shortest, and the third the longest: the former has two phalanges, the others three each, the distal or *ungual* phalanx of all the digits having a conical form, its dorsal surface being grooved for the firmer attachment of the horny claw.

The ends of the long bones in both limbs are separately ossified as *epiphyses* (compare p. 451), which eventually unite with the shaft of the bone in question. Small *sesamoid bones* are situated on the under or palmar side of the joints of the digits.

The **pelvic arch** (Fig. 194) consists of two lateral halves or *innominate bones*, the long axis of which is almost parallel with that of the vertebral column (Fig. 185), and which are firmly united anteriorly and internally with the transverse processes of the sacral vertebræ by a rough surface, while ventrally they are connected together by cartilage at the pelvic *symphysis*. On the outer surface of each innominate bone, at about the middle of its length, is a deeply concave cup, the *acetabulum*, for articulation with the head of the femur: in it, in young rabbits, a triradiate suture can be seen, marking the boundaries of the three bones of which the innominate is composed (p. 50).

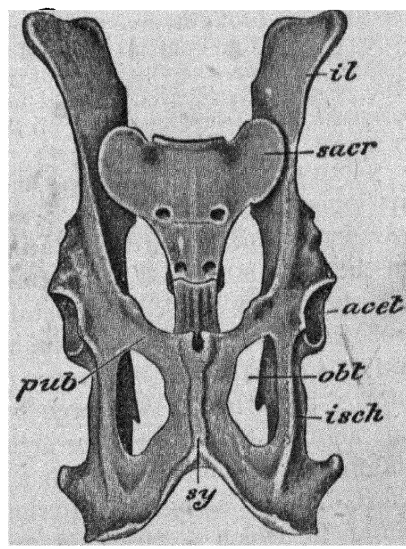


FIG. 194.—Pelvic girdle and sacrum of Rabbit, ventral aspect.
acet. acetabulum; *il.* ileum; *isch.* ischium; *obt.* obturator foramen; *pu.* pubis; *sacr.* sacrum; *sy.* symphysis. (From Parker and Haswell's *Zoology*.)

Of these, the antero-dorsal is the *ilium* (*il*), which is connected with the sacrum. The postero-ventral portion of the innominate is perforated by a large aperture —the *obturator foramen*, through which a nerve of that name passes (p. 492), the bone above and behind it being the *ischium* (*isch*), and that below and in front of it the *pubis* (*pu*). Behind the obturator foramen the ischium has a thickened posterior edge or *tuberosity*, and then curves round and becomes continuous with the pubis, both bones taking part in the symphysis.

The **hind-limb** has undergone rotation forwards (Fig. 185), so as to be brought, like the fore-limb, into a plane parallel with the median vertical plane of the body; but the rotation being forwards, and the bones of the shank not being crossed, the preaxial border is internal in the whole limb, and the original dorsal surface looks, on the whole, forwards.

Close to the proximal end of the *femur* (Fig. 195), on its inner (preaxial) border, is a rounded projecting *head* (*hd*) for articulation with the acetabulum: the actual end of the bone is formed by a strong process, the *great trochanter* (*tr.* 1), while just distal to the head is a *lesser trochanter* (*tr.* 2), and opposite this, on the outer (postaxial) side, a *third trochanter* (*tr.* 3). The distal end of the bone bears two large *condyles*, separated from one another by a notch, for articulation with the tibia: this notch is continuous with a groove extending for a short distance along the anterior (dorsal) surface of the femur in which a large sesamoid bone (p. 195), the knee-cap or *patella* (*p*), slides: the patella lies in the tendon of the extensor muscles of the leg, and is connected by ligament with the tibia. Two other sesamoid bones, the *fabellæ*, occur on the opposite side of the knee-joint.

The *tibia* (Fig. 195, T), or inner (preaxial) bone of the shank, is much larger than the *fibula* (Fig. 195, F), the

distal half of which in the adult becomes completely fused with it. The proximal end of the tibia bears two slightly concave articular surfaces for the condyles of the femur, and distally it articulates with the tarsus: a prominent ridge—the *cnemial crest*—extends along the proximal end of its anterior (dorsal) surface. The slender fibula is attached proximally to the tibia.

The skeleton of the foot or *pes* consists of the *tarsus*, the *metatarsus*, and the *phalanges*. The *tarsus* (Fig. 196) consists of six bones arranged in three rows. In the proximal row (compare p. 50) are two tarsals, of which the inner (preaxial) or *astragalus* (*t*) — probably corresponding to two bones fused together, the *tibiale* and *intermedium* — has a large pulley-like surface for articulation with the tibia; while the outer (postaxial) *calcaneum* or *fibulare* (*f.*) articulates with the fused end of the fibula, and is produced into a strong heel or *calcaneal process*. In the middle row is a single bone, the *centrale* (*navicular*) of the tarsus, and the distal row is made up of three bones, the true first, together with the corresponding digit (*hallux*), being absent as a distinct bone. The second (apparent first) distal tarsal articulates proximally

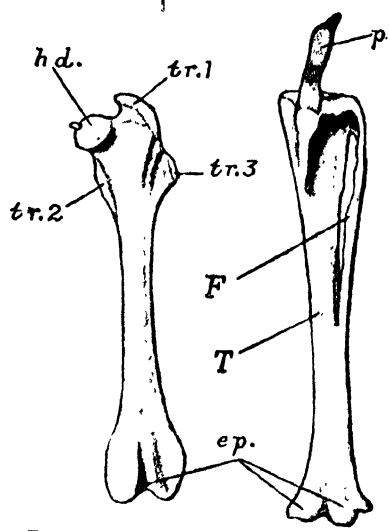


FIG. 195.—Femur, Tibia, and Fibula of Rabbit.
ep. epiphysis; F. fibula; *hd.* head; *p*, patella; T. tibia; *tr.* 1, greater trochanter; *tr.* 2, lesser trochanter; *tr.* 3, third trochanter.

with the centrale, and distally with the innermost (preaxial) metatarsal: the third (apparent second) with the centrale and the corresponding metatarsal: the fourth (apparent third), which corresponds to the two fused outer (postaxial) tarsals, with the centrale, calcaneum, and the remaining two digits.

Beyond the tarsus (Fig. 196) there are four *metatarsals* with their *phalanges*, of which there are three to each digit. The metatarsal of the hallux, together with the corresponding distal tarsal, is probably represented by a distinct ossification which in the adult becomes fused with the second (apparent first) metatarsal, and forms a process of that bone which articulates with the centrale. The phalanges are similar to those of the manus, and sesamoid bones are also present on the under surface of the foot.

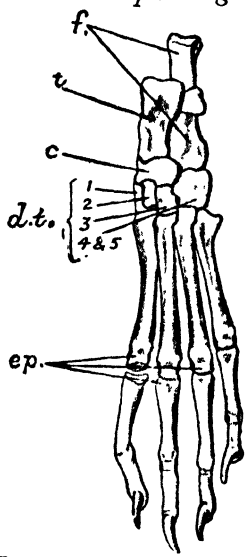


FIG. 196.—Tarsals, Metatarsals, and Phalanges of Rabbit.
c. centrale; *d. t.* 1, 2, 3, 4, and 5, distal tarsals; *ep.* epiphyses; *f.* fibulare (or calcaneum); *t.* tibiale (or astragalus).

Muscles and Body-wall.—It will be remembered that in the lancelet and dogfish the muscles of the trunk are divided up into myomeres (p. 411), while in the adult frog the only indication of such a segmentation of the muscles is seen in the recti of the abdomen. In the rabbit nearly all trace of a segmentation of the muscles has also disappeared, and the muscular system, although similar in its general arrangement to that of the frog (compare Fig. 3), is more highly differentiated and complicated. We shall have occasion to notice certain

of the muscles in the course of our examination of other organs.

Immediately beneath the skin, which consists of epidermis and dermis (Fig. 186), the whole ventral region of the trunk and neck is covered by a thin *cutaneous muscle*, by means of which the rabbit is able to twitch its skin. Internally to this muscle in the female are the *mammary glands* (p. 437), which, when secreting, appear as whitish branched masses, the ducts of which can be traced to the *teats*, on the apices of which they open by numerous small apertures.

A whitish band of connective-tissue passes along the mid-ventral line of the abdomen from the xiphisternum to the pubis : this separates two longitudinal bands of muscle, the *recti abdominis*, from one another; and laterally to them, the abdominal wall consists of three thin layers of muscle with their fibres running in different directions—the *external oblique*, the *internal oblique*, and the *transversalis*, the latter being lined on its inner surface by the peritoneum. A fibrous cord, known as *Poupart's ligament*, beneath which the blood-vessels and nerves pass outwards to the leg, extends upwards and forwards from each pubis to the corresponding ilium. In the thorax the muscles of the body-wall are broken up into separate portions by the ribs, and thus form a series of *intercostal muscles*, which, like the oblique muscles of the abdomen, are arranged in two layers, external and internal, and are important in respiration.

Extending from the thorax to the fore-limb of either side are the large *pectoral muscles*; and a number of other muscles can be seen in the neck, in the ventral middle line of which, covered by the cutaneous muscle, the windpipe or *trachea* is visible (Fig. 198). The trachea is strengthened by a series of cartilaginous rings and ends in front in the *larynx*, situated between the two rami of the mandible; and just in front of the larynx is the hyoid bone (p. 450), embedded in a mass of muscle.

The Cœlome and its Contents.—On cutting open the body-cavity (Fig. 197), it will be seen to be divided into

two main chambers—the *thoracic* and *abdominal cavities* —by means of the *diaphragm* (Fig. 197, B). The relatively

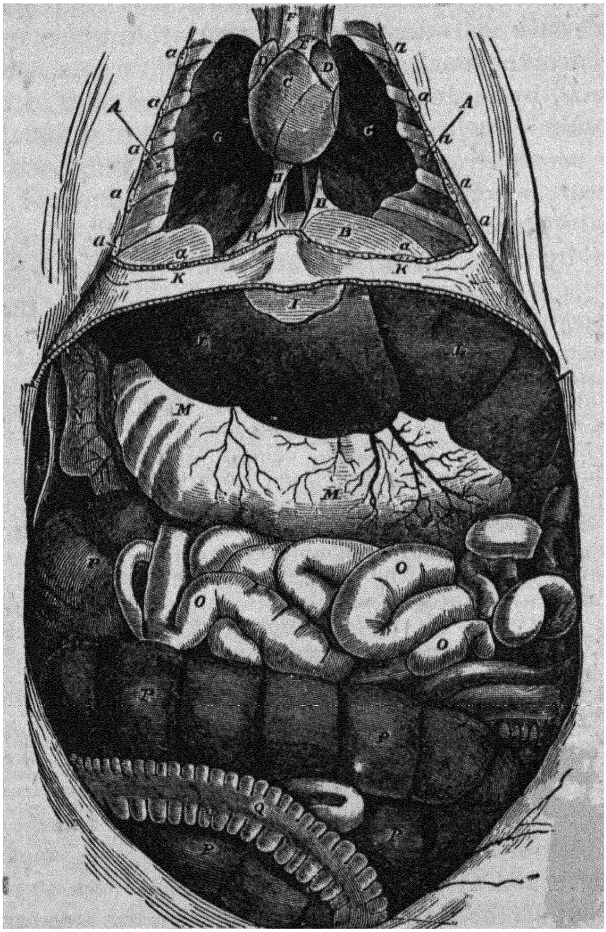


FIG. 197.—The viscera of a Rabbit as seen upon simply opening the cavities of the thorax and abdomen.

A. cavity of the thorax; *B*. diaphragm; *C*. ventricles of heart; *D*. auricles of heart; *E*. pulmonary artery; *F*. aorta; *G*. lungs, collapsed; *H*. part of pleura; *I*. cartilage at end of sternum; *K*. portion of body-wall left between thorax and abdomen; *a*. cut ends of ribs; *L*. liver; *M*. stomach; *N*. duodenum; *O*. small intestine; *P*. cæcum; *Q*. colon. (From Foster and Shore's *Physiology*.)

After entering the thorax, the trachea divides into two *bronchi*, one entering each lung and giving off branches to its different lobes: the bronchi, like the trachea, are supported by incomplete cartilaginous rings at their proximal ends, but these gradually disappear after the bronchi have entered the lungs.

The elastic *lungs* (Fig. 197, G) are not hollow sacs, like those of the frog, but are spongy bodies, of a light pink colour, situated on either side of and above the heart, and filling the greater part of the thoracic cavity, but collapsing as soon as the wall of the thorax is perforated. Each is subdivided into two *main lobes*, and the right lung has in addition two small *accessory lobes*, an anterior and a posterior, the latter lying in the median line, behind the heart, and being closely applied to the gullet.

Each pulmonary artery (Figs. 197, E, and 198, *p. a*) crosses the main bronchus anteriorly to the point at which it branches into the various lobes, except in the case of the anterior accessory lobe, the bronchus to which comes off in front of the artery and may even arise from the trachea before its bifurcation. Microscopic examination shows that the bronchi divide and subdivide to form a ramifying system of tubes, each ultimate branch of which opens into a minute chamber or *infundibulum*, which in structure closely resembles a frog's lung in miniature.

The parietal layer of the pleura (p. 465) lines the cavity of the thorax, and is reflected over each lung at the entrance of the bronchus to form the visceral layer: in the median line it forms a vertical partition, the *mediastinum*, with which it is continuous on the ventral side of the vertebral column above, and beneath the pericardium below (Fig. 202). Thus each lung (*l. lng*, *r. lng*) has its own separate *pleural cavity* (*l. pl*, *r. pl*), separated from its fellow by the right and left mediastinum, the space between which is called the *mediastinal*

space. The anterior and dorsal parts of this space are narrow, and enclose the posterior part of the trachea and the bronchi, as well as the gullet (*oes*) and main blood-vessels (*aort, az. v, pt. cav*); its middle part is wide, and encloses the heart (*l. vent, r. vent*), the mediastinum here fusing with the parietal layer of the pericardium (*par.*

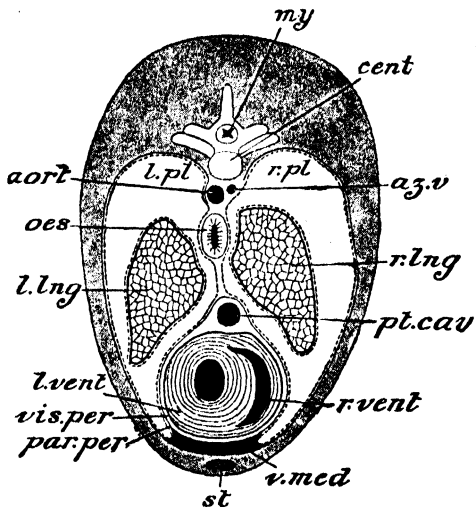


FIG. 202.—Diagrammatic transverse section of the Rabbit's thorax in the region of the ventricles, to show the relations of the pleuræ and mediastinum (dotted line), etc. The lungs are contracted. (× ⅔.)
aort. dorsal aorta; *az. v.* azygos vein; *cent.* centrum of thoracic vertebra; *l. lng.* left lung; *l. pl.* left pleural cavity; *l. vent.* left ventricle; *my.* spinal cord; *oes.* gullet; *par. per.* parietal layer of pericardium; *pt. cav.* postcaval, close to its entrance into right auricle; *r. lng.* right lung; *r. pl.* right pleural cavity; *r. vent.* right ventricle; *st.* sternum; *vis. per.* visceral layer of pericardium; *v. med.* ventral mediastinal space. (From Parker and Haswell's *Zoology.*)

per) and thus obliterating the space; below this it again narrows to form the ventral mediastinal space (*v. med*), in which the thymus (p. 465) is situated.

In the entire animal, the air-tight pleural cavities are completely filled by the lungs, so that the parietal and visceral layers of the pleuræ are practically in contact, there being only a lubricating serous fluid (lymph)

between them. The pressure of the air in the bronchial cavities of the lungs is therefore sufficient to keep them distended; but as soon as the pleural cavities are perforated, air passes in and equalises the pressure: the elasticity of the lungs then comes into play, causing them to collapse. When the muscles of the diaphragm contract (p. 465), air is drawn into the lungs, and this process is aided by the external intercostal muscles (p. 463) and, in forced respiration, by other muscles of the body-wall also. The mechanism of respiration may therefore be compared with a suction-pump, while that in the frog resembles a force-pump (p. 126).

On either side of the larynx is a soft, vascular, gland-like *thyroid* body, consisting of two lateral portions connected ventrally by a median bridge. Morphologically it represents a gland developed from the pharynx, but it loses its connection with the latter and thus has no duct. The glandular vesicles of which it is composed give rise to an albuminous substance containing iodine, which is passed into the blood and lymph. The effect of the internal secretion of the thyroid gland is to increase the chemical activity and growth of all parts of the body. A deficiency of that secretion leads to sluggishness and undergrowth. The thymus (p. 465), is largest in young animals, becoming reduced in size in adults.

Organs of Circulation.—The **heart,** as in all Vertebrates, is enclosed in a *pericardium* consisting of parietal and visceral layers (Fig. 202), between which is a serous pericardial fluid. There is a complete separation between the arterial and venous blood in the heart, for in addition to an auricular septum, as in the frog (p. 83), the ventricular portion is divided into right and left chambers by a partition (Fig. 202), as in the Birds (p. 435), the arterial blood from the lungs entering the left auricle and thence passing into the left ventricle to be pumped into the aorta, and the venous blood entering the right auricle and thence into the right

ventricle to pass to the lungs through the pulmonary artery. A distinct conus arteriosus and sinus venosus (p. 76) can no longer be recognized, the former having become practically absorbed into the ventricular portion of the heart, and the latter into the right auricle; so that the aorta (together with the carotids) and the pulmonary artery now arise directly from the left and right ventricles respectively, and the precavals and postcaval enter the right auricle directly (Figs. 203, 204).

The line of separation between the two ventricles can be seen externally as an oblique depression extending from the base of the heart backwards and to the right, but not reaching the apex, which is formed by the left ventricle only. The small, irregular cavity of the latter is enclosed by very thick muscular walls, and is partly surrounded by the right ventricle, the cavity of which is crescentic in transverse section (Fig. 201), while its walls are much thinner than those of the left ventricle as it has only to pump the blood to the lungs. The auricles have thin walls: each is produced into a little flap or *appendix* which envelops the base of the corresponding ventricle, and the walls of which are strengthened by a network of muscular bands.

In the auricular septum is a thin, oval area, the *fossa ovalis* (Fig. 203, *f. ov*), which in the embryo is perforated and so allows the blood from the posterior part of the body to pass directly into the left auricle without going to the lungs, which are not, of course, functional until the animal is born.

The two auriculo-ventricular apertures are guarded by valves—that of the left side, *bicuspid valve* or *mitral valve*, consisting of two membranous flaps, that of the right, or *tricuspid valve* (Fig. 203, *tri. v*), of three flaps: the valves are attached by their bases to the margins of the apertures, their apices extending into the corre-

sponding ventricles. Attached to their edges are tendinous cords arising from conical elevations of the ventricular walls known as *papillary muscles* (*m. pap*), which are much larger in the left ventricle than in the right: these serve to prevent the valves from being pushed into the auricles when the ventricles contract.

The right ventricle narrows towards its base, on the ventral side of the heart, to form a conical prolongation

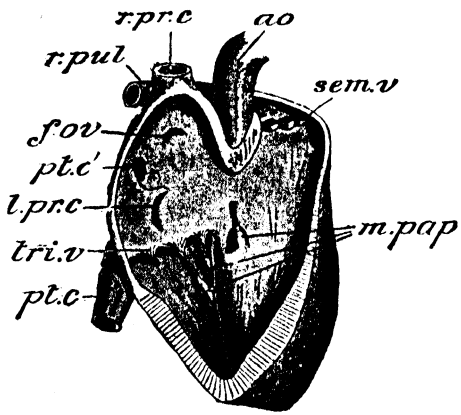


FIG. 203.—Heart of the Rabbit, seen from the right side, the walls of the right auricle and right ventricle partly removed so as to expose the cavities. (× 1½.)
ao. aorta; *f. ov.* fossa ovalis; *l. pr. c.* opening of left precaval; *m. pap.* papillary muscles; *pt. c.* postcaval; *pt. c'.* opening of postcaval, with Eustachian valve below; *r. pr. c.* right precaval; *r. pul.* right pulmonary artery; *sem. v.* semilunar valves at base of pulmonary artery; *tri. v.* tricuspid valve. (From Parker and Haswell's *Zoology*.)

from which arises the *pulmonary artery* (Figs. 197, E, and 204, *p. a*), its aperture being guarded by three pocket-like, semilunar valves (Fig. 203, *sem. v*): the aperture of the aorta from the left ventricle is similarly provided with three semilunar valves. The two precavals (*l. pr. c*, *r. pr. c*) and the postcaval (*pt. c*) communicate, as we have seen, directly with the right auricle, the right precaval opening into it anteriorly, the left precaval posteriorly, the aperture of the postcaval being just

anterior to that of the left precaval. The pulmonary veins from each lung unite and open close together into the left auricle.

A membranous fold, the *Eustachian valve*, extends into the right auricle from the circular ridge surrounding the fossa ovalis (*annulus ovalis*) to the apertures of the postcaval and left precaval respectively: in the embryo this helps to direct the blood through the aperture in the auricular septum (p. 478) and represents the remains of the sinu-auricular valve (p. 86). It, like the "*ductus arteriosus*" (p. 483, and compare Fig. 204), affords another example of a vestigial structure.

Arteries.—You will remember that in the frog (p. 76) there are two systemic trunks, representing the second arterial arch of the tadpole and fish (p. 420), and uniting dorsally to form the dorsal aorta. In the Mammal, one of these—the right—disappears in the course of development and all the blood from the left ventricle passes into the single *left aortic arch* (Figs. 203 and 204) from the base of which both carotid arteries arise, the aortic arch then curving over the left bronchus to pass into the dorsal aorta (*d. ao*).

