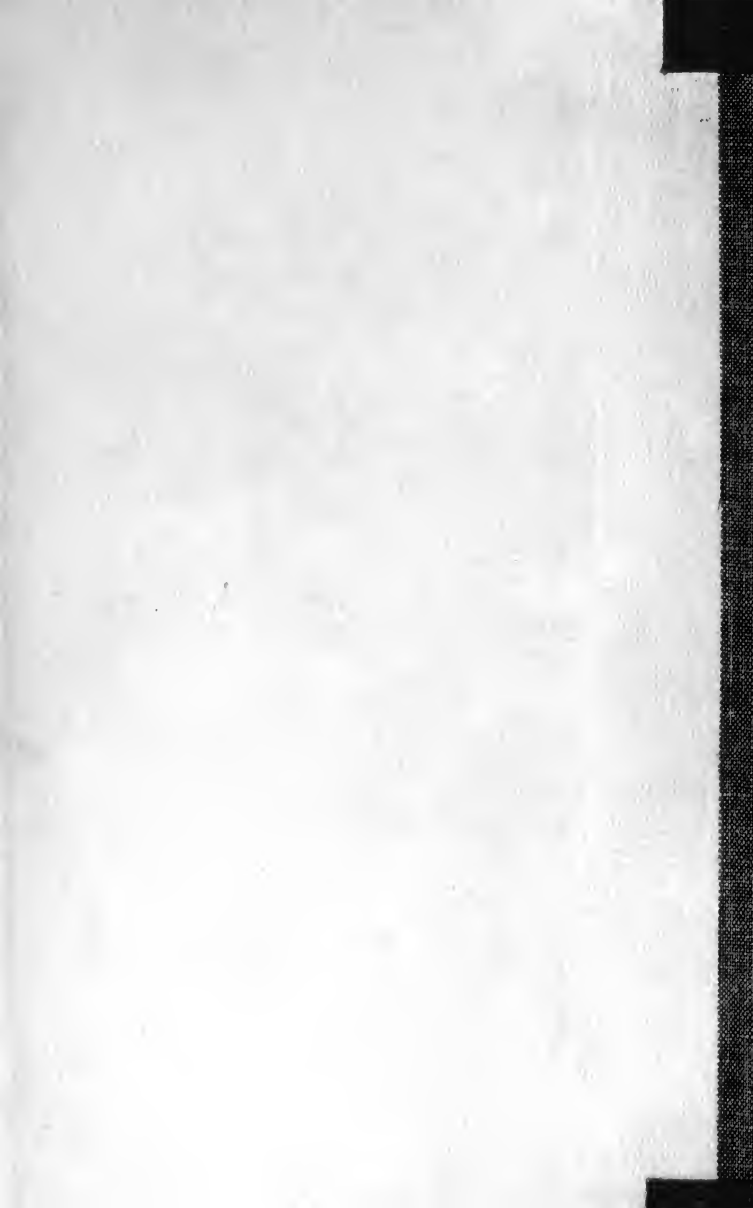
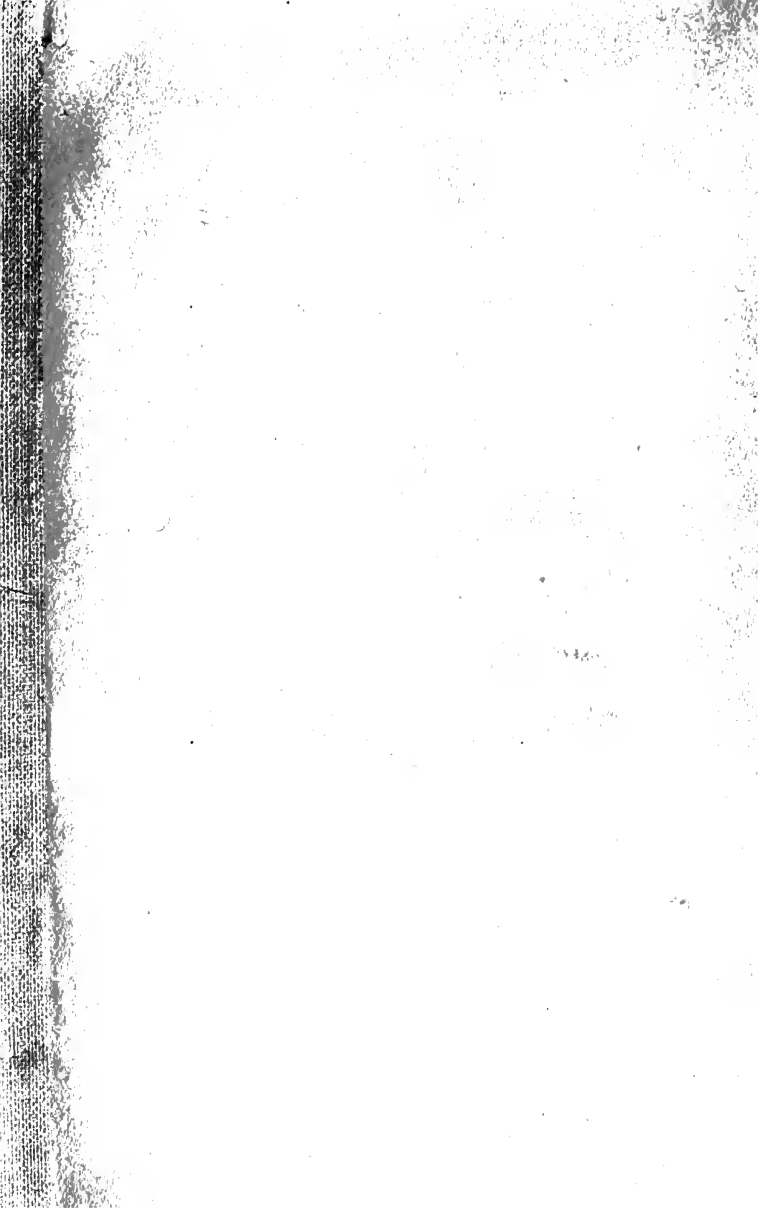