Close to the origin of the aortic arch, just beyond its semilunar valves, two small *coronary arteries* are given off to the walls of the heart; and more anteriorly, at the curve of the arch, arise the vessels which supply the head and fore-limb. There is a certain amount of variation as to the origin of these, which is asymmetrical, and is usually as follows. Springing from the arch of the aorta towards the right side is an *innominate artery* (Fig. 204, *in*), which gives off close to its origin the *left common carotid* (*l. c. c*), and then, passing forwards, divides into the *right common carotid* (*r. c. c*) and the right *subclavian* (*s. cl. a*), the *left subclavian* (*br*) taking its origin independently from the left side of the arch. Each common carotid passes forwards along the neck,

close to the trachea, and at about the level of the larynx divides into an *internal carotid* (*i. c*), which supplies the brain, and an *external carotid* (*e. c*) which goes to the head and face. Each subclavian forms several branches, the most important of which are a *brachial* (*br*) to the fore-limb, a *vertebral* (*vr*) which passes through the vertebrarterial canal of the cervical vertebræ (p. 452) and supplies the spinal cord and brain, and an *anterior epigastric* or *internal mammary* (*a. epg*) running along the inner side of the ventral wall of the thorax. The aorta gives off, in the thorax, a series of small paired *intercostal arteries* (*i. cs*) to the body-wall, and then passes into the abdomen, between the pillars of the diaphragm.

A short distance behind the diaphragm the *cœliac artery* (Figs. 200 and 204, *cœ*) arises, and supplies the liver, spleen, stomach, and duodenum; and about half or three-quarters of an inch farther back is the *anterior mesenteric artery* (*a. m. a*), the branches of which pass to the small intestine, pancreas, cæcum, and colon. Close behind the anterior mesenteric is the right—and rather further back the left—*renal artery* (Fig. 204, *r*), and still more posteriorly, a *posterior mesenteric* (*p. m*) to the rectum, and a pair of *spermatic* (*spm*) or *ovarian* arteries to the spermaries or ovaries, as the case may be. A small *caudal artery* (*m. sc*), corresponding to the caudal continuation of the aorta, arises from the dorsal surface of the posterior part of the latter just in front of a pair of large *common iliac arteries* (*c. il. a*), which appear like a bifurcation of the aorta. These are continued outwards and backwards towards the hind-limbs, each giving off an *ilio-lumbar artery* (*i. l*) to the dorsal body-wall and then dividing into an *internal iliac* (*i. il. a*) passing along the dorsal side of the pelvic cavity, and an *external iliac* (*e. il. a*) which gives off an artery to the bladder

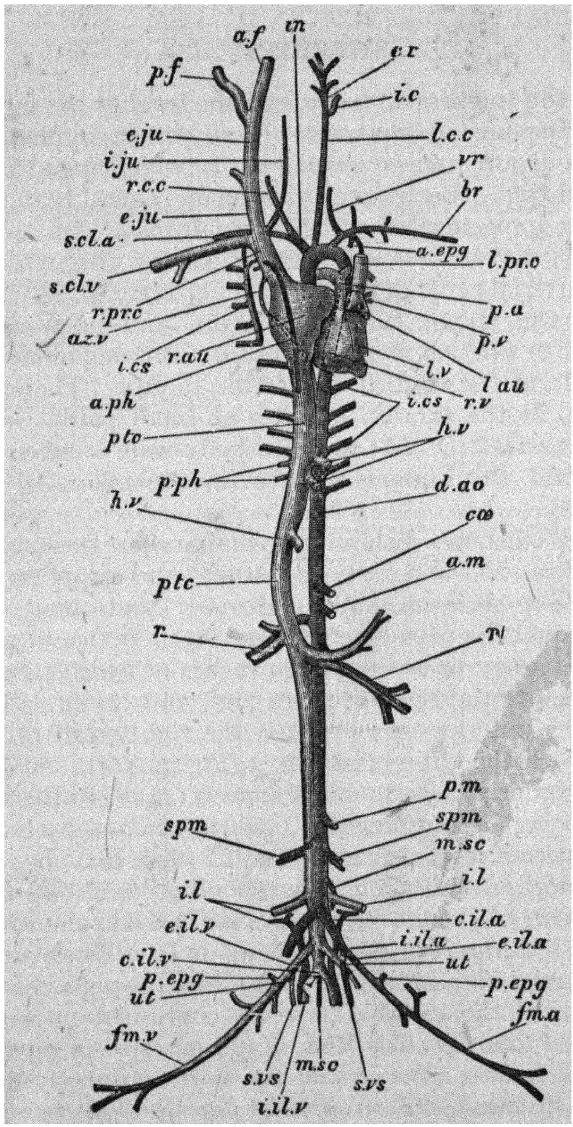


FIG. 204.—The vascular system of the Rabbit from the ventral side. The heart is somewhat displaced towards the left of the subject; the arteries of the right and the veins of the left side are in great measure removed. (× ½.)

a. epg. anterior epigastric artery; *a. .*. anterior facial vein; *a. m.* anterior mesenteric artery; *a. ph.* anterior phrenic vein; *az. v.* azygos vein; *br.* right brachial artery; *c. il. a.* common iliac artery; *c. il. v.* hinder end of postcaval; *cœ.* cœliac artery; *d. ao.* dorsal aorta; *e. c.* external carotid artery; *e. il. a.* external iliac artery; *e. il. v.* external iliac vein; *e. ju.* external jugular vein; *fm. a.* femoral artery; *fm. v.* femoral vein; *h. v.* hepatic veins; *i. c.* internal carotid artery; *i. cs.* intercostal vessels; *i. ju.* internal jugular vein; *i. l.* iliolumbar artery and vein; *in.* innominate artery; *l. au.* left auricle; *l. c. c.* left common carotid artery; *l. pr. c.* left precaval vein; *l. v.* left ventricle; *m. sc.* caudal artery; *p. a.* pulmonary artery; *p. epg.* posterior epigastric artery and vein; *p. f.* posterior facial vein; *p. m.* posterior mesenteric artery; *p. ph.* posterior phrenic veins; *ptc.* postcaval vein; *p. v.* pulmonary vein; *r.* renal artery and vein; *r. au.* right auricle; *r. c. c.* right common carotid artery; *r. prc.* right precaval vein; *r. v.* right ventricle; *scl. a.* right subclavian artery; *scl. v.* right subclavian vein; *spm.* spermatic artery and vein; *s. vs.* vesical artery and vein; *ut.* uterine artery and vein; *vr.* vertebral artery. (From Parker's *Zootomy*.)

(*s. vs*), and in the female one to the part of the oviduct known as the uterus (*ut*); and then, passing beneath Poupart's ligament (p. 463) to the hind-limb, becomes the *femoral artery* (*fm. a*), from the proximal end of which a *posterior epigastric* (*p. epg*) runs forwards in the ventral abdominal wall. Small *lumbar arteries* are also given off from the aorta to the walls of the abdomen.

The *pulmonary artery* (*p. a*) divides soon after its origin from the right ventricle into two branches, one supplying each lung. Just before its bifurcation it is connected by a short cord, known as the *ductus arteriosus*, with the aorta: this is the solid vestige of the embryonic connection between the fourth arterial arch and the aorta (compare p. 480, and Fig. 204).

Veins.—Each *precaval* (*l. pr. c, r. pr. c*) receives—(1) a *subclavian* (*s. cl. v*) from the fore-limb; (2) an *external jugular* (*e. ju*) from the head, running along the neck just beneath the skin; (3) a small *internal mammary* from the ventral thoracic wall; (4) an *anterior intercostal* (*i. cs*) formed by the union of small vessels from some of the anterior intercostal spaces; (5) *anterior phrenic* (*a. ph.*) from the anterior surface of the diaphragm; and (6) a small *internal jugular* (*i. ju*) from the brain, opening into the corresponding external jugular nearly opposite the subclavian. The right precavel also receives

(7) an *azygos vein* (*az. v*), representing part of the right cardinal of the embryo (compare p. 421) and receiving blood from the posterior intercostal spaces of both sides.

There is no renal portal system, as in the dogfish and frog (pp. 421 and 81). A pair of *internal iliac veins* (*i. il. v*) in the pelvic cavity unite to join a median vessel (*c. il. v*), the hinder end of the postcaval, which receives on either side an *external iliac* (*e. il. v*) : this latter is constituted by a *femoral vein* (*fm. v*) from the hind-limb; a *posterior epigastric* (*p. epg*), from the ventral walls of the abdomen, entering the femoral just external to Poupart's ligament; and by small veins from the bladder as well as from the uterus in the female. Slightly in front of the external iliacs the postcaval receives a pair of large *ilio-lumbar veins* (*i. l*) from the body-walls: the left ilio-lumbar sometimes runs forwards to open into the corresponding renal vein. Rather more anteriorly still are a pair of *spermatic* (*spm*) or *ovarian* veins, and a large *renal vein* (*r*) enters the postcaval from each kidney. As the postcaval passes through the dorsal border of the liver it receives several large *hepatic veins* (Figs. 200 and 204, *h. v*) from the lobes of that organ. Other small veins from the body-walls and from the posterior surface of the diaphragm also open into the postcaval, which then passes through the central tendon of the diaphragm and runs forward in the mediastinal space (Fig. 202, *pt. cav*) to open into the right auricle.

The *hepatic portal vein* (Fig. 200, *p. v*) is a large vessel situated in the mesentery, ventral to the postcaval. Anteriorly it passes into and divides up in the liver, sending a branch to each lobe: posteriorly it is constituted by a large *anterior mesenteric vein* (*m. v*) returning the blood from the small intestine, colon, and cæcum, and by smaller veins from the stomach, spleen, and duodenum,

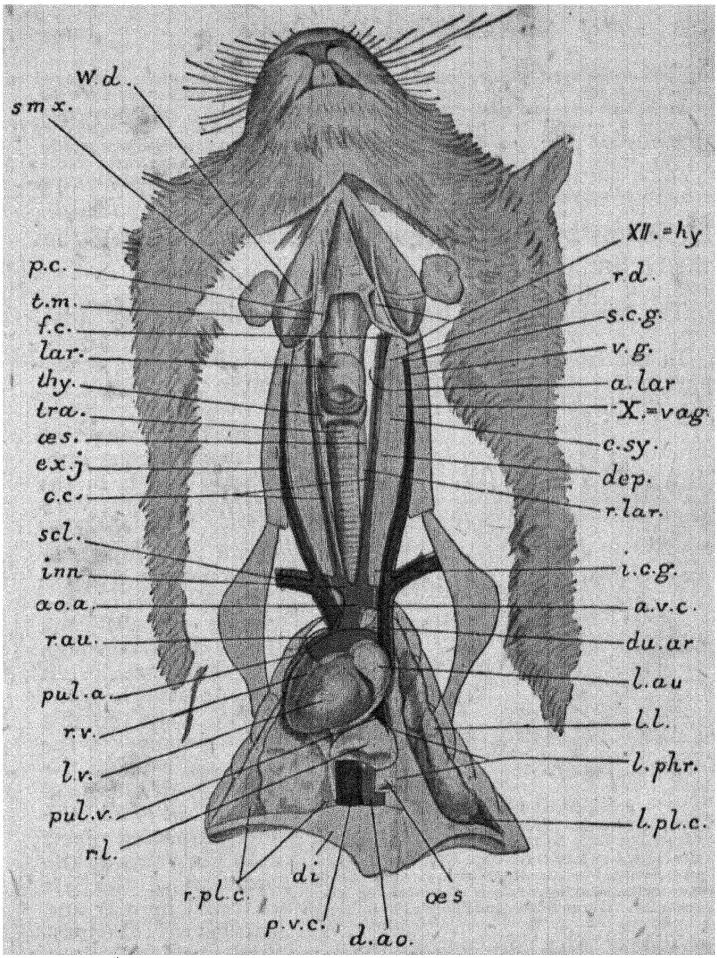


FIG. 205.—Dissection of the neck and thorax of the Rabbit. The heart has been displaced a little to the right, and the pericardium removed. Arteries are coloured red, veins blue, and nerves yellow.

a. lar. anterior laryngeal branch of the vagus; *ao. a.* aortic arch; *a. v. c.* anterior vena cava; *c. c.* common carotid arteries; *c. sy.* cervical sympathetic nerve; *d. ao.* dorsal aorta; *dep.* depressor nerve; *di.* diaphragm; *du. ar.* ductus arteriosus; *ex. j.* external jugular vein; *f. c.* point at which the common carotid divides; *hy.* hypoglossal nerve; *i. c. g.* inferior or posterior cervical sympathetic ganglion; *inn.* innominate artery; *l. au.* left auricle; *l. l.* left lung; *l. phr.* left phrenic nerve; *l. pl. c.* left pleural cavity; *l. v.* left ventricle; *lar.* larynx; *oes.* œsophagus in neck; *oes'.* the same in the thorax; *p. c.* posterior cornu of the hyoid; *p. lar.* posterior laryngeal branch of the vagus; *pul. a.* pulmonary artery; *pul. v.*

pulmonary vein; *p. v. c.* posterior vena cava; *r. au.* right auricle; *r. d.* ramus descendens; *r. l.* right lung, one part bulging into the mediastinum; *r. lar.* recurrent laryngeal nerve; *r. pl. c.* right pleural cavity; *r. v.* right ventricle; *s. c. g.* superior or anterior cervical sympathetic ganglion; *scl.* subclavian artery and vein; *smx.* submaxillary gland; *t. m.* tendon of mandibular muscle; *thy.* thyroid gland; *tra.* trachea; *v. g.* vagus ganglion; *vag.* vagus nerve; *w. d.* duct of submaxillary gland (Wharton's duct); X, XII, cranial nerves. (After Borradaille, modified.)

as well as by a *posterior mesenteric vein* (*p. m. v.*) from the rectum.

The *pulmonary veins* have already been described (p. 480).

In the freshly-killed animal a number of delicate, transparent *lymphatic vessels* (p. 94) can be made out, those from the intestine (*lacteals*) running in the mesentery. They come into connection with numerous lymphatic glands in the mesentery and elsewhere, and most of them communicate with a main trunk—the *thoracic duct*—which extends from the abdomen through the thorax on the left and dorsal side of the aorta. The thoracic duct also receives the lymphatics from the left side of the head and neck and the fore-limb, and opens into the veins at the junction of the left external jugular and subclavian: the lymphatics of the right side of the head and neck and right fore-limb communicate with the corresponding veins of the right side.

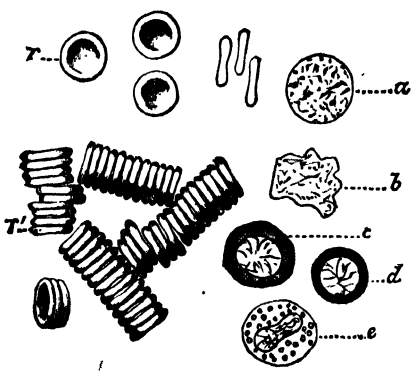


FIG. 206.—Blood-corpuscles of Man. *r.* red corpuscles seen on the flat; *r'.* red corpuscles seen on edge, and run together in rows; *a. b.* white corpuscles showing amœboid movement, nucleus not seen; *c. d. e.* white corpuscles showing nuclei; *e.* containing also granules. (From Foster and Shore's *Physiology*.)

Blood.—The blood of the rabbit differs from that of the frog in certain respects. The red blood-corpuscles are circular, biconcave, non-nucleated discs, instead of being oval, biconvex, and nucleated as in the other

classes of vertebrates; and the white corpuscles are irregular in shape, nucleated, and slightly larger than the red corpuscles. The temperature of the blood, instead of varying with that of the surrounding air, is almost constant at about 100° F. This is what is meant when we say that the rabbit is a warm-blooded animal.

Nervous System.—The **brain** (Figs. 198, 206*a*, 207, and 208) reaches a much higher development than in the

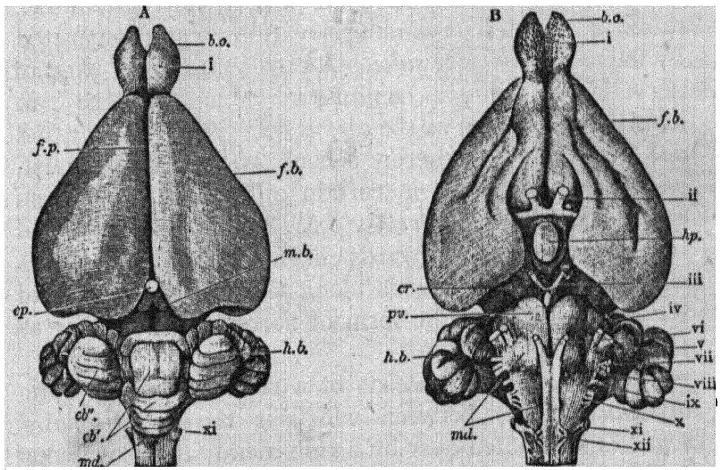


FIG. 206*a*. The brain of the Rabbit. A, dorsal; B, ventral view. *b.o.* olfactory lobe; *cb'*. central lobe of cerebellum; *cb''*. lateral lobe of cerebellum; *cr.* crura cerebri; *ep.* pineal body; *f. b.* cerebral hemisphere; *f. p.* dorsal fissure; *h. b.* hind brain; *hp.* pituitary body; *m. b.* mid-brain; *md.* medulla oblongata; *p. v.* pons Varolii; i–xii. cerebral nerves. (After Wiedersheim.)

other Vertebrates we have already studied. The fore-brain consists, as usual, of the prosencephalon and the diencephalon. The prosencephalon is sub-divided into two *cerebral hemispheres* (Figs. 206*a*, *f.b.*, 207, *ch*), of much larger relative size than those of the frog and forming about two-thirds of the whole brain. They are closely applied to one another along their flat

internal surfaces, are roughly conical in form, narrower in front (*frontal lobes*), broadening out posteriorly (*parietal lobes*)—where they overlap the diencephalon and optic lobes and abut against the cerebellum, and produced downwards into the prominent *temporal lobes* which partly overlap the crura cerebri below. Their external layer or *cortex* is formed of grey matter, and their surface is convex and smooth, except for the presence of slight lateral grooves between the lobes: in many Mammals the hemispheres are highly convoluted, *i.e.*, raised into numerous winding elevations or *gyri*, separated by narrow grooves or *sulci*. A broad transverse band of nerve-fibres forms a commissure connecting the two hemispheres known as the *corpus callosum* (Figs. 207 and 208, *cp. cl*): this structure is confined to the Mammalia, and is even wanting in certain of the lower members of the class. The *olfactory lobes* (*olf*) are club-shaped bodies projecting forwards beyond the hemispheres and extending backwards along the ventral surface of the hemispheres in the form of narrow bands as far as the temporal lobes.

The *diencephalon* consists of a right and a left *optic thalamus* (*o. th*) between which is the slit-like *third ventricle* (v^3) roofed over by a thin membrane continuous with a vascular *choroid plexus* (Fig. 208, *vl. ip*), and from its hinder part arises a stalk bearing at the end a small, rounded *pineal body* (*pn*). The floor of the diencephalon is produced downwards to form the *infundibulum* (*inf*), to which the *pituitary body* (*pty*) is attached. In front of the infundibulum is the *optic chiasma* (*o. ch*), and behind it a small rounded, lobe (*c. ma*).

In the mid-brain each *optic lobe* is divided into two by a transverse furrow, so that there are four rounded elevations in this region—an anterior, larger pair (*o.* l^1), and a posterior, smaller pair (*o.* l^2). Below the optic

lobes are the *crura cerebri* (*c. c*)—two strong, diverging bands passing forwards and outwards from the bulb to the hemispheres.

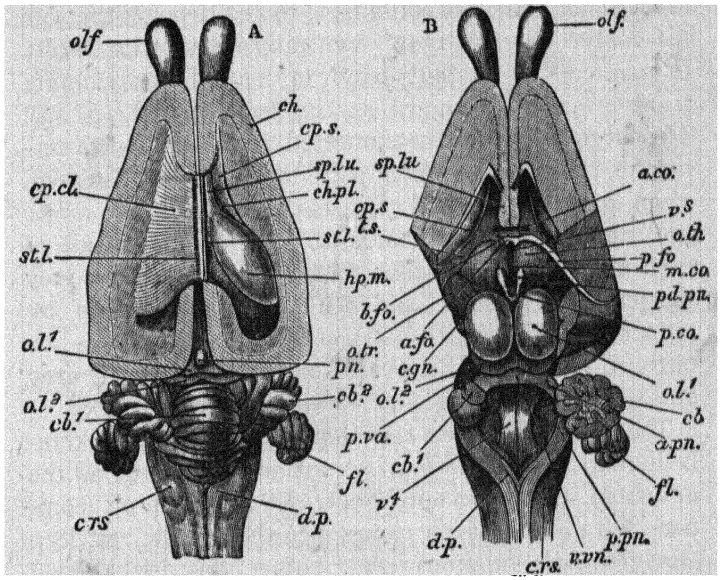


FIG. 207.—Two dissections of the Rabbit's brain, from above. (× 1¼.) In A, the left hemisphere is dissected down to the level of the corpus callosum; on the right side the lateral ventricle is exposed. In B, the hemispheres are dissected down to a little below the level of the anterior end of the corpus callosum; only the frontal lobe of the left hemisphere is retained, of the right a portion of the temporal lobe also remains; the choroid plexus and pineal body are removed, as well as the greater part of the body of the fornix and the whole of its left posterior pillar; the cerebellum is removed with the exception of a part of its right lateral lobe with the flocculus.

a. co. anterior commissure; *a. fo.* anterior pillar of fornix; *a. pn.* anterior peduncles of cerebellum; *b. fo.* body of fornix; *cb*¹. central lobe of cerebellum; *cb*². its lateral lobe; *c. gn.* elevation on the optic thalamus; *c. h.* cerebral hemisphere; *ch. pl.* part of choroid plexus; *cp. cl.* corpus callosum; *cp. s.* corpus striatum; *c. rs.* and *d. p.* elevations on the bulb; *fl.* flocculus; *hp. m.* hippocampus; *m. co.* middle commissure; *o. l*¹., *o. l*²., optic lobes; *olf.* olfactory lobe; *o. th.* optic thalamus; *o, tr.* optic tract (continuation of chiasma); *p. co.* posterior commissure; *p. fo.* posterior pillar of fornix; *pn.* pineal body; *pd. pn.* its peduncle; *p. pn.* posterior peduncles of cerebellum; *p. va.* fibres of pons Varolii forming middle peduncles of cerebellum; *sp. lu.* septum lucidum; *st. l.* line on corpus callosum; *t. s.* band of white matter lying beneath choroid plexus; *v. vn.* valve of Vieussens; *v*³. third ventricle; *v*⁴. fourth ventricle. (From Parker's *Zootomy*.)

The hind brain comprises the medulla oblongata, the cerebellum, and the pons Varolii. The *medulla oblongata*

(*m. o*) is slightly flattened dorso-ventrally, and passes behind into the spinal cord, the dorsal and ventral fissures of which are continued into it: the *fourth ventricle* (v^4) which it contains is roofed over by the thin pia mater only (p. 139). Ventrally its anterior border is marked by a stout band of nerve-fibres running transversely, and known as the *pons Varolii* (*p, va*). The large *cerebellum* is connected with the dorsal surface of the brain by three pairs of peduncles (Fig. 207, *a. pn, p. va, p. pn*), and consists of a median *central lobe* (cb^1) and of two *lateral lobes* (cb^2), on the outer side of each of which is a smaller *floccular lobe* (*fl*). The grey matter is superficial, and the surface is marked by numerous folds which in section present a tree-like pattern, brought about by the arrangement of the grey and white matter (Fig. 208).

The fourth ventricle is not prolonged into the cerebellum to any extent: it is continued forwards as the *iter*, from which two optic ventricles are given off (compare p. 139) and which passes into the narrow but deep *third ventricle* in front (Fig. 208): this is bounded anteriorly by a thin wall (*l. t*), and extends into the infundibulum below. At its anterior end are the *foramina of Monro* (*f. m*), leading into the middle of the *lateral ventricles* in the hemispheres (Fig. 207, A). In this region each lateral ventricle is broad from side to side, but narrow from above downwards; it extends forwards into the frontal lobe, backwards into the parietal lobe, and downwards into the temporal lobe. The olfactory lobes are solid.

A prominent, convex ridge of white matter—the *hippocampus* (Fig. 207, *hp. m*)—projects into the inner side and floor of each lateral ventricle where it descends into the temporal lobe, and closely applied to it is a continuation of the choroid plexus (*ch. pl*), which passes from the roof of the third ventricle into the lateral ventricle through the foramen

of Monro. In front of the hippocampus the outer side and floor of the anterior part of the lateral ventricle are thickened to form an eminence of grey matter, the *corpus striatum* (*cp. s*). Just beneath the corpus callosum the internal wall of each lateral ventricle is thin, and is known as the *septum lucidum* (*sp. lu*); and below it and above the foramina of Monro is another commissure known as the body of the *fornix* (Figs. 207 and 208, *b. fo*) which is continuous on either side with two bands—one (posterior pillar) lying along the anterior edge of the hippocampus, and the other (anterior pillar) passing downwards and backwards in the side walls of

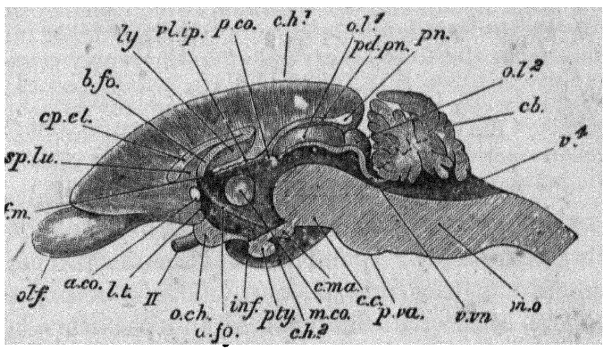


FIG. 208.—Longitudinal vertical section of the Rabbit's brain. (× 1½.) Letters as in preceding figure; in addition—*cb.* central lobe of cerebellum; *c. c.* crus cerebrum; *c. h*¹. parietal, and *c. h*². temporal lobe of cerebral hemisphere; *c. ma.* elevation behind the infundibulum; *f. m.* foramen of Monro; *inf.* infundibulum; *l. t.* anterior wall of the third ventricle; *ly.* part of hippocampus; *m. o.* medulla oblongata; *o. ch.* optic chiasma; *pty.* pituitary body; *vl. ip.* choroid plexus; *v. vn.* valve of Vieussens; *II.* optic nerve. (From Parker's *Zootomy*.)

the third ventricle. Connecting the two optic thalami are three transverse bands of nerve-fibres, known respectively as the *anterior* (*a. co*), *middle* (*m. co*), and *posterior* (*p. co*) *commissures* : the middle commissure, which is much the largest, is not represented in the lower Vertebrata.

The **spinal cord** (Fig. 198) is similar in structure to that already described in other Vertebrates (p. 137). It extends through the entire neural canal, ends in a *filum terminale*, and is swollen opposite the fore- and hind-limbs, where the nerves arise which form the limb-plexuses (p. 137).

The dorsal and ventral roots of the spinal nerves lie in the same transverse plane, as in the frog (p. 146), but are relatively shorter than in that animal; after uniting to form the nerve-trunks, they pass directly outwards through the intervertebral foramina. The *brachial plexus* is formed from the four posterior cervical and the first thoracic nerves, and gives off a number of nerves to the shoulder and fore-limb. The *sciatic* or *lumbosacral* plexus is constituted by the two or three hindermost lumbar and the first two or three sacral nerves, and gives off branches to the pelvic region and hind-limb, a *femoral* and a *peroneal* going to the extensor muscles, and a large *sciatic* and an *obturator* (which passes through the obturator foramen, p. 460) supplying the flexor muscles. Arising from the fourth cervical spinal nerve of either side is a *phrenic nerve* (Fig. 205, *l. phr.*), which passes backwards, between the heart and the lung of its own side, to supply the muscles of the diaphragm; and a large *auricular nerve*, arising from the third cervical nerve, supplies the external ear.

The origin and distribution of the first ten pairs of **cerebral nerves** correspond in their main features with those seen in the frog (p. 146). The olfactory nerves arise as a number of fine threads and pass through the numerous openings of the cribriform plate at the front end of the cranium. The facial is almost entirely a motor nerve and is chiefly important in supplying the facial muscles, which are very highly developed in Mammals. The vagus (Fig. 205) runs backwards outside the carotid artery and gives off an *anterior laryngeal* branch to the larynx (*a. l*), a *depressor* branch (*dep*) which arises near the anterior laryngeal, and passes backwards just external to the carotid artery, and a *posterior* or *recurrent laryngeal* branch (*r. lar*) which loops round an artery and runs forwards beside the trachea. After giving off these branches, the vagus passes backwards along the œsophagus and gives the usual branches in the thorax, where it can be readily seen lying dorsal to the heart and the root of the lung.

In addition to the ten cerebral nerves enumerated in

the frog (p. 146), two others—the *spinal accessory* and the *hypoglossal* (represented in the frog by fibres in connection with the vagus and by the first spinal nerve respectively, p. 143)—emerge from the skull and are therefore counted as the eleventh and twelfth cerebral nerves. The former arises from the side of the medulla oblongata and the spinal cord by numerous fibres, the posterior of which are opposite the fifth spinal nerve, from which point it runs forwards between the dorsal and ventral roots and leaves the skull together with the glosso-pharyngeal and vagus (p. 449), supplying certain muscles of the neck and shoulder. The hypoglossal arises by a number of fibres from the ventral surface of the medulla oblongata, passes out through the condylar foramen, curving forwards round the angle of the jaw to supply the muscles of the tongue, and sending a branch backwards, known as the *ramus descendens* (Fig. 205, *r. d*) which goes to certain muscles of the neck.

The relations of the **sympathetic nerves** are also essentially similar to those occurring in the frog (p. 145). Each passes backwards along the neck (Fig. 205, *c. sy.*) close to the vagus (*vg*) and alongside the carotid artery, enlarging to form an anterior and a posterior cervical ganglion (*s. c. g, i. e. g*). In the thorax it runs just beneath the heads of the ribs, having a ganglion in each intercostal space: it then passes into the abdomen, lying close to the centra of the vertebræ and having ganglia at intervals. From all the sympathetic ganglia branches are given off connecting them with the spinal nerves (*rami communicantes*), others going to the blood-vessels: others again, in the thorax and abdomen, are connected with plexuses from which nerves pass to the heart and abdominal viscera.

In the thorax two large *splanchnic nerves* run off from the cords and, piercing the diaphragm, fuse with a large

cœliac ganglion, placed in the mesentery just in front of the origin of the anterior mesenteric artery, and united with an *anterior mesenteric ganglion* just behind it. From these ganglia numerous branches run off to the abdominal viscera. These ganglia and nerves are together spoken of as the *cœliac plexus*.

Sensory Organs.—The sense of touch is situated in microscopic *tactile organs* in the skin, and groups of cells, called *taste-buds*, are present on the papillæ of the tongue (p. 466) and on the soft palate (compare pp. 161 and 162).

The *organs of smell* are situated in the olfactory capsules, the form of which has already been described (p. 446). They open externally by the *external nostrils*, and are produced backwards above the palate into the passage of the *internal nostrils*, which communicate with the naso-pharynx (p. 469). The olfactory epithelium, supplied by the olfactory nerves, is situated on the ethmoturbinal (*e. tb*): the mucous membrane of the maxilloturbinal (*m. tb*) probably serves merely to warm the inspired air.

On the ventral side of the nasal septum is a pair of small, tubular structures known as the *vomero-nasal* or *Jacobson's organs*, lined by epithelium and enclosed in cartilages situated just to the inner side of the palatine processes of the premaxillæ (p. 448). The function of these organs is not understood.

The structure of the *eye* (Fig. 209) is similar to that already described in other Vertebrates (p. 163) except that the sclerotic is not cartilaginous, but is composed of dense fibrous tissue, and the lens is relatively smaller than in the frog and is markedly biconvex in form, the outer surface being rather flatter than the inner: it is capable of adjustment by means of the *ciliary muscle*. This is a continuous ring of delicate muscle consisting of fine unstriped fibres arising from the junction of the sclerotic and cornea and passing backwards into the

ciliary processes (Fig. 209, CP). These are a series of folds or plaits arranged in a radiating manner all round, into which the choroid is thrown just externally to the iris (compare p. 166).

When the ciliary muscle contracts, it pulls the ciliary

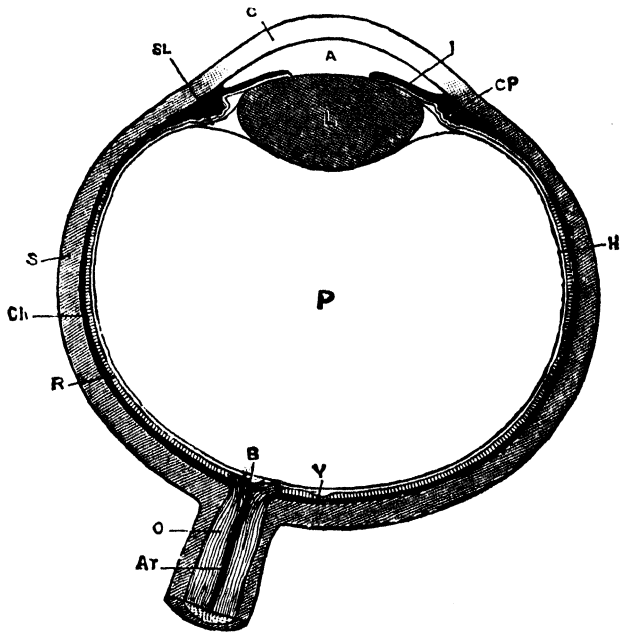


FIG. 209.—A diagrammatic transverse section through the Human Eye. *A*. anterior chamber; *Ar*. central artery of the retina; *B*. blind spot; *C*. cornea; *Ch*. choroid; *CP*. ciliary processes; *H*. hyaloid membrane enclosing the vitreous humour; *I*. iris; *L*. lens; *O*. optic nerve; *P*. posterior chamber; *R*. retina; *S*. sclerotic; *SL*. suspensory ligament; *Y*. yellow spot. (There is no yellow spot in the eye of rabbit.)

processes with the loosely attached choroid forwards towards the origin of the muscle. The ciliary processes carry the attachment of the suspensory ligament with them nearer to the lens, the whole suspensory ligament being thus slackened. In looking at a near object the ciliary muscle contracts, and so slackens the suspensory ligament, and the pressure on the anterior surface of the lens being lessened, it becomes more convex by its own elasticity. This

power of adjustment for objects at varying distances from the eye is called accommodation.

The eyelids have already been described (p. 440). The four *recti muscles* ensheath the optic nerve, as in the frog (p. 168), but the *superior oblique*, instead of arising—like the *inferior oblique*—in the anterior part of the orbit, takes its origin further back, near the recti, passes forwards through a fibro-cartilaginous pulley at the anterior angle of the orbit, and then backwards and outwards to its insertion on the eyeball.

Between the wall of the orbit and the eyeball are two glands, the secretion of which, passing through ducts perforating the conjunctiva lining the eyelids, serves to keep the outer surface of the eye moist, and is then conducted into the nasal chambers by means of the naso-lacrymal duct (pp. 168 and 447). These two glands correspond to special differentiations of a primarily continuous structure: one, the *Harderian gland*—already met with in the frog—is situated in the antero-ventral region of the orbit: the other, or *lacrymal gland* proper, in its postero-dorsal region. Besides these, a series of small *Meibomian glands* is present on the inner side of the edges of the eyelids, and produces a fatty secretion.

The ear or the *auditory organ* is extremely complicated, and consists of three parts, viz., the external ear, the middle ear, and the internal ear. The *external ear* consists of the pinna (p. 440) and the auditory passage (Fig. 210, Ex) leading to the drum or the *tympanic membrane* (M), which is situated obliquely at the boundary of the tubular and bulbous portions of the tympanic bone, separating the external ear from the middle ear.

The *middle ear* is constituted by the tympanic cavity in the tympanic bulla, and communicates with the pharynx by the Eustachian tube (Fig. 210, E). Its external boundary is formed by the tympanic membrane, which is raised inwards like the roof of a tent, and is kept

on the stretch by a small muscle. The tympanic cavity is crossed by a chain of three small bones known as the auditory ossicles, viz., the hammer-shaped *malleus*, the anvil-shaped *incus*, and the stirrup-shaped *stapes* (p. 446). The *malleus* (O_3) is attached by its handle-like process to the inner surface of the tympanic membrane,

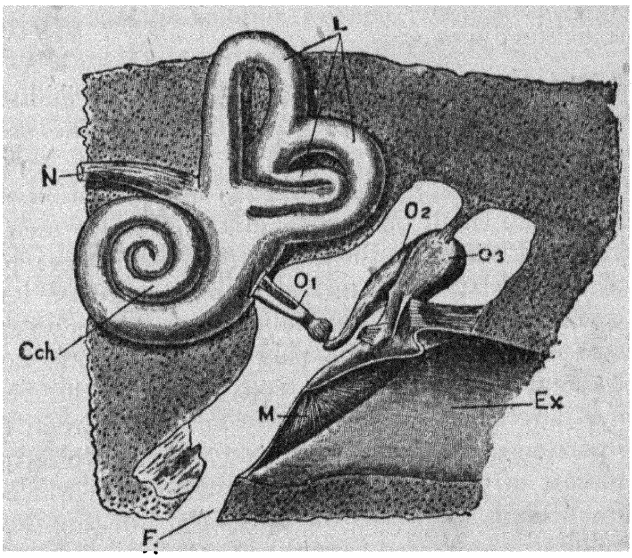


FIG. 210.—Diagram of the mammalian bony labyrinth, tympanic cavity, and external auditory passage.

Cch. bony cochlea; *E.* Eustachian tube; *Ex.* external auditory passage; *L.* bony semicircular canals; *M.* tympanic membrane; *N.* auditory nerve; O_1. stapes; O_2. incus; O_3. malleus. (After Headley.)

and its head articulates with the body of the *incus* (O_2), a process of the latter bone articulating through the intermediation of a small bony nodule, with the *stapes* (O_1). The inner end of the latter fits into the fenestra ovalis of the periotic bone (p. 446). The chain of ossicles serve to convey the vibrations of the tympanic membrane to the internal ear. Morphologically, the stapes corre-

sponds to part or the whole of the frog's columella (Fig. 12).

The study of development indicates that the malleus corresponds to the ossified articular part of the mandibular cartilage of lower Vertebrates, and the incus to the quadrate (pp. 41 and 431): the articulation of the bony mandible with the squamosal in Mammals has rendered these parts unnecessary for their original purpose; and they have undergone a *change of function*, forming an accessory part of the auditory apparatus.

The *internal ear* or the essential part of the auditory organ consists, as in other Vertebrates, of the *membranous labyrinth* with its three *semicircular canals* (p. 169) enclosed in the auditory capsule (periotic bone, p. 445). The small outgrowth of the sacculus seen in the frog, and known as the *cochlea* (Fig. 62, *cc*), is represented by a relatively larger structure, coiled on itself in a spiral manner, and especially important as regards the sense of hearing. The part of the periotic bone which directly surrounds the cavity in which the membranous labyrinth lies is especially hard, and when the outer portion of the bone is cut away, is seen to form a sort of cast of the enclosed organ, the form of which it repeats: this is known as the *bony labyrinth* (Fig. 210). Internally it is separated from the membranous labyrinth by a narrow space all round, containing the perilymph (p. 171) and only shut off from the tympanic cavity at the fenestra ovalis and fenestra rotunda (p. 446) by the membrane which closes each of them.

The membranous cochlea does not run up in the centre of the bony cochlea, but is attached between its outer wall and a shelf projecting inwards into the cavity, from its inner wall. Thus a transverse section through a coil of the cochlea shows three passages, the upper *scala vestibuli*, the lower *scala tympani*, and the *scala media* or membranous cochlea between the two. On the floor of the membranous cochlea lies the real terminal apparatus of the sense of hearing, called

The brain has reached a higher degree of differentiation than in any other class of Vertebrates. The two cerebral hemispheres, in all except the Prototheria and Marsupials (see below), are connected together by a band of transverse fibres, the corpus callosum, not represented in the other Vertebrates. The dorsal part of the mid-brain is divided into four optic lobes, the corpora quadrigemina. On the ventral side of the hind-brain is a transverse band of fibres, the pons Varolii, by which the lateral portions of the cerebellum are connected together.

The kidneys are derived from the metanephros, and the ureters, except in Prototheria, open into the bladder, and not directly into a cloaca.

With the exception of the Prototheria, mammals are all viviparous. In all the higher mammals the ova are minute, and after fertilization are retained in the uterus, in which each develops into a fœtus. The fœtus is nourished from the blood system of the parent through a special development of the allantois and the lining membrane of the uterus, termed the placenta. After birth, the young ones are nourished for a longer or shorter period by the milk or secretion of the mammary glands of the parent.

Classification.—The class Mammalia is divided into three primary divisions or sub-classes, which are called :—

I. Prototheria, or primitive mammals.
II. Metatheria, or modified mammals.
III. Eutheria, or perfect mammals.

The **Prototheria** include two extraordinary animals, the Duck-billed Mole and the Spiny Ant-eater, which are found only in Australia, New Guinea, and Tasmania. In these animals large eggs containing abundant yolk and with a firm shell are laid in a nest and incubated by the

mother. The oviducts are large and separate throughout, opening along with the intestine into a common cloaca, as is the case with Birds and Reptiles. The ureters do not open into the bladder as they do in all other Mammalia, but they, as well as the bladder, open separately into the cloaca. After they are hatched the young receive milk from the mother. There is no teat, but the fluid from the mammary glands seems to soak into the hair, and thence is sucked by the young. These

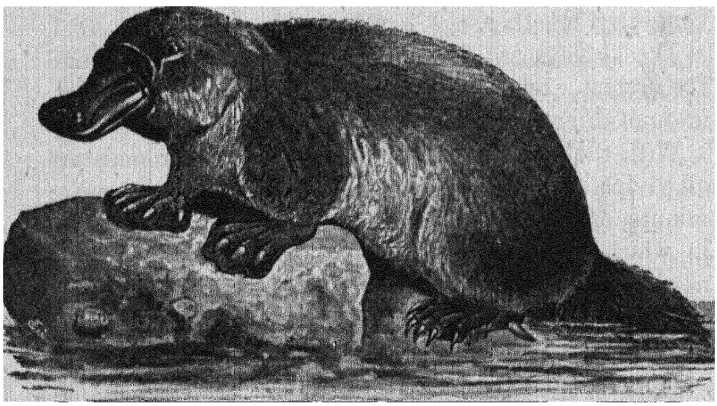


FIG. 216.—Duck-billed Mole (*Ornithorhynchus anatinus*). (After Vogt and Specht.)

animals are of great interest from an evolutionary point of view, as showing many affinities with the Reptiles, from some of which the great group of Mammals is believed to have been evolved. The skeleton also presents many interesting features of agreement with the Reptiles; there are large coracoids articulating with the sternum, a T-shaped episternum, and a pair of epipubic (marsupial) bones.