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5.
(CATECHISM SERIES.)

ZOOLOGY

COMPLETE VOLUME

BY

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CORRIGENDA.

- Page 11. Line 7 from top, for "bivalents" read "univalents."
- " 56. Line 2 from bottom, for "spem-morula" read "sperm-morula."
- " 91. Line 11 from bottom, for "diseases" read "disease."
- " 94. Line 11 from top, for "with a simple gut, a cerebral" read "without a gut. It has a cerebral."
- " 94. Line 15 from top, read "and, in blood spaces in the wall of the snail's."
- " 99. Line 5 from top, read "of the dog. The eggs from the."
- " 105. Left side of Figure 23. For N read Nc. Nucleus.
- " 106. Line 16 from top, for "*Oxyurus*" read "*Oxyuris*."
- " 110. Line 4 from top, delete "blood."
- " 110. Line 9 from top, for "glands" read "spaces."
- " 110. Line 23 from top, for "are" read "may be."
- " 119. Line 6 from top, for "body-wall" read "section."
- " 126. Lines 1, 5 and 13 from top, for blood read "blood."
- " 127. Line 12 from bottom, for "Cypris" read "Cypris stage."
- " 145. Line 10 from bottom, for "diseminator" read "dis-seminator."
- " 146. Line 10 from top, for "between" read "in."
- " 150. Figure 29, line 6, read "short in female *Culicine* mosquitoes."
- " 156. Line 13 from top, delete "six."
- " 156. Line 11 from bottom, for "First pair of abdominal" read "Eighth pair of."
- " 163. Line 8 from bottom, for "form" read "surround."
- " 165. Line 4 from bottom, for "nephridium" read "nephridia."
- " 165. Lines 12 and 11 from bottom, delete "one part being divided into 'arms' with suckers and the other portion."
- " 165. Line 18 from bottom, delete "not."
- " 166. Line 10 from bottom, delete "Worm-like."
- " 168. Line 11 from bottom, delete "front."
- " 168. Line 10 from bottom, delete "portion of the" and delete "sucker-bearing 'arms', and the."
- " 168. Line 9 from bottom, delete "hind portion forms."
- " 171. Line 11 from bottom, for "but" read "ripening."
- " 174. Line 11 from top, for "branchia" read "branchiae."
- " 174. Line 6 from bottom, for "chitinous" read "calcified."
- " 175. Line 2 from bottom, for "drops" read "and drops."