The section **Metatheria** includes all the pouch-bearing mammals, such as the Opossums of America, and the Dasyures, the Bandicoots, the Wombats, the Phalangers,

and the Kangaroos of Australia and the neighbouring islands. In these animals the egg is very small, and the ovarian tube is divided into an upper part of narrow

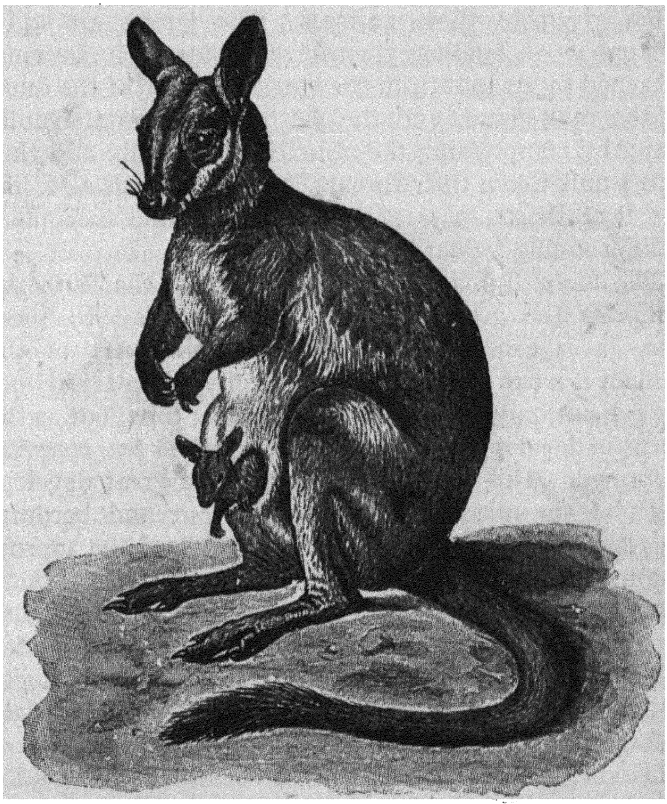


FIG. 217.—The Rock Wallaby (*Petrogale xanthopus*) with young in pouch. After Vogt and Specht.)

diameter called the Fallopian tube and a lower, wider part called the uterus. In the uterus the small egg is retained for some time and develops a close adhesion to its wall for obtaining nourishment.

The young are born in a rudimentary and helpless condition and are placed by the mother in a pouch formed by a fold of skin on the lower part of her body, whence the name Marsupials (Lat. *marsupium*, a pouch) often given to these animals. The young are quite incapable of feeding themselves, but each becomes attached by its mouth to the opening of one of the ducts of the milk-gland, and the mother squeezes the milk-gland by compressing the muscles of the belly and thus forces milk down their throats. These animals also, like the Prototheria, possess a pair of epipubic (sesamoid) bones running forward from the pubes.

The highest division of the mammals, the **Eutheria,** comprise the great majority of mammals. In them the egg is exceedingly small. The first part of the oviduct is narrow, but the uterus is greatly enlarged, and the egg not only remains there for a long time, but as the fœtus is developing, a special organ, called the *placenta*, is formed. This organ is the result of a great development of the allantois, which grows out and becomes interlocked with depressions in the wall of the uterus. The middle portions of the oviducts, or uteri, are sometimes quite separate, as in the rabbit (p. 504), sometimes partly united, as in the cat, rarely completely united, as in monkeys and man. The third part of the oviducts are, however, completely joined and form a single passage, the vagina.

Leaving aside the fossil forms, the Eutheria are usually arranged in the following eleven orders :—

1. *Edentata*, comprising the Sloths, Ant-eaters, and Armadillos of South America.

2. *Effodientia*, the Scaly Ant-eaters and the Cape Ant-eaters of Africa.

3. *Insectivora*, including the Moles, Shrews, and Hedgehogs.

4. *Carnivora*, or the Cats, Dogs, Bears, Otters, and the Seals and Walruses.

5. *Cetacea*, including the Whales, Porpoises, and Dolphins.

6. *Ungulata*, a very large order, comprising, among other forms, the Horses, Tapirs, and Rhinoceroses, the Ruminants (Camels, Oxen, Sheep, Goats, Antelopes, Giraffes, and Deer), the Pigs and Hippopotami, and the Hyraxes.

7. *Proboscidea*, or the Elephants.

8. *Sirenia*, or Dugongs and Manatees (Sea-cows).

9. *Rodentia*, a large order, including, among others, the Rats and Mice, Hares and Rabbits, Squirrels, Beavers, and Porcupines.

10. *Chiroptera*, or Bats, and Fruit-eating Bats ("Flying Foxes").

11. *Primates*, comprising the Lemurs, Monkeys, Baboons and Apes, and Man.

We cannot enter here into a description of the structural peculiarities exhibited by members of all these orders, but there are certain points of organization which even an elementary student of Zoology may like to make acquaintance with. We shall therefore deal with some of the more important features in the following pages, which, it is hoped, will enable him to understand better the Doctrine of Evolution, dealt with in a subsequent chapter (pp. 584 *et seq.*).

The **Carnivora** are distinguished above all by their teeth. Their incisors are small and insignificant, but their canines (teeth which are quite absent in a typically herbivorous mammal like the rabbit) are large and pointed, and it is with these the animal seizes and kills its prey. The premolars have cutting edges, and the molars are mostly broad and crushing. The last premolar in the upper jaw and the first molar in the lower

jaw are very large and blade-like, and bite on one another like a pair of scissors, and are called the carnassial teeth. The skull of the Dog, on account of its larger size, is sometimes substituted for that of the Rabbit for detailed study of a mammalian skull; and in any case it would be a most useful exercise for a student after having studied the skull of the Rabbit (pp. 441–450) to trace out the various bones and find the different foramina on the skull of the Dog, noting any points of difference that he may come across. For this study no separate description is required, as the figures here given will afford all the help the student may need.

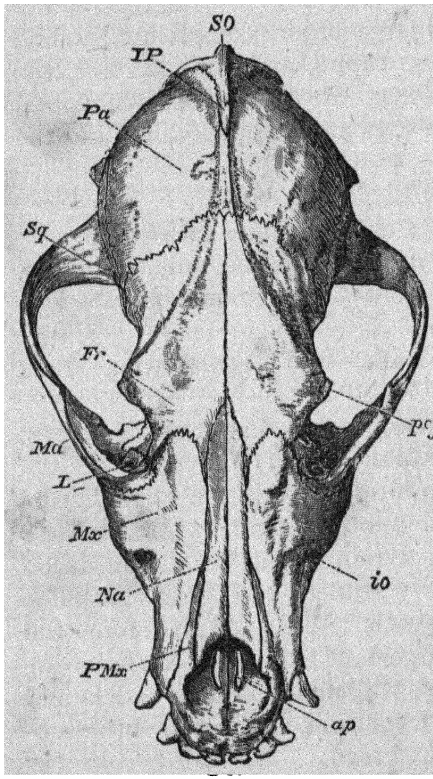


FIG. 218.—Dorsal view of the cranium of a Dog (*Canis familiaris*), half natural size.
So. supra-occipital; *IP.* inter-parietal; *Pa.* parietal; *Sq.* squamosal; *Fr.* frontal; *L.* lacrymal; *Ma.* malar or jugal; *Mx.* maxilla; *Na.* nasal; *Pmx.* premaxilla; *ap.* anterior palatine foramen; *io.* infra-orbital foramen; *pof.* postorbital process of frontal bone. (From Flower's *Osteology of the Mammalia.*)

As special features in which the skull of Dog differs from that of Rabbit might be mentioned the prominent sagittal and lambdoidal crests, the deep temporal fossæ,

the strong and greatly arched zygoma, and the greater development of the facial region. The glenoid cavity

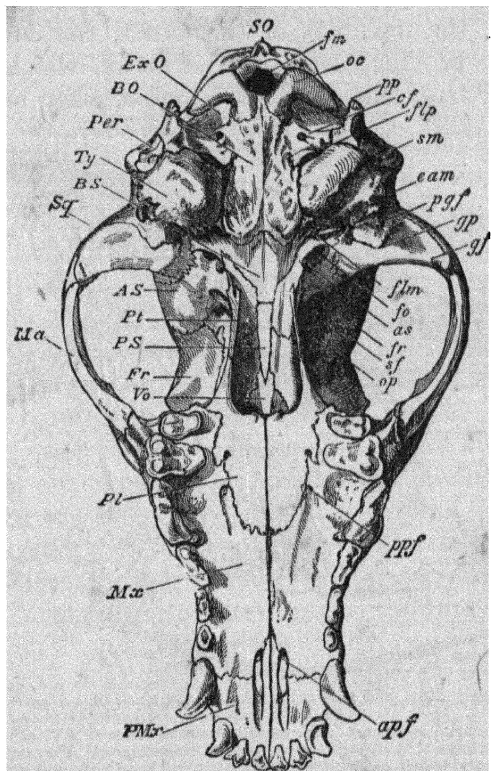


FIG. 219.—Ventral view of the cranium of a Dog, half size.

Exo. exoccipital; *BO.* basioccipital; *Per.* mastoid portion of periotic; *Ty.* tympanic bulla; *BS.* basisphenoid; *Sq.* zygomatic process of the squamosal; *As.* alisphenoid; *Pt.* pterygoid; *Ps.* presphenoid; *Vo.* vomer; *Pl.* palatine; *fm.* foramen magnum; *oc.* occipital condyle; *pp.* paroccipital process; *cf.* condylar foramen for the XII nerve; *sm.* stylomastoid foramen for the exit of the VII nerve; *eam.* external auditory meatus; *pgf.* postglenoid foramen; *gp.* postglenoid process; *gf.* glenoid fossa; *flm.* foramen lacerum medium, through which the internal carotid passes to the brain; *fo.* foramen ovale, for the exit of the mandibular division of the V nerve; *as.* posterior opening of alisphenoid canal (through which external carotid artery runs for part of its course); *fr.* foramen rotundum (for the maxillary division of the V nerve) and anterior opening of alisphenoid canal; *sf* sphenoidal fissure or foramen lacerum anterius for III, IV, ophthalmic division of V, and VI nerves; *op.* optic foramen for II nerve; *ppf.* posterior palatine foramen. Other letters as in the preceding figure. (From Flower's *Osteology of the Mammalia.*)

is in the form of a transverse groove to the shape of which the transversely elongated condyle of the mandible is adapted. The dental formula is $i\ \frac{3}{3}\ c\ \frac{1}{1}\ pm\ \frac{4}{4}\ m\ \frac{2}{3} = 42$.

Among the members of this order, the ends of the digits are provided with curved claws, which may be very long and sharp, and are capable, when not in use,

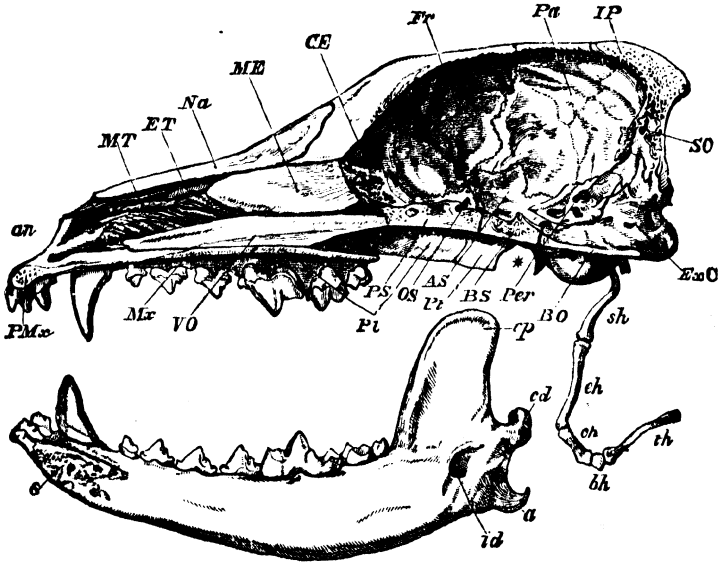


FIG. 220.—Longitudinal and vertical section of the skull of a Dog with mandible and hyoid arch. (× ½.)

an. anterior narial aperture; *MT.* maxillo-turbinal bone; *ET.* ethmo-turbinal; *ME.* mesethmoid; *CE.* cribriform plate of the ethmoid; *Per.* petrous portion of the periotic bone; *os.* orbitosphenoid; *sh.* stylohyal; *eh.* epihyal; *ch.* ceratohyal; *bh.* basihyal; *th.* thyrohyal; *s.* symphysis of mandible; *cp.* coronoid process; *cd.* condyle; *a.* angle; *id.* inferior dental canal. The mandible is displaced downwards to show its entire form; the * indicates the part of the cranium to which the condyle is articulated. (From Flower's *Osteology of the Mammalia.*)

of being retracted into a sheath of skin (as in the cats); or relatively short and blunt, in which case they are incompletely or not at all retractile. The Otter differs from the rest in having short limbs with the toes connected by webs of skin. The Seals and Walruses show greater or lesser adaptation to an aquatic life.

The Dog, *Canis familiaris*, the Wolf, *C. lupus*, the Jackal, *C. aureus*, and the Fox, *C. vulpes*, are all species of the same genus, being distinguished from each other by size and slight peculiarities of hair, etc.; and similarly the Lion, *Felis leo*, the Tiger, *F. tigris*, the Leopard or Panther, *F. pardus*, so closely resemble the common cat, *F. catus*, that they also are regarded as different species of one genus. The differences in the colour of skin which help to distinguish them are in all probability due to the fact that the colours are protective, enabling the animals when in their natural surroundings to come close to their prey without the latter noticing them. Lions live as a rule in dry and rather open places, and are of a dun colour which harmonizes well with the surroundings; the stripes of the tiger's skin deceptively resemble the alternating shadows and sunlit spaces of ground found amongst the reeds in which it lives; the spots of a leopard are unnoticeable amidst the patches of light and shade caused by the sunlight struggling through the interstices between leaves of trees in a forest.

The **Cetacea,** which include the Whales, the largest of existing Mammals, are interesting as showing a complete adaptation to an aquatic mode of life. As is well known, they pass all their life in water and show great differences in structure from all land Mammals in all parts of their body.

The body is fusiform, fish-like, tapering backwards to the tail, provided with a flattened tail-fin, which is expanded in the horizontal plane, not in the vertical plane as in Fishes. Whales progress by moving the tail-fin up and down, whereas the movement in fish is from side to side. A dorsal median fin is usually present. All external trace of hind-limbs has disappeared, though a pair of small bones representing the pelvic girdle are found embedded in the body. The

fore-limbs have become flappers, with the digits devoid of claws and bound together by skin to their very tips. The number of phalanges in each finger (Fig. 222) is greatly increased. The limb is buried in the body almost to the wrist, yet the skeleton clearly shows that it consists of the same bones as in other Mammals, and has no resemblance with that of the Fishes. The mouth is very wide, the nostrils are situated on the summit of the head, and the auditory pinna is absent. Hairs are

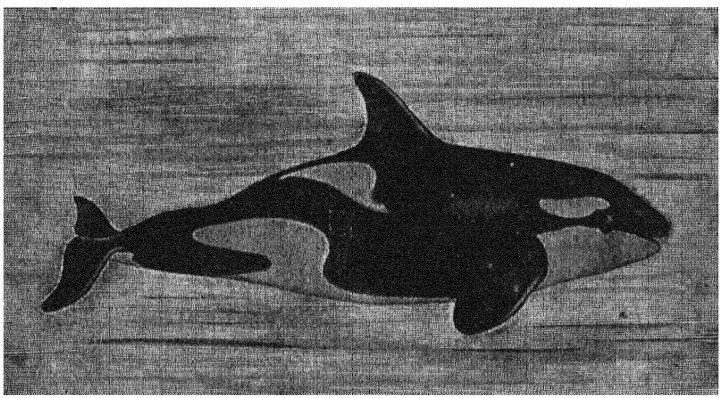


FIG. 221.—Killer (*Orca gladiator.*) After True.)

almost completely absent, only one or two being found in the region of the lips in the embryo only. The body is covered with a thick layer of fat termed blubber, which preserves the heat of the body and protects the animal against the cold of the watery medium.

In the great group of the **Ungulata,** or hoofed animals, all power of grasping with the limbs is absent, and all the four " feet " are purely adapted for running, the " toes " being encased in hard blunt nails which are called hoofs. The thigh and the upper arm are more or less buried in the body, whilst the heel and the wrist are raised in

walking so that the animal goes along on the tips of its toes. The bones of the wrist are arranged in transverse rows, the members of the two adjacent rows alternating with one another. The first digit in both fore- and hind-limbs is always absent. The Ungulates are divided into two great groups—(1) the **Perissodactyla,** in which there is an odd number of toes and in which the true central

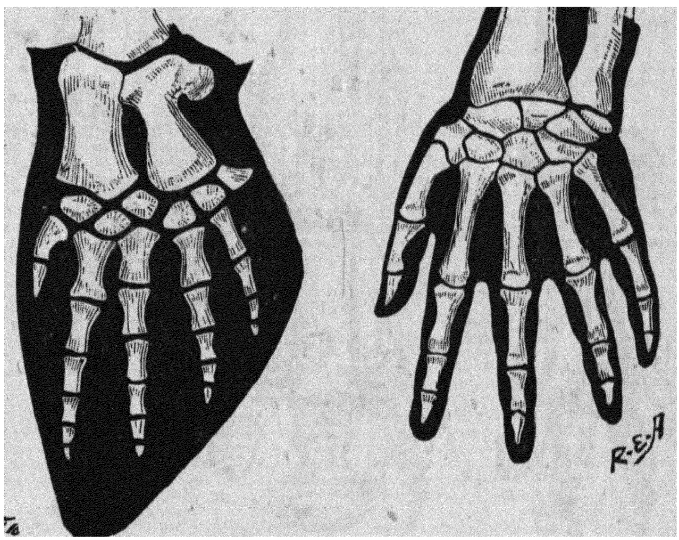


FIG. 222.—The paddle of a Whale and the hand of Man compared. (From Romanes *Darwin and after Darwin.*)

axis of both arm and leg passes through the centre of the third finger or toe (Fig. 223), and (2) the **Artiodactyla,** or even-toed, in which the third and fourth digits of each foot form a symmetrical pair, and in the majority are the only completely developed digits. (Fig. 224).

In the **Elephants,** the largest of existing terrestrial Mammals, the limbs are much more typically developed than in the true Ungulates. There are five compara-

tively short digits, enclosed in a common integument in each foot, most of which end in broad flat nails. The limbs are very stout and pillar-like, the thighs and upper arms being quite free from the body, and not buried in the general contour of the body, as in most other Mam-

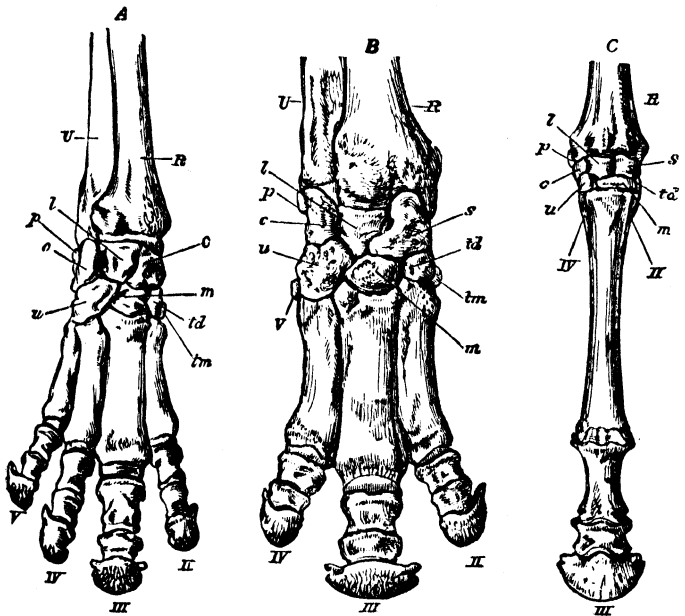


FIG. 223.—Bones of the fore-foot of existing Perissodactyles. *A*, Tapir, *Tapirus indicus*, × ⅛; *B*, Rhinoceros, *Rhinoceros sumatriensis*, × ⅛; *C*, Horse, *Equus caballus*, × ⅛.

R. radius; *U.* ulna; *s.* scaphoid (radiale); *l.* lunar (intermedium); *c.* cuneiform (ulnare); *p.* pisiform; *tm.* trapezium (first distal carpal); *td.* trapezoid (second distal carpal); *m.* magnum (third distal carpal); *u.* unciform, fused fourth and fifth distal carpal. II—V, second to fifth digits. (From Flower's *Osteology of the Mammalia.*)

mals. The trunk, or proboscis, is really a long, flexible snout, at the end of which are situated the nostrils; and in the Indian elephant a finger-like lip is attached to the upper margin of the end of the trunk. The tusks are the incisor teeth of the upper jaw. The canines are

absent. The molars are so large that the jaws cannot at one time accommodate more than at the most two and a part of a third. These molars being the only functional teeth, the elephant is popularly described as having different teeth for mastication and for show.

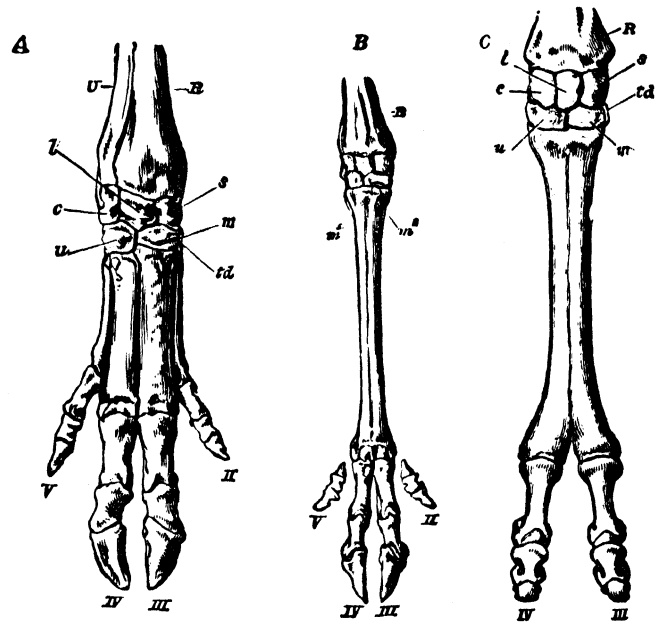


FIG. 224.—Bones of the fore-foot of some Artiodactyla. *A*, Pig, *Sus scrofa*, × ½; *B*, Red deer, *Cervus elaphus*, × ⅓; *C*, Camel, *Camelus bactrianus*, × ¼. Letters as in the preceding figure. (From Flower.)

The **Rodentia** or Gnawers (Lat. *rodo*, to gnaw) are all vegetable feeders and are sharply marked off from other mammals by the character of their teeth (which has been fully described in the case of the Rabbit, see p. 467). Their incisors, which are adapted for gnawing, are never more than two in number in the lower jaw and in most of them there are only two in the upper jaw also. There

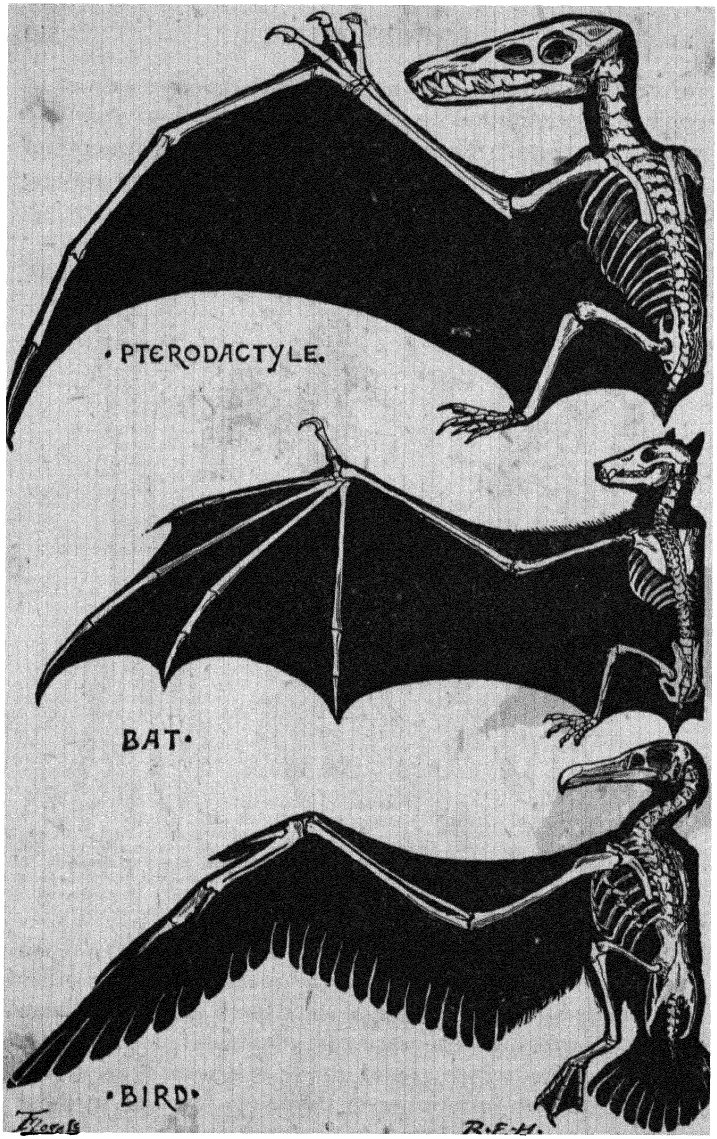


FIG. 225.—Wing of an extinct flying Reptile, Bat, and Bird compared. (From Romanes' *Darwin and after Darwin.*)

are no canines, so that there is a considerable space or diastema between the front and the back teeth.

The **Chiroptera** (Gk. *cheir*, a hand; *pteron*, wing) or Bats are the only mammals which are capable of active flight, for which purpose their arms are modified into wings. As in birds, the fore-arm is bent up on the upper arm, the wrist bent down on the fore-arm; but, unlike the wing of birds, the flying membrane is of skin and not of feathers. The membrane is stretched chiefly between the fingers of the five-fingered hand, and further extends back to the hind-limbs. Part of the membrane extends down the thighs, and in some even the tail is involved. The hand is enormous, the "little finger" being, as a rule, very greatly elongated, while the thumb alone, is small, is not included in the membrane, and ends in a curved claw.

The **Primates,** as stated above, include Lemurs, Monkeys, and Man. The order is characteristically arboreal—that is to say, most of its members live among trees, climbing from branch to branch. The thigh and the upper arm are quite free from the body, and the whole sole of the foot and palm of the hand are placed on the ground in walking. There are five fingers and five toes, some of which at least have flat nails. The big toe is shorter than the rest, and, except in Man, can be separated from them so as to be used for grasping, in the same way as can the thumb in Man and most Monkeys. Thus at one time in the History of Zoology Monkeys were wrongly regarded as possessing four hands and placed in a separate order (Quadrumana) from that of Man (Bimana). The eyes are placed in the front of the skull instead of at the sides of the head, and the jugal joins the postorbital process of the frontal, so that the orbit is surrounded by a bony ring. There are two large mammæ situated on the breast only (an extra

pair on the abdomen found only in some Lemurs being vestigial).

The order is divided into two sub-orders, the **Lemuroidea,** including the Lemurs, and the **Anthropoidea,** including the true Monkeys and Man. The Anthropoidea are distinguished by the fact that the bony ring surrounding the orbit sends inward a plate which completely separates off the orbit from the temporal fossa. The cerebral hemispheres conceal the cerebellum when the

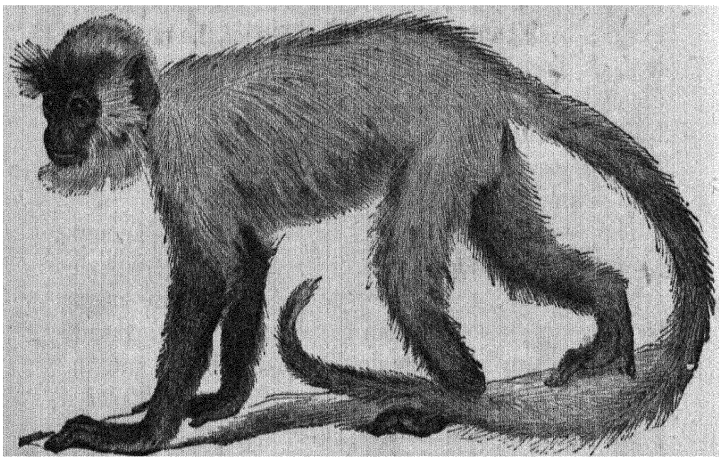
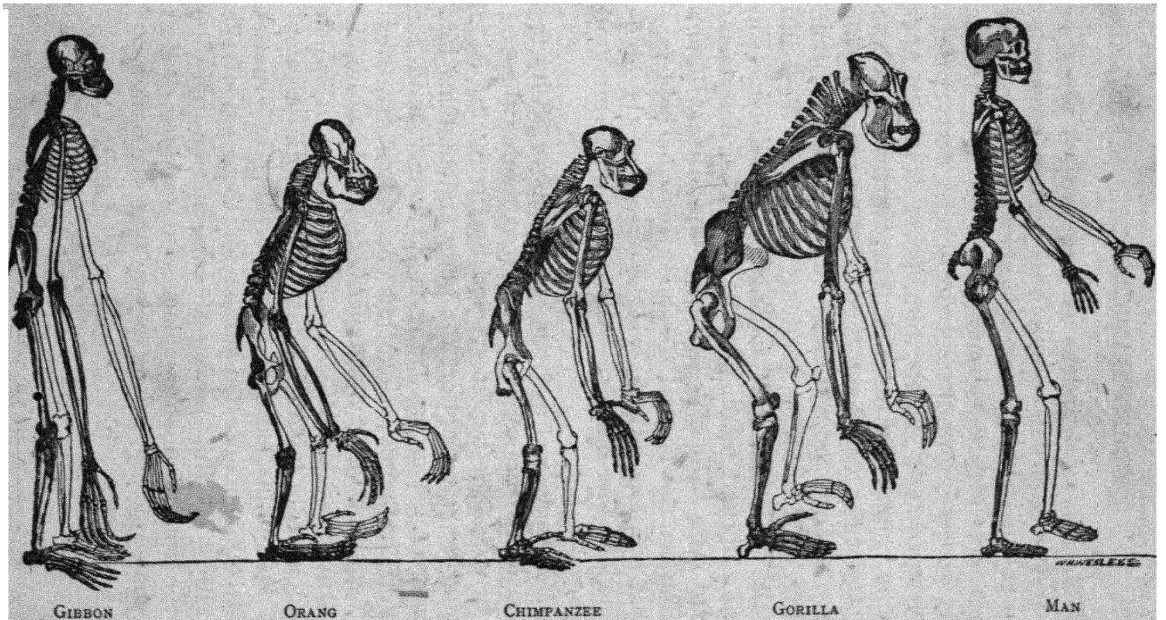


FIG. 226.—*Semnopithecus*, the Sacred Langur. (From *Cambridge Natural History.*)

brain is viewed from above. The placenta is at first spread all over the surface of the embryo, but later becomes concentrated on one part of the wall of the uterus (metadiscoidal placenta), and is deciduate (see p. 581). There are never more than two mammæ. Leaving aside the Marmosets and the Howling and the Spider Monkeys of America, we come to the old world Monkeys which belong to the families *Cercopithecidæ* and *Simiidæ*. The former include the Macaques, the Baboons, and the Sacred Langur (*Semnopithecus*) of



GIBBON ORANG CHIMPANZEE GORILLA MAN

FIG. 227.—Skeletons of the Anthropoid Apes and Man. (From Huxley's *Man's Place in Nature.*)

[Photographically reduced from diagrams of the natural size (except that of Gibbon, which was twice the natural size).]

India. They have their legs as long as their arms, or longer, and go habitually on all fours. There are always brightly coloured bare patches of skin (callosities) over the ischia, on which the animals rest when they assume a sitting posture, and there is in almost every case a well-developed tail. In the Simiidæ or Man-like Apes the tail is completely absent. There are four genera known, *Hylobates* (Gibbons), *Simia* (Orang-utan), *Gorilla* (Gorilla), and *Anthropopithecus* (Chimpanzee). In all these (Fig. 227) the arms are longer than the legs, and they walk in a semi-erect manner. The Gibbons can walk in an upright manner holding out their long arms as if they were balancing poles; in the others, though in walking on the ground the body may be held in a semi-erect position with the weight resting on the hind-limbs, the long fore-limbs reach the ground and are used as crutches.

Man (*Homo sapiens*) is distinguished above all by the great size of the brain, which is about double the size of that of the highest monkey, and by the modification of the hind-limbs to support the body and enabling him to walk erect. The great toe is no longer used for grasping. The hands being thus entirely set free were used to acquire a variety of experiences, and the intelligence of man awakened. Another great factor which must undoubtedly have stimulated the mental development of Man is his habit of living together in societies and undertaking concerted action for the good of the community. To this power of combination may be traced the evolution of language and morals. "Man did not make society, it was society that made Man."

Early Development of other Types.—The presence of a greater amount of food-material in the egg renders it possible for the embryo to go on developing further than the gastrula-stage before being hatched, and, as a general rule, the greater the relative quantity of yolk present in the ovum of an animal, the less clearly can a gastrula-stage be recognized.

In the **earthworm** and **mussel** the segmentation is entire, but unequal, and the larger lower cells become invaginated to form the endoderm and enteron while the smaller upper cells give rise to the ectoderm. In the earthworm the blastopore does not become closed, but gives rise to the mouth.

In the **frog** (p. 180) the enteron arises by a split appearing amongst the yolk-cells, beginning at the edge of the blastopore and gradually extending inwards: the process is supplemented by an invagination of the ectoderm. The enteron is at first a very narrow cleft, but soon widens considerably (Fig. 66, I, *ent*): for some time it does not actually communicate with the exterior, the blastopore (*blp*) being filled up by a yolk-plug (*yk. pl*). As the enteron extends forwards, and the relatively small segmentation-cavity (*bl. cœl*) gradually disappears, the edges of the lower margin of the blastopore approach one another and, uniting in the median plane, give rise to a vertical band at the hinder end of the embryo, in which the three germinal layers are fused together. This band is spoken of as the *primitive streak*, and the faint median groove which runs along it and marks the line of union of the right and left lips of the blastopore is called the primitive groove. There is no stage in the frog which exactly corresponds with the gastrula-stage in Amphioxus, but the stage represented in Fig. 66, I, most nearly approaches to it.

In the centrolecithal egg of the **crayfish** a gastrula-

stage is formed by invagination, but as the centre of the oosperm is filled with solid yolk in the place of a segmentation-cavity containing fluid, the invagination only extends a short distance inwards, the enteron being relatively very small and the ectoderm separated from the endoderm by the yolk.

The gastrula-stage is much less clearly distinguishable in the segmenting telolecithal eggs of the **dogfish** and **bird** (p. 543), in which the relatively enormous mass of unsegmented yolk is, as in the arthropods, sufficient to nourish the embryo until it has reached a stage closely resembling the adult in almost every essential respect except size. A blastopore can sometimes be recognised in such cases, but in the embryo of the common fowl it is to some extent represented by a *primitive streak* and *groove* (see p. 551 and Fig. 236, E, *pr. st*). The blastoderm becomes differentiated into an outer ectoderm and an inner, lower layer of cells (compare Fig. 236, F), between which and the yolk the enteric cavity is formed: a segmentation-cavity is recognisable in early stages. As the embryo develops, it becomes folded off from the yolk, which is gradually reduced in amount and in later stages is contained in an extra-embryonic part of the embryo—the *yolk-sac* (Fig. 236).

A more detailed account of the early stages of the chick is given below, as the hen's egg is an easily procurable type for the practical study of development.

The hen's egg has already been described in detail (p. 534, Fig. 231). Its essential part, the yolk, corresponds, as we have seen, to a single cell enormously enlarged by the mass of yolk-granules it contains, the only part in which they are absent being a small area which, owing to its lesser specific gravity, is always found at the upper pole; this area, in which the nucleus lies, is known as the *germinal disc*. Fertilization takes place in the anterior end of the oviduct, and then the nucleus divides and initiates the process of seg-

mentation which is completed by the time the egg is laid, when the germinal disc has thus become converted into a multicellular *blastoderm* (p. 534).

The first stage of segmentation is indicated by the formation of a vertical furrow across the centre of the germinal disc (Fig. 236, A), and this is followed by another furrow at right angles to it (B). Further radial and concentric furrows then arise (C) until the blastoderm is seen to consist of a number of irregular cells (D). Horizontal furrows are in the meantime formed, so that the originally single layered blastoderm, beneath which a narrow space representing the *segmentation-cavity* can be recognised, comes to consist of several layers of cells, the outer of which corresponds to the *ectoderm*; the inner, or lower layer cells, extend rapidly through the segmentation-cavity between the ectoderm and the yolk and give rise to the *endoderm*, the space remaining beneath this layer and the yolk forming the rudiment of the *enteron* (F). New cells are gradually formed round the edge of the blastoderm, which, when the egg is laid, forms a circular patch, about 3·5 mm. in diameter, on the surface of the yolk (Fig. 231): its central part, or *area pellucida*, owing to the presence of fluid in the underlying space, is more transparent than the rim, or *area opaca*.

When the egg is incubated, the blastoderm grows rapidly at its periphery (area opaca), and eventually, as we shall see, encloses the whole yolk. The area pellucida extends less rapidly and becomes pear-shaped in outline (Fig. 236, E), its broader end corresponding to what will become the anterior end of the embryo: in this region most of the lower layer cells are arranged so as to form a definite layer of endoderm, which can be recognised somewhat later in the area opaca also. The ectoderm and lower layer cells are at first continuous round the edge of the blastoderm, but later on this is only the case at the posterior border (F), and results in the appearance of a narrow band, the *primitive streak* (E, *pr. st.*), along which a median *primitive groove* is formed. This, as already mentioned, represents the fused lips of the blastopore of the frog and other forms; it extends from the centre to the posterior border of the area pellucida, and rapidly grows backwards. The primitive streak is due to the multiplication of ectoderm cells, which grow inwards and spread out right and left under the covering ectoderm, between it and the endoderm, so as to form a horizontal wing of cells on either side (G). The *mesoderm* is formed from these wing-like ectodermic sheets, with which the endoderm becomes united, so that the three layers are for a time

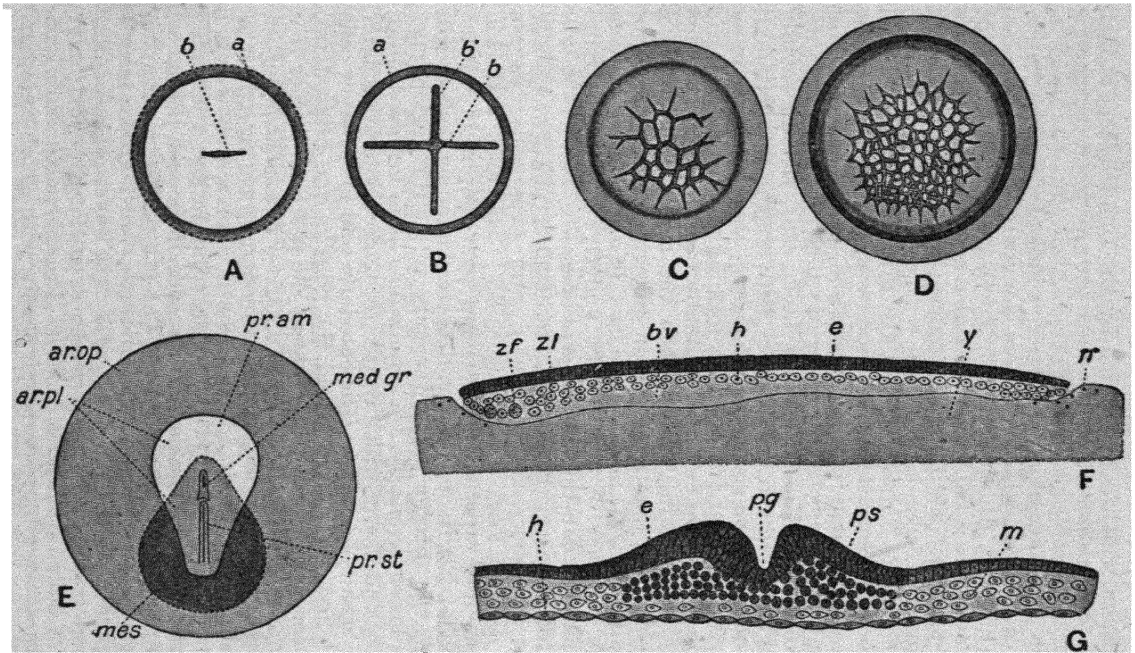


FIG. 236.—Early stages in the development of the blastoderm in a Hen's egg.
A, germinal disc, showing first segmentation furrow; *B*, second furrow; *C*, later stage with numerous blastomeres; *D*, stage towards completion of segmentation (*A*—*D* × 7½); *E*, Diagram of blastoderm at about the twentieth hour of incubation (× 6);

F, vertical section of blastoderm and adjacent part of the egg at the time of laying, before incubation: the anterior edge of the blastoderm is to the right, the posterior edge to the left of the figure (× 25); *G*, transverse section of blastoderm at about the twentieth hour of incubation, the section passing through the primitive streak and groove at about the middle of its length (× 200).

a. periphery of germinal disc; *ar. op*. area opaca; *ar. pl*. area pellucida; *b*. first, and *b'*. second furrow; *bv*. rudiment of enteron; *e*. ectoderm; *h*. endoderm; *n'*. nucleus in yolk around which a cell will be formed later; *m. mes*. mesoderm; *med. gr*. medullary groove; *pg*. primitive groove; *pr.am* pro-amnion; *pr. st*. primitive streak; *y*. yolk; *zf*. formative cell; *zl*. lower layer cells. (*A* and *B*, from Foster and Balfour; *C*—*G*, from Marshall, after Duval and Coste.)

indistinguishable in this region. The mesoderm eventually forms a sheet of loosely arranged cells which spreads rapidly in all directions except anteriorly (E), in which region, known as the *pro-amnion*, the blastoderm consists of ectoderm and endoderm only until the end of the second day of incubation, and by the third day the three germinal layers have become established in the whole of the blastoderm.

Before tracing the development of the various organs derived from the three germinal layers respectively, it must be remembered that the actual chick embryo is formed from the area pellucida, and gradually becomes folded off from the yolk, while the area opaca extends over the yolk until the latter is entirely covered by it (17th day of incubation): thus we can distinguish between an *embryonic* and an *extra-embryonic* portion of the blastoderm. In the mesoderm of the latter portion blood-vessels are formed, so that it is then known as the *area vasculosa* (see Fig. 236, E).

The minute egg of the **rabbit** (compare p. 505) and of most other mammals, although microlecithal and undergoing a holoblastic segmentation, has presumably been derived from a meroblastic type with abundant yolk, like that of the reptiles and birds, and some lower mammals (*Ornithorhynchus* and *Echidna*) living in Australia at the present day still possess eggs of this type. In the higher Mammalia the yolk has disappeared, as it is no longer needed, the embryo, as we have seen (p. 505), being nourished by means of a *placenta*, which will be described presently. The early processes of development are therefore somewhat peculiar, and though the segmentation is holoblastic, the subsequent development is for some time essentially similar to that of the bird:

it is not until later stages that the more special characteristics of the mammal on the one hand and the bird on the other become apparent.