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ZOOLOGY.

THE INVERTEBRATA.

INTRODUCTORY.

What is Protoplasm?

Living matter; or, as Huxley termed it, "the physical basis of life." It is glutinous and usually somewhat fluid. Chemically it consists of a very complex substance known as protein, which is mainly composed of carbon, nitrogen, oxygen, hydrogen, sulphur, with phosphorus and other elements in combination.

Living protoplasm exhibits ceaseless change. There is a continual slow combustion; oxygen is taken in and combined with carbon and given off as carbon dioxide; food material is absorbed, elaborated, and assimilated. Concurrently with the building up (anabolism) there is the breaking down (katabolism) into non-living matter or wastes. The whole process is termed metabolism, and to its resultant energies movement and other visible manifestations of life are attributable.

Contrast Anabolism and Katabolism.

Anabolism is a building-up. That process through which the living substance is maintained and regenerated by reconstitution and by the assimilation of elaborated food materials.

Katabolism is a breaking-down of living substance into non-living material. It is that process of chemical change which produces wastes or excretions.

Define a Cell. Write a short Account of its Structure and Physiology.

A cell may be defined as a unit mass of living matter or protoplasm which has a more or less definite boundary and which usually contains a nucleus. Both in size and in shape cells vary greatly.

Morphologically, the general substance of the cell is called cytoplasm, and this term includes the living matter or protoplasm and the non-living or metaplasm. Besides the cytoplasm and the nucleus, there are other organised structures in the cell. Such are the vacuoles, cavities of

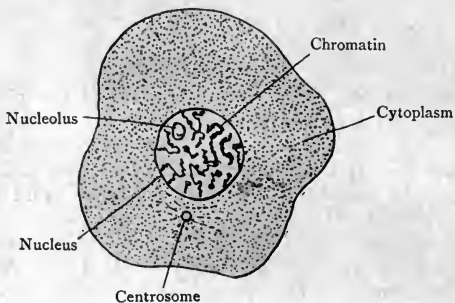


FIG. 1.—**Diagram of a Cell.** After Carnoy.)

the protoplasm lined with a specialised portion of it, and the minute centrosomes which play an important rôle in cell-division.

The centrosomes are usually situated close to the nucleus and are often contained in a distinct, but transient part of the cytoplasm known as the archoplasm.

The nucleus is the governing centre; it is the seat of dynamic activity; it controls the metabolism of the cell. For example, it has been shown experimentally that nutrition is impossible without it. "Life depends upon the mutual reactions of nucleus and protoplasm." The nucleus is essential also in cell-division (in the multiplication of ordinary body cells), and in fertilisation (in reproduction

by special sex or germ cells) where the nucleus of the male cell or spermatozoön unites with that of the female cell or ovum. As seen in the resting state (i.e., before division takes place) it is a body of rounded shape, and it appears to be enclosed in a very delicate membrane. Its contents partly consist of **linin**, which forms a kind of network, and is a substance difficult to stain. Amidst the linin are many granules of **chromatin**, a very complex nitrogenous compound which always contains phosphorus and has a marked affinity for certain stains.

Most nuclei contain one or more smaller bodies known as **nucleoli**, and these are probably reserves of complex materials which can be drawn on at certain periods of nuclear activity, for it is at such times that the nucleolus exhibits great change or wholly disappears. In some cells the nuclear material is scattered throughout the cytoplasm and does not appear as a compact nucleus.

Describe the Process of Cell Division.