Fertilization and segmentation take place in the uterine tubes (p. 504), and each oosperm is surrounded by a membrane, the *zona radiata*, apparently formed from the follicle cells, and a layer of albumen secreted from the oviduct. The oosperm divides into two blastomeres (Fig. 237, A), and then further divisions follow and result in the formation of a mulberry-like mass (B), which, however, is not hollow, as in Amphioxus (Fig. 235), but consists of an outer layer enclosing a solid mass of larger and more granular cells (C), and at this stage it passes into the uterus. The outer layer of cells then grows rapidly, so that a space appears and gradually increases in size, between it and the inner mass except at one point where the latter is attached to the former (D, E). This hollow ball is known as the *blastocyst* or *blastodermic vesicle*, and may be compared to the embryo and yolk-sac of a bird, except that it contains a fluid instead of yolk. The outer layer probably corresponds to the extra-embryonic ectoderm of the chick (p. 553) and takes no direct part in the formation of the embryo, which arises from the inner mass (*embryonic area*), in much the same way as the chick is formed from the blastoderm in the case of the hen's egg. Thus later on an embryonic portion with a primitive streak, and an extra-embryonic portion gradually growing round beneath the outer layer, can be recognised in the embryonic area, the body of the embryo being gradually folded off from the blastocyst, which has similar relations to the embryo as the yolk-sac has to the body of the chick, to which it corresponds (see p. 550 and Figs. 236 and 242).

In Amphioxus alone amongst the triploblastic animals described in this book does the mesoderm arise as a series of enterocœlic pouches: as we have seen, it is usually at first solid, and may be budded off from the ectoderm and endoderm, or from the ectoderm only, at the margin of the blastopore or primitive groove (chick, p. 551); or both endoderm and mesoderm may be differentiated at the same time from the lower-layer cells or yolk-cells (frog, p. 181); or finally, it may arise

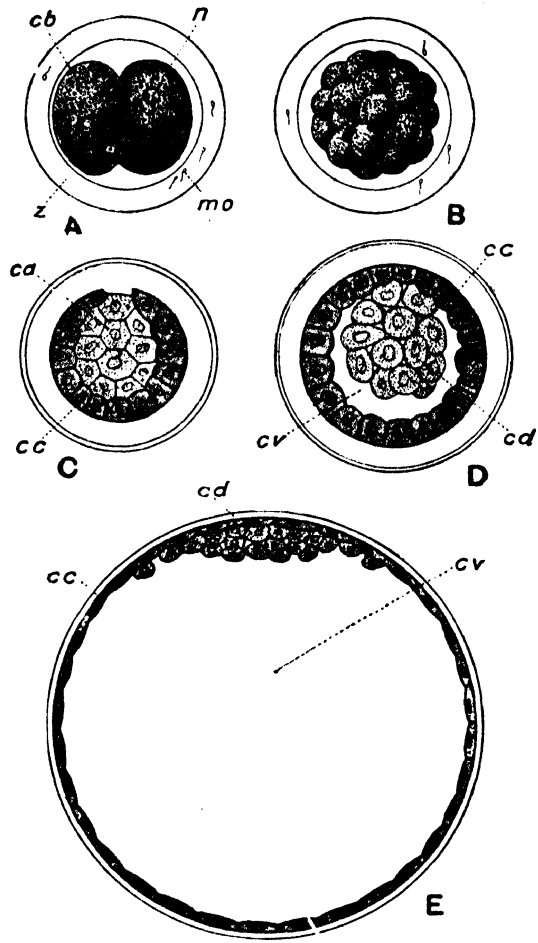


FIG. 237.—Early stages in the development of the oosperm of the Rabbit. *A*, two-celled stage, from middle part of the uterine tube, about twenty-two hours after copulation; *B*, polyplast or morula stage, from lower end of uterine tube, about the middle of the third day; *C*, close of segmentation, from lower end of uterine tube just before entering uterus, seventy hours after copulation; *D*, first stage in formation of blastocyst, from uterus, seventy-five hours after copulation; *E*, section of blastocyst at the end of fourth day. (× about 160.)

cb. blastomere; *cc.* outer layer of cells; *cd.* inner mass of cells (embryonic area); *cv.* cavity of blastocyst; *mo.* sperms imbedded in the zona radiata (*z*); *n.* nucleus. (From Marshall; *A*, *B*, after Bischoff; *C*—*E* after Van Beneden.)

in all these ways. The cœlome is formed secondarily by a split taking place in the mesoderm on either side (Figs. 248 and 250), the split gradually extending with the extension of the mesoderm between the ectoderm and endoderm. Thus the cœlome is formed, not as an enterocœle, but as a *schizocœle*.

In Vertebrates each mesoderm-band becomes differentiated into a dorsal portion abutting against the medullary cord and notochord known as the *vertebral plate*—which soon loses its cœlomic space, and a ventral portion, the *lateral plate*, which is divided into parietal and visceral layers by the cœlome (Figs. 67 and 250 B, C). The vertebral plate undergoes metameric segmentation, becoming divided into a row of squarish masses, the *mesodermal segments* or "*protovertebræ*" (*pr. v, ms. s*), from the outer parts of which (*muscle-plates*, the muscular segments or myomeres are formed (p. 411), and from the inner parts the vertebral column, the segmentation of which alternates with that of the myomeres.

Outline of the Development of the Chief Organs in the Vertebrata (compare pp. 180–186).—The **nervous system** as well as the essential parts of the **sensory organs,** are, as we have seen, in all cases formed from the ectoderm. The development of the central nervous system takes place in essentially the same manner as in the frog (p. 182).

In the chick the ectoderm in front of the primitive streak early becomes thickened along the median line to form the *medullary plate* (Fig. 236, E); this gradually increases in length at the expense of the primitive streak, from the cells of which the greater part of the embryo is eventually developed. A *medullary groove*, bounded by *medullary folds* (Fig, 238, A and B), is formed along the median line of the medullary plate and passes into the primitive groove posteriorly; while near their anterior ends the folds meet and unite, so as to constrict off a *medullary tube* from the

outer ectoderm (Figs. 236, E and 238, A). This closure of the tube then gradually extends both forwards and backwards, the groove remaining open longest at its posterior end. In the region of the pro-amnion (p. 553, Figs. 236, E, and 238, A) a transverse crescentric fold of both ectoderm and endoderm, extending across the area pellucida a short

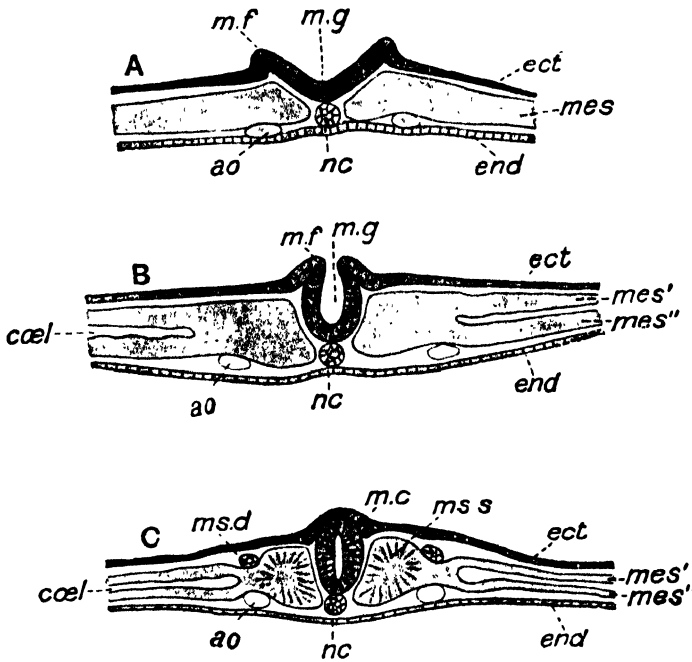


FIG. 238.—Transverse sections across the body of a chick embryo at the twenty-fourth to thirtieth hour of incubation, to show stages in the formation of the medullary cord and cœlome. (× 100.)
ao. aorta, *mes.* mesoderm; *mes'.* parietal, and *mes''.* visceral layer of mesoderm; *m. f.* medullary fold; *m. g.* medullary groove; *ms. d.* mesonephric duct; *ms s.* mesodermal segment; *nc.* notochord.

distance in front of the anterior end of the embryo (*head-process*), is formed as the *head-fold* and marks off the anterior end of the embryo from the rest of the blastoderm.

In Vertebrates the anterior end of the hollow medullary tube becomes dilated, forming three bulb-like

swellings—the fore-brain (Fig. 239, A, *f. b*), mid-brain (*m. b*), and hind-brain (*h. b*). Soon another hollow swelling grows forwards from the first vesicle (B, *prs. en*), and the third gives off a similar hollow outgrowth (*cblm*) from its dorsal surface. The brain now consists of five divisions: the *prosencephalon* (*prs. en*) and *diencephalon* (*dien*) derived from the fore-brain, with the pineal structures (*pn. b*, *pn. e*) and the infundibulum, to which the pituitary body becomes attached (*inf*, *pty*); the *mid-brain* or *mesencephalon* (*m.b*), which gives rise to the *optic lobes* and *crura cerebri*; and the *epencephalon* or *cerebellum* (*cblm*) and *metencephalon* or *medulla oblongata* (*med. obl*) derived from the hind-brain. The original cavity of the brain becomes correspondingly divided into a series of chambers or *ventricles* (compare Figs. 52 and 239), all communicating with one another, and called respectively the *fore-ventricle* or *prosocœle*, *third ventricle* or *diacœle*, *mid-ventricle* or *mesocœle* (*iter*, and *optic ventricles* or *optocœles*), *cerebellar ventricle* or *epicœle*, and *fourth ventricle* or *metacœle*.

In some fishes (*e.g.*, dogfish) the brain consists throughout life of these five divisions, but in most cases (Figs. 51 and 207) the prosencephalon grows out into paired lobes, the right and left *cerebral hemispheres* or *parencephala* (Figs. 239, I–L, *c. h*), each containing a cavity, the *lateral ventricle* or *paracœle* (*pa. cœ*) which communicates with the diacœle (*di. cœ*) by a narrow passage, the *foramen of Monro* (*f. m*). From the prosencephalon or the hemispheres are given off a pair of anterior prolongations, the *olfactory lobes* or *rhinencephala* (*olf. l*), each containing an *olfactory ventricle* or *rhinocœle* (*rh. cœ*).

In the preceding description the brain has been described as if its parts were in one horizontal plane; but, as a matter of fact, at a very early period of development the anterior

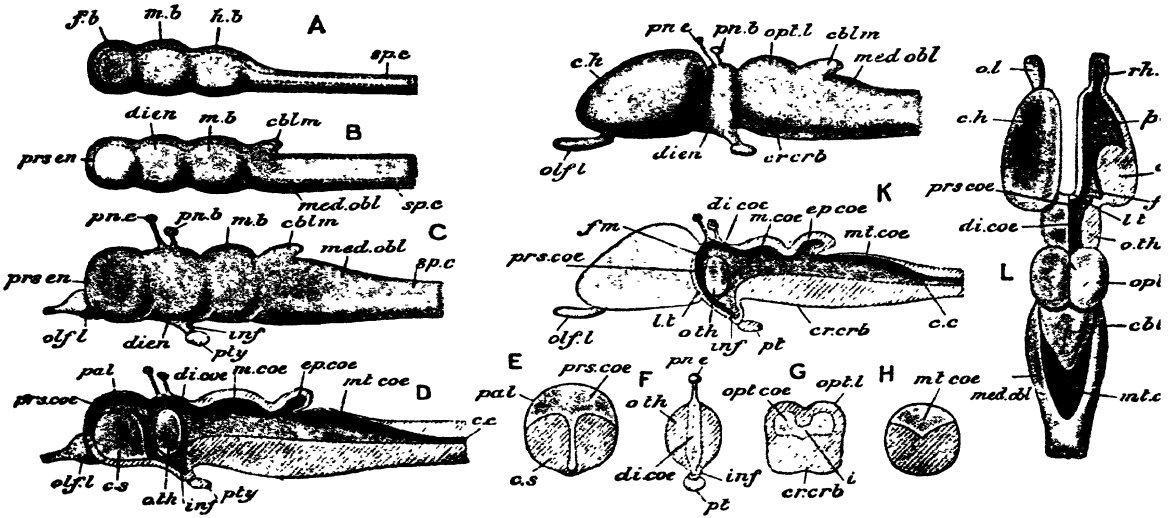


FIG. 239.—Diagrams of the Craniate Brain.

A, First stage, side view, the cavity indicated by a dotted line; *B*, second stage; *C*, side view of fully-formed brain with undivid prosencephalon; *D*, the same in sagittal section; *E*, transverse section of prosencephalon; *F*, of diencephalon; *G*, of mesencephalo *H*, of metencephalon; *I*, side view of brain with cerebral hemispheres; *K*, sagittal section of the same; *L*, dorsal view, the caviti exposed on the right side.

cblm. cerebellum; *c. c.* central canal; *cr. crb.* crura cerebri; *c. h.* cerebral hemispheres; *c. s.* corpora striata; *di.cœ.* diacœle or thi ventricle; *dien.* diencephalon; *ep.cœ.* epicœle; *f.b.* fore-brain; *f. m.* foramen of Monro; *h.b* hind-brain; *inf.* infundibulum; *i.* ite *l. t.* lamina terminalis; *m.b.* mid-brain; *m.cœ.* mesocœle; *med. obl.* medulla oblongata; *mt.cœ.* metaecele or fourth ventricl *olf. l.* olfactory lobes; *opt.cœ.* optocœles; *opt. l.* optic lobes; *o. th.* optic thalami; *pa.cœ.* paracœles or lateral ventricles; *pal.* pallium or roof of prosencephalon; *pn. b.* pineal body; *pn. e.* pineal or parietal eye (compare p. 141); *prs.cœ.* prosocœle; *prs.en.* prosenc phalon; *pt. pty.* pituitary body; *rh.cœ.* rhinocœles or olfactory ventricles; *sp. c.* spinal cord. (From Parker and Haswell's *Zoology*

part becomes bent down over the end of the notochord so that the whole organ assumes a retort-shape, the axis of the fore-brain being strongly inclined to that of the hind-brain. The bend is known as the *cerebral flexure* (Fig. 241, B): it is really permanent, but as the hemispheres grow forwards parallel to the hind-brain, and the floor of the mid-brain and hind-brain thickens, it becomes obscure and is not noticeable in the adult.

The central cavity of the embryonic spinal cord has at first the form of a narrow vertical slit (Fig. 238, *c*), the walls of which eventually fuse dorsally, while ventrally part of the slit forms the central canal of the adult spinal cord. The lateral walls continue to thicken and finally the cord becomes approximately circular in section and the dorsal and ventral fissures are developed.

The ganglia of the dorsal roots of the *spinal nerves* are developed from a paired *neural crest* (Fig. 247, *n. cr*) arising close to the junction of the medullary plate and outer ectoderm: this becomes segmented to form the ganglia, from the cells of which the sensory fibres arise and extend into the spinal cord. The ventral roots arise as direct outgrowths from cells in the ventral region of the medullary cord. Certain of the *cerebral nerves* are developed in an essentially similar manner to the dorsal roots of the spinal nerves, while others arise as direct ventral outgrowths from the brain, like the ventral roots. The fibres of all the typical nerves grow peripherally until they reach the parts which they ultimately supply.

The *olfactory organs* arise as sac-like invaginations of the ectoderm, one on either side of the snout (Fig. 239), and become enclosed by the cartilaginous olfactory capsules, developed, with the rest of the skeleton, from the mesoderm. The aperture of invagination gives rise to the external nostril, the internal

nostrils (in air-breathing forms) being developed subsequently.

The mode of development of the paired *eye* of vertebrates is peculiar and characteristic.

At an early stage of development a hollow outgrowth —the *optic vesicle* (Fig. 240, A, *op. v*)—is given off from either side of the fore-brain and extends towards the side of the head, where it meets with an in-pushing of the ectoderm (*l*), which becomes thickened, and finally, separating from the ectoderm, forms a closed, spherical sac (B, *l*) with a very small cavity and thick walls (compare Figs. 66, L, *e*, and 240). This body is the rudiment of the lens: as it enlarges it pushes against the optic vesicle, which becomes invaginated, the single-layered optic vesicle, thus being converted into a two-layered *optic cup* (Fig. 240, B, *oc'*, *oc''*), its cavity, originally continuous with the diacœle, becoming obliterated. Between the edge of the cup and the lens, on the ventral side, is a small space which gradually extends towards the stalk of the cup, and thus gives rise to a slit in the wall of the latter: this *choroid fissure* C, *aus*), as it is called, soon becomes closed by the union of its edges. The outer layer of the optic cup gives rise to the pigment-layer of the retina (p. 167): from its inner layer the rest of the retina—including the rods and cones—is formed. The stalk of the optic cup occupies, in the embryonic eye, the place of the optic nerve, but the actual fibres of the nerve are formed from the nerve-cells of the retina and grow inwards to the brain.

During the formation of the lens, mesoderm extends in between the ingrowth from which it arises and the external ectoderm; from this the main substance of the cornea and its inner or posterior epithelium are formed, the adjacent ectoderm becoming the external epithelium,

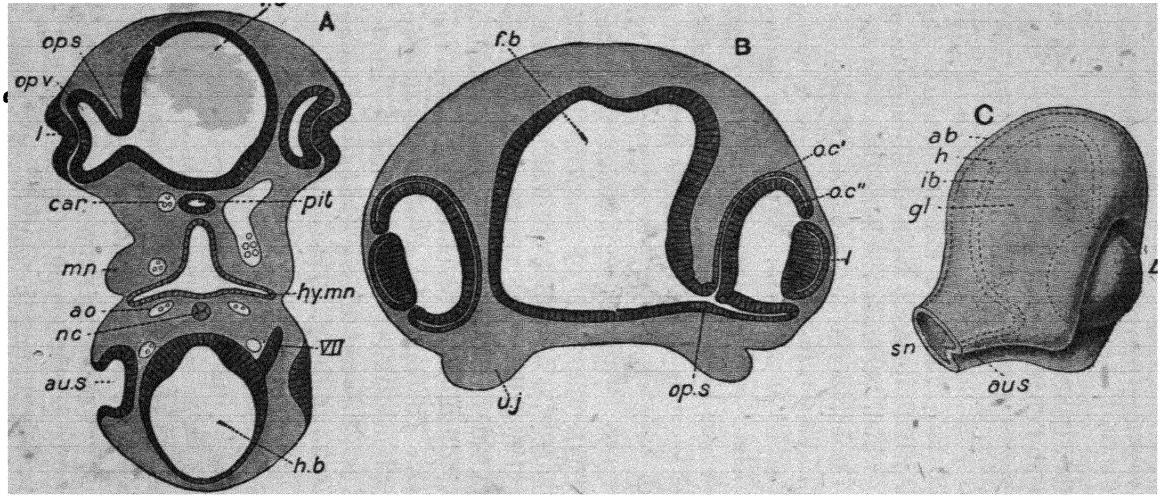


FIG. 240.—*A*, Transverse section across the head of a Chick embryo at the forty-eighth hour of incubation; the section is taken along a line corresponding to one joining the reference letters *au. s.* and *l.* in the three-day embryo shown in Fig. 241, *B*; owing to the cerebral flexure, both fore-brain and hind-brain are cut by the section; the right side of the section is slightly anterior in position to the left side (× 45); *B*, transverse section across the fore-brain and eye of a chick embryo at the sixtieth hour of incubation; on the right side the section passes through the optic stalk, and on the left side just behind the stalk (× 35); *C*, plastic representation of the optic cup and lens. (*A* and *B*, after Marshall; *C*, after Hertwig.)

A and *B*—*ao.* aorta; *au. s.* auditory pit; *car.* carotid artery; *f.b.* fore-brain; *h.b.* hind-brain; *hy.mn.* hyomandibular cleft; *l.* lens; *mn.* mandibular arch; *nc.* notochord; *o. c'.* outer, and *o. c''.* inner wall of optic cup; *op. v.* optic vesicle; *op. s.* optic stalk; *pit.* pituitary body; *u. j.* upper jaw; *VII.* facial nerve.

C—*ab.* outer wall of optic cup; *aus.* choroid fissure; *gl.* cavity of optic cup; *h.* space between the two walls, which afterwards disappears; *ib.* inner wall of optic cup; *l.* lens; *sn.* stalk of optic cup (rudiment of optic nerve).

i.e., that of the conjunctiva (p. 164). Mesoderm also makes its way into the optic cup through the choroid fissure, and gives rise to the vitreous humour. Lastly, the mesoderm immediately surrounding the optic cup is differentiated to form the choroid, the iris, and the sclerotic.

Thus the eye of Vertebrates has a threefold origin: the sclerotic, choroid, iris, vitreous humour, and the greater part of the cornea are mesodermal; the lens and external epithelium of the cornea are derived from the ectoderm of the head: the retina and optic nerve are developed from a hollow pouch of the brain, and are therefore in their ultimate origin ectodermal. The sensory cells of the retina—the rods and cones—although not directly formed from the external ectoderm, as in Invertebrates, are ultimately traceable to the superficial layer of ectoderm, since they are developed from the inner layer of the optic cup, which is a prolongation of the inner layer of the brain, the latter being continuous, before the closure of the medullary groove, with the ectoderm covering the general surface of the body (compare Figs. 66 and 240).

The *internal ear*, like the organ of smell, arises in the embryo as a paired invagination of the ectoderm in the region of the hind-brain, a shallow depression being formed (Figs. 66, L, 240, A, and 241, *au. s*) which deepens and becomes flask-shaped; and finally, as a rule, loses its connection with the external ectoderm, giving rise to a closed sac surrounded by mesoderm in which the cartilaginous auditory capsule is subsequently developed. At first simple, it soon becomes divided by a constriction into dorsal and ventral compartments, from the former of which arise the utriculus and semicircular canals, and from the latter the sacculus and cochlea.

The early development of the **alimentary canal** has already been dealt with in the case of the frog (pp. 180 and 183), and it will be remembered that the greater part

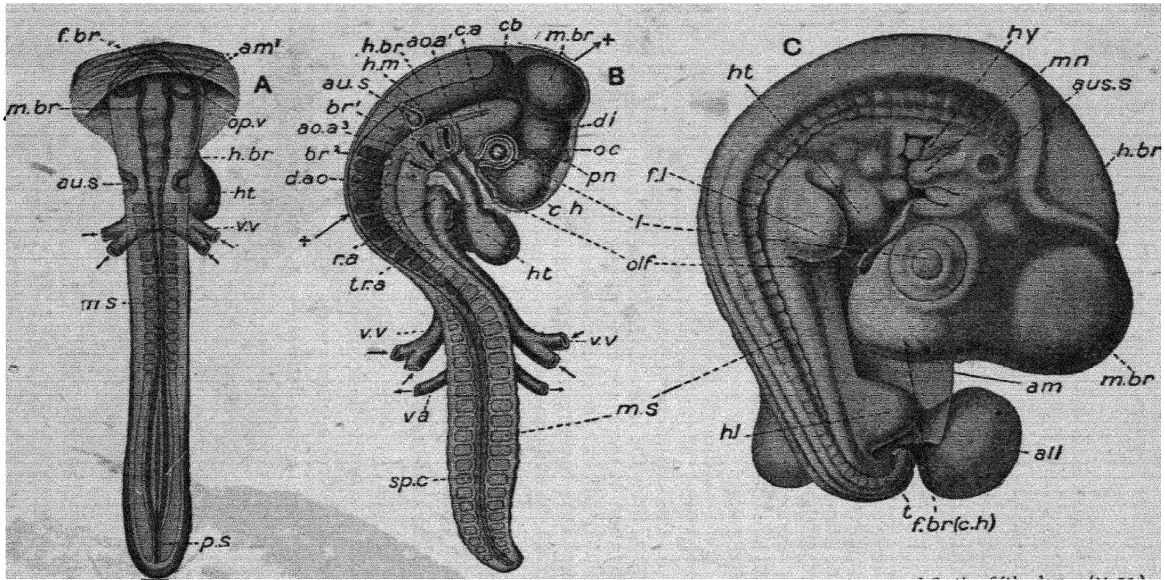


FIG. 241.—Chick embryos at, *A*, the thirty-sixth hour of incubation; *B*, the end of the third day; and *C*, the fifth day. (× 15.)
(Compare Fig. 240.)

*am.*¹ head-fold of the amnion; *all.* allantois; *ao.*¹, *ao.*³, first and third aortic arches; *au. s*, *aus. s*, auditory sac; *br.*¹, *br.*², first and second branchial clefts; *am.* cut edge of amnion; *am.*¹ pro-amnion; *c. a.* carotid artery; *cb.* cerebellum; *c. h.* cerebral hemisphere; *d. ao.* dorsal aorta; *di.* diencephalon; *f.br.* fore-brain; *f.l.* fore-limb; *h.br.* hind-brain; *h.l.* hind-limb; *h.m.* hyomandibular cleft; *ht.* heart (ventricle); *hy.* hyoid arch; *l.* lens of eye; *m.br.* mid-brain; *mn.* mandibular arch; *m. s.* mesodermal segments; *o. c.* optic cup; *olf.* olfactory pit; *op. v.* optic vesicle; *pn.* pineal body; *r. a.* right auricle; *sp. c.* spinal cord; *t.* tail; *tr.a.* conus arteriosus; *v. a.* vitelline artery; *v. v.* vitelline vein. (*A* and *B*, from Marshall; *C*, from Parker

of it (*mesenteron*) is lined by endoderm, its cavity being at first bounded by the yolk below, but gradually becoming closed in by endoderm cells. When a yolk-sac is formed (dogfish, bird, mammal, Figs. 236, 242), it of course communicates with the mesenteron; but as the embryo is gradually folded off from the yolk-sac, the mesenteron becomes tubular along its whole length, and eventually the stalk of the yolk-sac becomes solid, at hatching (or birth) its point of communication with the body being marked by the *navel* (*umbilicus*). The ectodermic *stomodæum* (p. 183), which gives rise to the mouth-cavity and also to the greater part of the pituitary body, comes to communicate with the mesenteron anteriorly, and the ectodermic *proctodæum* opens into it posteriorly. The muscular and peritoneal layers of the canal are formed, it will be remembered, from the mesoderm.

The first traces of the *liver* (Fig. 66, K) and *pancreas* are seen as simple endodermic offshoots of the mesenteron, which gradually become branched in a complicated manner, the numerous lobules being more or less closely connected together by mesoderm.

The *gill-pouches* arise as paired outgrowths of the endoderm lining the pharynx, which come into contact with the ectoderm, the latter becoming perforated to form the external branchial apertures. The bars, with their contained skeletal and vascular structures, which separate the pouches, are called the visceral arches; there are similar skeletal and vascular structures in front of the first and behind the last cleft; so that, in all, five visceral arches are reckoned, with four intervening gill-clefts. Four gill-clefts appear also in the embryo of reptiles, birds, and mammals—animals in which gills are never developed (Fig. 241), but they early disappear with the exception of the first cleft, corresponding

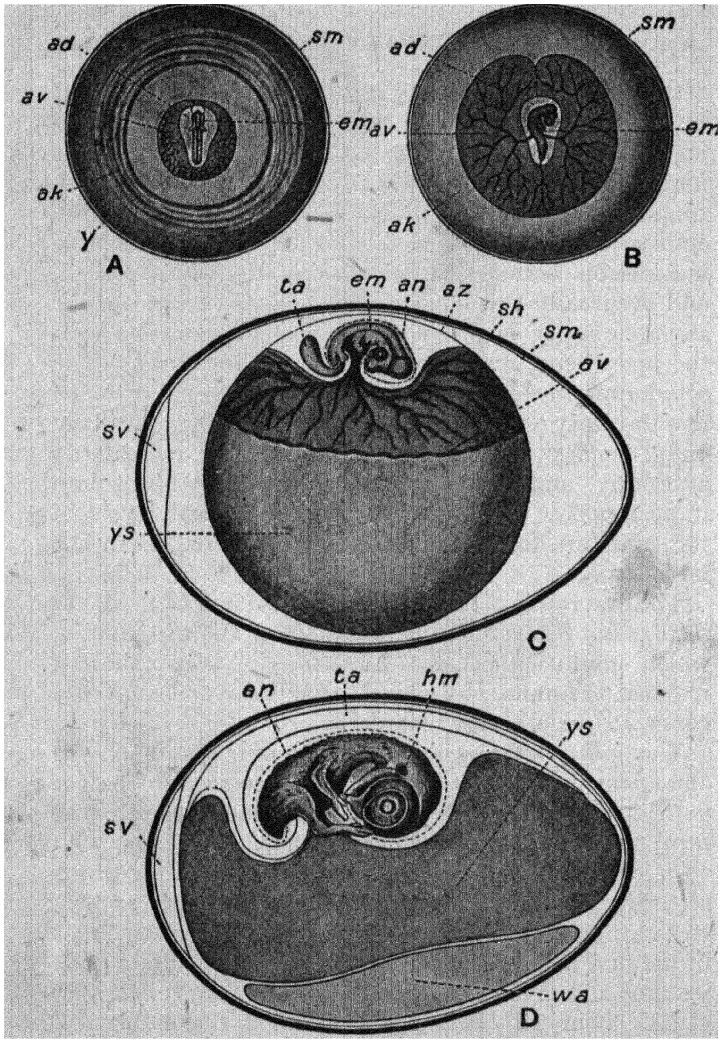
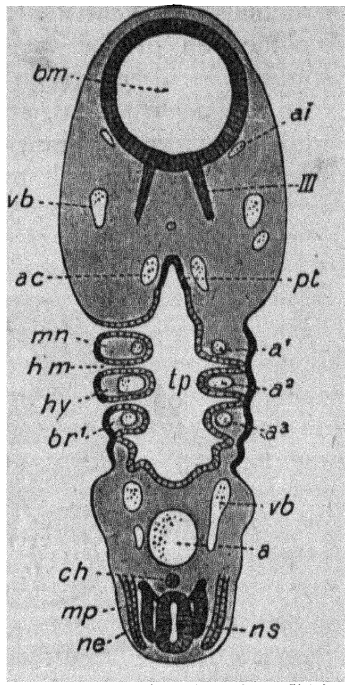


FIG. 242.—The yolk of a Hen's egg at, *A*, the thirty-sixth hour from the beginning of incubation; *B*, the third day; *C*, the end of the fifth day; and *D*, the end of the ninth day (about nat. size). (Compare Fig. 190.)

ad. area pellucida; ***an.*** inner or "true" amnion; ***ak.*** area opaca; ***av.*** area vasculosa (in *C* its outer margin); ***az.*** outer or "false" amnion (serous membrane); together with the vitelline membrane; ***em.*** embryo; ***hm.*** hyomandibular cleft; ***sh.*** egg-shell; ***sm.*** vitelline membrane (in *C*, shell membrane); ***sv.*** air-chamber; ***ta.*** allantois; ***wa.*** white or albumen; *ys* yolk-sac. (From Marshall.)

with the spiracle (p. 415) of the dogfish, which gives rise in all Vertebrates above fishes to the tympano-eustachian passage: the branchial skeleton, as we have seen, undergoes a corresponding reduction or modification (pp. 418 and 450). In air-breathing Vertebrates the *lungs* arise as a ventral outgrowth of the pharynx, lined by endoderm and covered by mesoderm.

The **circulatory organs** are developed from the mesoderm, the *heart* arising in the visceral layer on the ventral side of the pharynx. It has at first the form of a straight tube, developed in the chick and rabbit by the fusion of two longitudinal vessels (vitelline veins, see below), it soon becomes twisted into an S-shape, and transverse constrictions are formed dividing it into the different chambers. The auricular and ventricular portions are each at first single, but from the Amphibia onwards the former subsequently becomes divided into two by a septum, and in birds and



G. 243.—A section through a Chick embryo at the end of the third day of incubation, the section being taken along a plane indicated by the two arrows and crosses in Fig. 241, *B*; the right side of the section is at a level slightly dorsal to that of the left side. (× 30.) (After Marshall.)

a. dorsal aorta; a^1. first aortic arch, in the mandibular arch; a^2. second aortic arch, in the hyoid arch; a^3. third aortic arch, in the first branchial arch; *ac*. carotid artery; *ai*. internal carotid artery; *bm*. cavity of midbrain; br^1. first branchial arch; *ch*. notochord; *hm*. hyomandibular cleft; *hy*. hyoid arch; *mn*. mandibular arch; *mp*. muscle-plate; *ne*. ganglion of spinal nerve; *ns*. spinal cord; *pt*. pituitary outgrowth; *tp*. pharynx; *vb*. jugular vein.

mammals the ventricle is similarly subdivided. The modification of the arterial arches in the examples studied has already been described (pp. 420 and 480).

In the dogfish, bird, and rabbit the dorsal aorta, in addition to its other branches, gives rise to paired *vitelline arteries*: these branch over the extra-embryonic part of the blastoderm (p. 551) which spreads over the

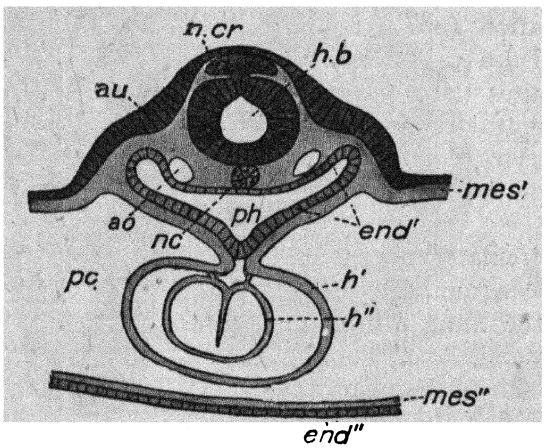


FIG. 244.—Transverse section across the head of a Chick embryo at about the fortieth hour of incubation, in the region of the hind-brain and heart. (× about 90.)
ao. aorta; *au.* beginning of auditory pit; *end'.* endoderm of pharynx; *end''.* endoderm of yolk-sac; *h'.* muscular wall of heart; *h''.* epithelial lining of heart (the septum, which subsequently disppears, indicates the paired origin of the heart); *h.b.* hind-brain; *mes'.* parietal, and *mes''.* visceral layer of mesoderm; *nc.* notochord; *n. cr.* neural crest; *pc.* pericardial cœlome; *ph.* pharynx.

yolk-sac, and in the two former types the capillary network takes an important share in the absorption of the yolk by the embryo. From this network in the *area vasculosa* (Fig. 242) the blood is returned by splanchnopleuric *vitelline veins*, which join with a *subintestinal vein* and open into vessels which eventually give rise to the hepatic portal veins. The chief somatopleuric veins in all embryonic Vertebrates are, as in the dogfish,

the jugulars and the cardinals (Figs. 240 and 243). In all Vertebrates above the fishes, the cardinals become subsequently more or less entirely replaced functionally by the postcaval: the anterior part of one or both cardinals may, however, persist as the azygos vein or veins (*e.g.*, rabbit, p. 484).

Urinogenital Organs.—The *excretory organs*, speaking of Vertebrates as a whole, arise as a series of tubules situated along the dorsal region of the cœlome; but owing to the fact that they do not all arise at the same time and that their development is modified by neighbouring structures, there is much variation as regards these tubules and their relations. They may in general be classified into three groups, constituting what are known respectively as the *fore-kidney* or *pronephros* (Fig. 245, A, *p. nph*), the *mid-kidney* or *mesonephros* (*ms. nph*), and the *hind-kidney* or *metanephros* (*mt. nph*).

The *pronephros* appears at an early stage of development, and very rarely remains functional throughout life, though in some cases (*e.g.*, tadpole) it serves as an excretory organ in the larva; in many cases it is merely represented by vestiges (*e.g.*, dogfish, bird, rabbit). The pronephric tubules open at one end into the cœlome by ciliated *peritoneal funnels*, and at the other into a longitudinal *archinephric duct* or *segment duct* (*sg. d*), which communicates with the cloaca posteriorly. They are generally from two to four in number, are not strictly segmental, and are confined to the anterior end of the cœlome: opposite their peritoneal funnels a single large glomerulus (see p. 129) is present on either side of the body.

The *mesonephros* appears rather later than the pronephros, and extends along the greater part of the cœlome. Its tubules are segmentally arranged, and thus furnish another example of metamerism in the Verte-

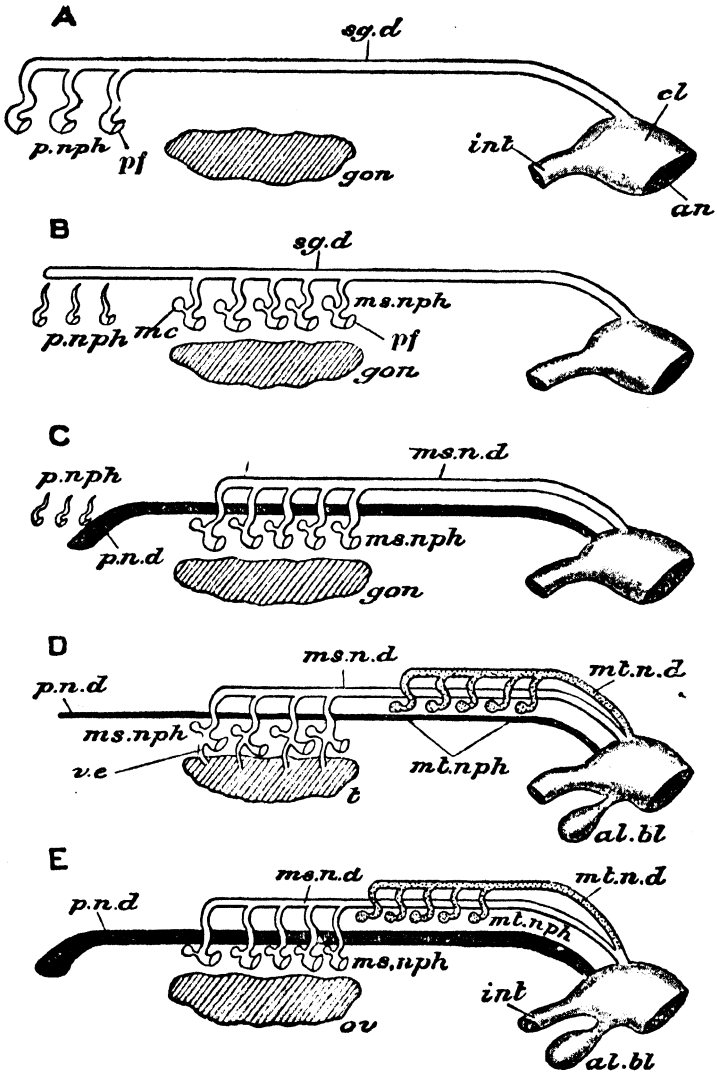


FIG. 245.—Diagrams illustrating the development of the urinogenital organs of Vertebrate.

A, pronephros in functional activity; *B*, atrophy of pronephros, development of mesonephros; *C*, condition in the adult female frog showing differentiation of Wolffian and Müllerian ducts; *D*, *E*, condition found in the higher craniate, showing *D*, development of metanephros, male type; *E*, female type.

al. bl. allantoic bladder; *an.* anus; *cl.* cloaca; *gon.* gonad; *int.* intestine; *mc.* Malpighian capsule; *mesn. d.* mesonephric (Wolffian) duct; *ms.nph.* mesonephros; *mt.n. d.* metanephric duct; *mt nph.* metanephros; *pf.* peritoneal funnels; *ov.* ovary; *p. n. d.* Müllerian duct; *p.nph.* pronephros; *sg. d.* archinephric or segmental duct; *t.* testis; *v.e.* efferent ducts. (From Parker and Haswell's *Zoology*.)

brate body; each tubule is provided with a separate glomerulus enclosed within a Malpighian capsule (*mc*). The peritoneal funnels of the mesonephros may lose their connection with the tubules and come to open into certain veins (*e.g.*, frog, Fig. 49), or may disappear at a later stage to a greater or less extent (dogfish) or entirely (*e.g.*, bird, rabbit): at their other ends the tubules communicate with the archinephric duct, which may now be spoken of as the *mesonephric duct* (Fig. 245, *ms. n. d, ms. t*). In Fishes and Amphibians (Fig. 245, C) the mesonephros remains as the functional kidney throughout life, though the posterior part alone may retain the renal function and develop special ducts (dogfish), thus foreshadowing the metanephros of higher Vertebrates.

The *metanephros* is characteristic of Reptiles, Birds, and Mammals (Fig. 245, D and E). Its tubules arise later than those of the mesonephros and open into a special ureter or *metanephric duct* (*mt.n. d*), which arises as an outgrowth from the posterior end of the mesonephric duct: they resemble the mesonephric tubules except that they possess no peritoneal funnels and usually show no signs of a metametric arrangement.

In the majority of Vertebrates the *generative organs* take on a close connection with certain of the urinary tubules and their ducts (p. 173), which may thus undergo a change of function. In the dogfish the archinephric duct early undergoes longitudinal subdivision into two, one of which is retained as a mesonephric duct (now often spoken of as the *Wolffian duct*);

while the other (*Müllerian duct*), retaining its connection anteriorly with the cœlome by a persistent pronephric peritoneal funnel, assumes the function of an oviduct in the female, and atrophies in the male, though traces of it may persist in the adult. Owing to the connection which is formed between the testis and certain of the mesonephric tubules by means of efferent ducts, the Wolffian duct may now serve as a urinogenital duct (frog, p. 173); or when an *epididymis* is formed from the mesonephros (Fig. 245, D), and special ureters arise in connection with the functional renal tubules, the Wolffian duct serves as a spermiduct mainly if not entirely (mammal, p. 502).

In most Vertebrates the oviducts arise quite independently of the mesonephric ducts, each being formed as a groove of the cœlomic epithelium which becomes closed in and grows from before backwards to the cloaca, its anterior opening into the cœlome being a funnel with ciliated lips drawn out in the Mammals into fimbriated lobes. In the lower forms (Amphibia) the funnel retains its position far forward, but in others the duct becomes shortened.

In the higher Vertebrates, in which the kidney of the adult is a metanephros (p. 571), the only parts of the mesonephros and its duct which persist as more than a vestige are the epididymis and spermiduct of the male.

The *gonads* arise as ridges covered by cœlomic epithelium on the dorsal wall of the body-cavity close to the inner side of the developing kidneys. Their epithelium is known as *germinal epithelium*, and from it either ova or sperms are eventually developed (pp. 173–174, and 503).

The majority of the **muscles** are developed, as we have seen (pp. 182 and 556), from the mesodermal

segments, others arising from the parietal and visceral layers of the mesoderm.

The first part of the **endoskeleton** to be formed is the *notochord* (pp. 182 and 548), developed primarily from the endoderm, but in the chick and rabbit arising from the central part of the mass of cells continued forwards from the front end of the primitive streak where the endoderm and mesoderm are united in a secondary median fusion for some time. In the mesoderm surrounding the notohcord cartilages appear and give rise to the *vertebræ*, the notochord becoming constricted by the ingrowing cartilage and eventually disappearing more or less completely (p. 420): it at first extends into the head as far as the pituitary body (Fig. 246.) The cranial cartilages do not become segmented, but give rise to a pair of horizontal bars, the *parachordals* (*pa. ch*): these are continued forwards, diverging around the pituitary body, as the *trabeculæ cranii* (*tr*). The two parachordals and trabeculæ then unite respectively with one another, and so form a firm floor for the future

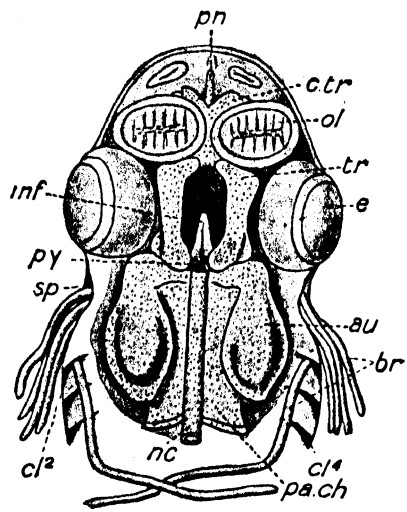


FIG. 246.—Dissection of the head of an embryo Dogfish (*Scyllium canicula*) from the dorsal side, to show the developing chondrocranium (dotted). (× 8.)
au. auditory capsule; *br.* external gills; *c. tr.* cornu of trabecula; cl^2, cl^4. gill-clefts; *inf.* infundibulum of brain (left *in situ*); *nc.* notochord; *ol.* olfactory sac; *pa. ch.* parachordal cartilage; *pn.* prenasal cartilage; *py.* pituitary body (left *in situ*); *sp.* spiracular cleft; *tr.* trabecula. (After W. K. Parker.)

brain-case: this is gradually developed by the cartilage growing up on either side and eventually meeting to a greater or less extent above the brain: there is never, however, a complete cartilaginous roof to the cranium, parts of which are only membranous and form the fontanelles (p. 41). In the meantime the cartilaginous sense-capsules are developed, the olfactory and auditory capsules uniting with the brain-case in front and behind respectively.

The *visceral skeleton* is formed as a series of cartilaginous bars within the visceral arches, the first of which forms the mandibular arch, the second the hyoid, and the others the branchial arches.

The limbs appear as small buds (Fig. 241, C) composed of ectoderm with a core of mesoderm, in which latter their skeleton arises by the formation of cartilage extending inwards to form the arches, and outwards to form the skeleton of the free portions of the limbs.

As we have seen, the endoskeleton may remain practically entirely cartilaginous in the adult (*e.g.*, dog-fish), but in higher forms extensive processes of ossification set in, certain bones replacing the cartilage to a greater or less extent, and others being formed in the surrounding connective-tissue (compare p. 41).

Development of the Amnion, Allantois, and Placenta.—We must now consider some important and characteristic structures which are developed in the embryos of Reptiles, Birds, and Mammals, and known as *embryonic membranes*. Taking the chick as a convenient example, these are formed as follows.

The blastoderm, as we have seen (p. 551 and Fig. 242), gradually extends peripherally so as to cover the yolk, and thereby becomes divisible into an *embryonic portion*, from which the embryo is formed, and an *extra-embryonic portion*, which invests the yolk-sac and takes

no direct share in the formation of the embryo. The extension of the ectoderm and endoderm takes place regularly and symmetrically; but the mesoderm, while extending equally in the lateral and posterior regions, grows forwards in the form of paired prolongations which afterwards unite, so that for a time there is an area of the blastoderm in front of the head of the

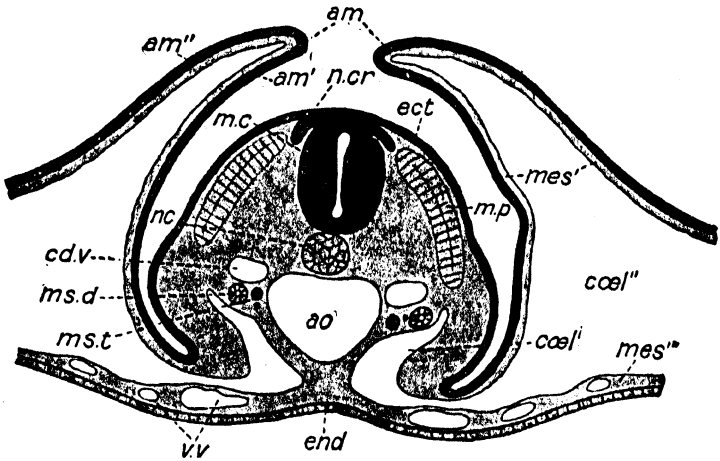


FIG. 247.—Transverse section across the body of a Chick embryo at about the sixtieth hour of incubation. (× about 90.)

ao. aorta; *am.* amniotic folds; *am'.* true amnion, and *am''.* serous membrane; *cd. v.* cardinal vein; *cœl'.* cœlome in body of embryo; *cœl''.* extra-embryonic cœlome; *ect.* ectoderm; *end.* endoderm; *m. c.* medullary cord; *mes'.* parietal, and *mes''.* visceral layer of mesoderm; *m.p.* muscle-plate; *ms. d.* mesonephric duct; *ms. t.* mesonephric tubule; *nc.* notochord; *n. cr.* neural crest; *v. v.* vitelline veins.

embryo formed of ectoderm and endoderm only and called the *pro-amnion* (p. 553 and Fig. 238, E, *pr. am*).

Before the embryo has begun to be folded off from the yolk the rudiment of one of the two embryonic membranes, the **amnion,** has appeared. A crescentic *amniotic fold* (Fig. 241 A, and 248, A, *am. f'*) arises in front of the head end of the embryo from the region of the pro-amnion: it consists at first of ectoderm only,

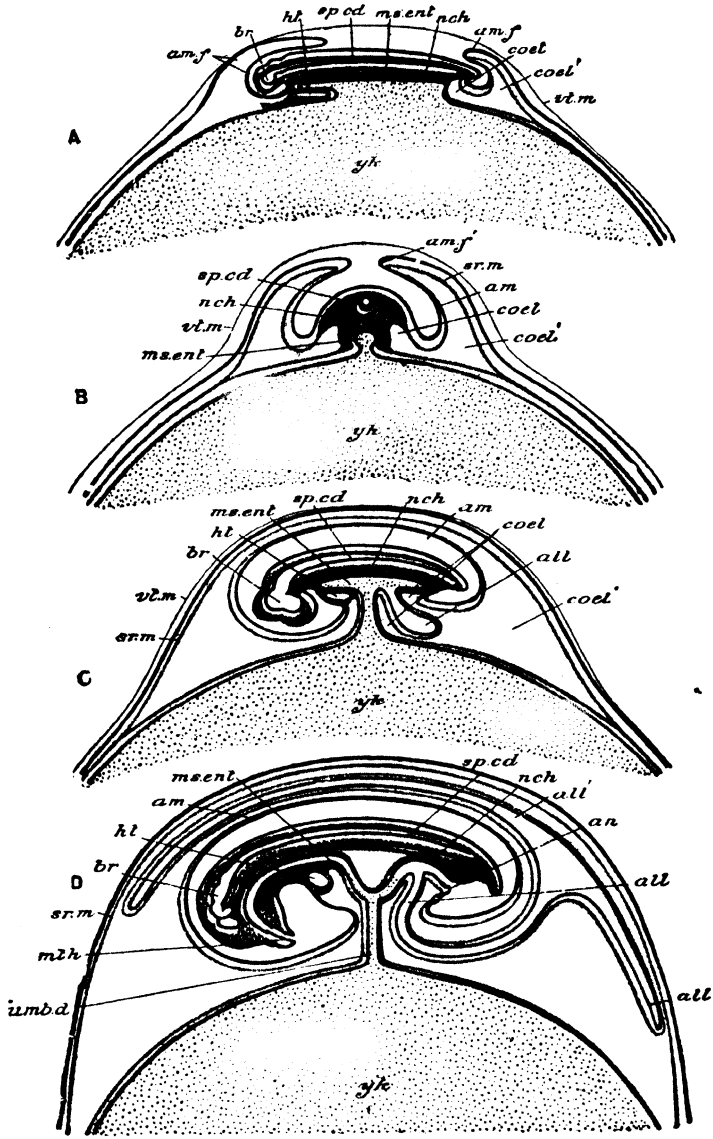


FIG. 248.—Diagrams illustrating the development of the fœtal membranes of a Bird, A, early stage in the formation of the amnion, longitudinal vertical section; B.

slightly later stage, transverse section; C, stage with completed amnion and commencing allantois; D, stage in which the allantois has begun to envelop the embryo and yolk-sac. The ectoderm is represented by a blue, the endoderm by a red line; the mesoderm is grey.

all. allantois; *all'.* the same growing round the embryo and yolk-sac; *am.* amnion; *am. f.* amniotic fold; *an.* anus; *br.* brain; *cœl.* cœlome; *cœl'.* extra-embryonic cœlome; *ht.* heart; *ms.ent.* mesenteron; *mth.* mouth; *nch.* notochord; *sp. cd.* spinal cord; *sr. m.* serous membrane; *umb. d.* umbilical duct; *vt. m.* vitelline membrane; *yk.* yolk-sac. (Reduced from Parker and Haswell's *Zoology*.)

the mesoderm not having yet spread into the pro-amnion. The fold is soon continued backwards along the sides of the body (Fig. 248, B) and a similar fold appears round the tail end (A), but in these regions (*am. f*) it consists from the first of ectoderm *plus* the parietal layer of mesoderm, *i.e.*, it is a fold of what may be called the embryonic body-wall or *somatopleure* (p. 548). Its cavity is a prolongation of the space between the parietal and visceral layers of mesoderm—*i.e.*, is an extension of the extra embryonic cœlome.

The entire amniotic fold gradually closes in above (Fig. 248, C) forming a double-layered dome over the embryo. Its inner layer, formed of ectoderm internally and mesoderm externally, is the *amnion* (*am*, and Fig. 241, *am'*), the cavity enclosed by which becomes filled with a watery *amniotic fluid*, serving as a protective water-cushion to the contained embryo. Its outer layer, formed of ectoderm externally and mesoderm internally, is the *serous membrane*, sometimes spoken of as the *false amnion* (*sr. m*, *am''*) : this comes to lie just beneath the vitelline membrane (p. 533), with which it subsequently fuses.

The second of the embryonic membranes, the **allantois,** is developed as an outpushing of the ventral wall of the mesenteron near its posterior end (Figs. 248, C, *all*, and 242), and consists, therefore, of a layer of visceral mesoderm lined by endoderm (*splanchnopleure*, p. 548). It has at first the form of a small, ovoid sac having the precise anatomical relations of the urinary bladder of the frog. Increasing rapidly in size, it makes its way, back-

wards and to the right, into the extra-embryonic cœlome, between the amnion and the serous membrane (C, D). Allantoic arteries pass to it from the dorsal aorta, and its veins, joining with the vitelline veins from the yolk-sac, take the blood through the liver to the heart (p. 568). Next, the distal end of the sac spreads itself out and extends all round the embryo and yolk-sac (D, *all'*), fusing, as it does so, with the serous and vitelline membranes, and thus coming to lie immediately beneath the shell-membrane. It finally encloses the whole embryo and yolk-sac, together with the remains of the albumen, which has, by this time, been largely absorbed (Fig. 248, D). The allantois serves as the embryonic respiratory organ, gaseous exchange readily taking place through the porous shell; its cavity is an embryonic urinary bladder, excretory products being discharged into it from the kidneys.

At the end of incubation the embryo breaks the shell by means of a little horny elevation or *caruncle* at the end of the beak. By this time the remainder of the yolk-sac has been drawn into the cœlome, and the ventral body-walls have closed round it. On the shell being broken the allantois gradually shrivels up, respiratory movements begin, the aperture in the shell is enlarged, and the young bird is hatched and begins a free life.

In the higher Mammalia the allantois takes on a further important function. The relations of the amnion and allantois in the rabbit are essentially similar to those described above in the case of the bird. But the later history of the allantois is widely different, owing to the modifications which it undergoes in order to take part in the formation of the **placenta,** the structure by means of which the fœtus receives its nourishment from the walls of the uterus, with which the blastocyst (p. 554) first becomes adherent over the future placental area by the proliferation of the cells of its outer

layer in this region, which forms irregular processes extending into the thickened mucous membrane on the dorsal side of the uterus (Fig. 249, *e'*). As the embryo develops, it sinks down and causes the vascular "yolk-

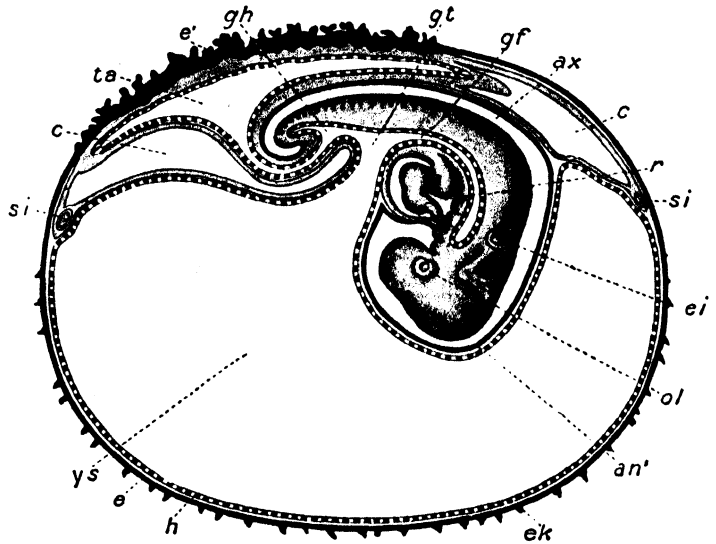


FIG. 249.—A Rabbit embryo and blastodermic vesicle ("yolk-sac") at the end of the tenth day. The embryo is represented in surface view from the right side, the course of the alimentary canal being indicated by the broad dotted line; the blastodermic veiscle is shown in median longitudinal section. The greater part of the tail has been removed. (× 7½.)

an'. pro-amnion; *a.x.* cavity of amnion, between the inner or true amnion and the embryo; *c.* extra-embryonic portion of cœlome; *e.* ectoderm; *e'.* thickened part of *e* by which the blastodermic vesicle is attached to the uterus, and from which the development of the fœtal part of the placenta proceeds; *ei.* auditory vesicle; *ek.* ectodermal villi; *gf, gi, gh.* enteron; *h.* endoderm; *ol.* eye; *r.* heart; *si.* circular marginal vessel of area vasculosa; *ta.* cavity of allantois; *ys.* cavity of "yolk-sac." (From Marshall, in part after Van Beneden and Julin.)

sac" or umbilical vesicle (*ys*) to be doubled in and take on a flattened form (Figs. 250, *ds*, 249 and 251, *ys*): this early becomes attached to the mucous membrane of the uterus, and represents a *vitelline* or *yolk-sac placenta* such as occurs in some viviparous dogfishes;

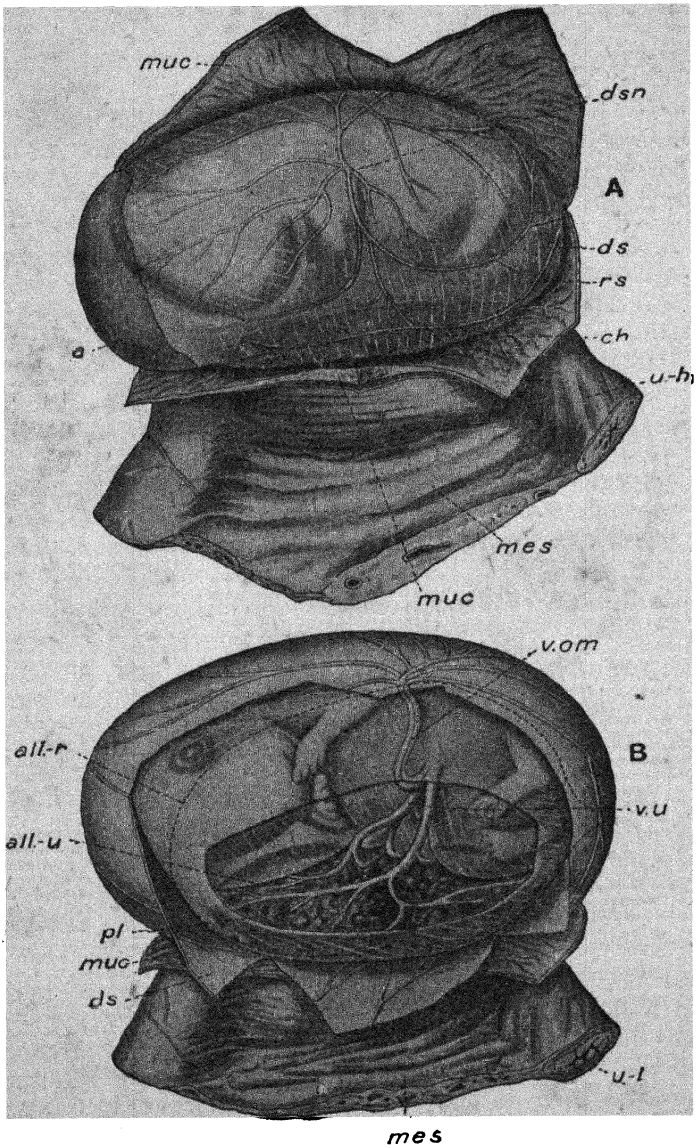


FIG. 250.—Portion of the uterus of a Rabbit containing an advanced fœtus. (× ⅔.) In A, the uterus has been opened and its wall reflected, and part of the "yolk-

sac" (umbilical vesicle) cut away (left of the figure) to show the underlying amnion. In B, part of the uterine wall has been removed and part of the yolk-sac and amnion cut out so as to expose the fœtus and placenta.

a. amnion; *all.-r.* dotted line indicating margin of allantois (compare Figs. 249 and 251, *ta*); *all.-u.* line along which the allantois is reflected over the placental region; *ch.* chorion; *ds.* yolk-sac; *dsn.* point at which the umbilical vessels branch out from the umbilical stalk; *mes.* mesentery of uterus; *muc.* mucous membrane of uterus; *pl.* fœtal surface of placenta covered by the distal wall of the allantois; *rs.* circular marginal vessel of area vasculosa of yolk sac; *u-h.* undilated narrow portion of uterus between two fœtus-containing swellings; *u-l.* lumen of uterus; *v. om.* vitelline vessels; *v. u.* allantoic vessels. (From Grosser's *Vergl. Anat. u. Entwick. geschichte der Eihäute und der Placenta.*)

but its nutritive function in the mammal is of only minor importance.

The *fœtal part* of the placenta is formed from the outer layer of the amnion (serous membrane) in a limited disc-shaped area covered by the thickened part of the outer layer where the distal portion of the allantois coalesces with it (Fig. 249). The membrane thus formed (*chorion*) develops vascular processes or septa—the *chorionic villi*, which are received into depressions—the *uterine crypts*—in the thickened placental folds of mucous membrane on the dorsal wall of the uterus which constitute the *maternal portion* of the placenta (Figs. 249 and 250). The fœtal portion of the placenta with its villi is supplied with blood by the allantoic vessels, and the blood-supply of the uterus is at the same time greatly increased: the fœtal and dilated maternal capillaries and sinuses are thus brought into intimate relation with one another in the placenta, being only separated by thin layers of epithelium: diffusion can thus take place between them, nutrient matter and oxygen diffusing from the blood of the mother into that of the fœtus, while excretory substances pass from the blood of the fœtus into that of the mother.

The disc-shaped or *discoidal* placenta of the Rabbit is of the type termed *deciduate*, its villi being so intimately connected with the uterine mucous membrane that a part of the latter comes away with it at birth in the *decidua*, or afterbirth, which is attached to the newly-

born young by the *umbilical cord*, consisting of the stalks of the allantois and flattened yolk-sac twisted together

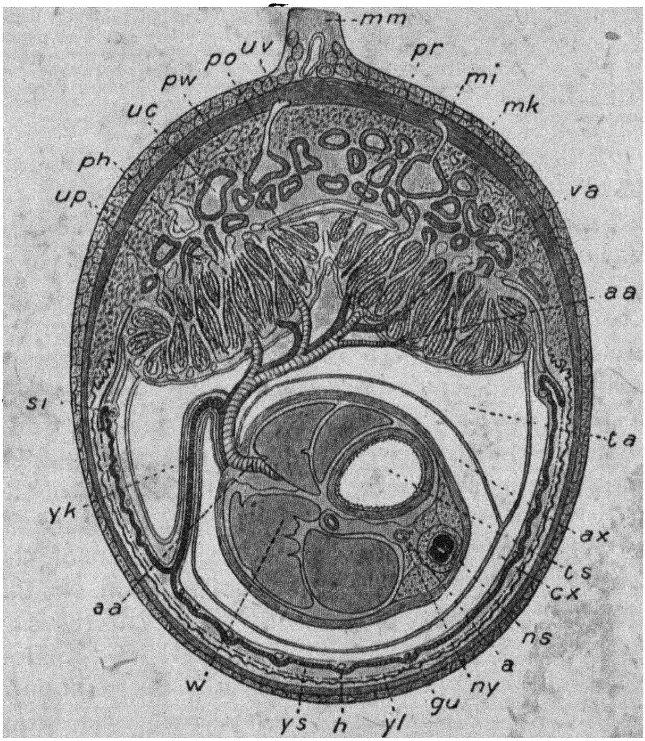


FIG. 251.—A transverse section across the uterus and the contained embryo of a Rabbit at the end of the nineteenth day. The embryo is cut transversely about the middle of the body, the section passing through the "yolk-stalk" and allantoic stalk. (× 2½.)

A, dorsal aorta; *aa.* allantoic artery; *a.x.* cavity of amnion, between the inner or true amnion and the embryo; *cx.* space between the inner and outer layers of the amnion; *gu.* uterine glands; *h.* endoderm of upper or vascular wall of "yolk-sac" (umbilical vesicle); *mi, mk.* outer or longitudinal, and inner or circular muscles of wall of uterus; *mm.* mesentery of uterus; *ns.* spinal cord; *ny.* sympathetic nerve-cord; *ph.* lobule of placenta; *po.* region along which the separation of the placenta occurs at birth; *pr.* inter-placental groove; *pw.* sub-placental cavity; *si.* circular marginal vessel of yolk-sac; *ts.* cavity of the allantois (see Fig. 249); *ts.* stomach; *uc.* dilated uterine capillary, with thick perivascular wall; *up* uterine or maternal sinuses of placenta; *uv.* blood-vessels of uterus; *va.* allantoic vein; *w.* liver; *yk.* stalk of yolk-sac; *yl.* dotted line representing the lower or non-vascular wall of the yolk-sac, now completely absorbed; *ys.* cavity of yolk-sac, continuous with the uterine cavity owing to absorption of the lower wall of the yolk-sac. (From Marshall.)

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