The multiplication of the ordinary uninucleate somatic or body cells is brought about by division (fission). Division of the cell is preceded by division of the nucleus, which in some instances is effected by simple constriction, and this method is described as **direct (amitosis)**. In most cases the division is more complicated, and involves re-arrangement of certain nuclear constituents. That method is **indirect (mitosis or karyokinesis)**, and the phenomena are as follows:—

The centrosome (if only one is present) divides into two. These go apart to opposite poles of the nucleus, and from each, and from its surrounding archoplasm, a number of fibrils radiate out and extend into the cytoplasm. This is the **aster stage**, the figures being the star-like astrospheres or attraction spheres. Meanwhile in the nucleus the chromatin has become a thickened thread skein or spireme, and this breaks up into segments, called **chromosomes**, the number of which is definite and constant in each species of animal. Then the nuclear membrane disappears, and a group of

very fine fibres is seen. These are the prolonged rays of the asters, and they form the nuclear spindle which converges towards the poles and diverges about its equator. The chromosomes are now ranged in a ring (the equatorial plate), lying flat around the equator, and this completes the first stage of division, the Prophase.

Then the chromosomes split longitudinally, and the two sets of halves draw apart towards the poles. That is the second stage, the Metaphase. It is succeeded by the Anaphase, a brief period occupied by the chromosomes passing to their respective poles where they undergo regressive changes, repeating the prophase processes in the reverse order, and becoming normal resting nuclei. Finally the original cell is constricted about the middle (the Telophase stage) and thus two are formed, each containing a daughter nucleus.

The whole process evidently ensures equal division (quality and quantity) of the chromatin of the original nucleus between the two resulting nuclei.

What are Germ Cells?

In certain Protozoa (e.g., *Volvox*) and in all Metazoa (many-celled animals) the body is composed of two distinct kinds of cells—(1) those which are concerned with the general metabolism but which are incapable of conjugation or syngamy, namely, the somatic or body cells; and (2) those which, retaining the inherent qualities of the individual, function solely as reproductive, namely, the germ cells.) In the Protozoa the germ cells arise by process of fission and breaking up of the individual (e.g., *Coccidiidæ* and certain *Hæmoflagellates*), or of certain individuals of a colony (e.g., *Volvox*). In *Hydra* they are developed from special interstitial cells, and in *Sponges* from some of the amœbocytes.

In higher animals they arise from that thickened part of the epithelial lining of the coelome known as the germinal epithelium. These primitive germ cells grow larger than their ordinary epithelial neighbours; they multiply by repeated division, accumulate reserve material, and

give rise to two different reproductive types of cell expressive of difference of sex. In certain animals both types occur in the same individual (hermaphroditism); but in most of the higher forms the sexes are separate, and the sex-cells are produced in special reproductive organs or gonads (testis in the male, ovary in the female) formed from the germinal epithelium. Both types are termed gametes because they conjugate (to form the zygote). The male gamete (microgamete or spermatozoon) is very small, very active, and produced in great numbers. The female gamete (macrogamete or ovum) is stored with food-yolk for the future embryo and is proportionately larger; it is not active and is produced in smaller numbers.

Write a short Account of Spermatogenesis and Oögenesis, or the History of the Production and Maturation of the Male and Female Gametes in the higher Animals or Metazoa.

The primitive male germ cell becomes a **mother-sperm-cell** or **spermatogonium**, which by ordinary mitotic division becomes a **spermatocyte**, which then undergoes meiotic or reducing division (meiosis). Each spermatocyte divides into two, each of these again divides into two, and thus four **spermatozoa** are formed.

The history of the female gamete (oögenesis or maturation of the ovum) is at first similar to that of the male, and the resulting **oöcyte** (immature ovum) undergoes meiotic or reduction division (meiosis). This does not, however, result in an equal division of cell substance, but only in the extrusion of a small portion known as a **polar body**. A further (but ordinary mitotic) division results in the extrusion of a second polar body; and the first polar body often divides into two. In this way four potential ova are formed. Three of these (the **polar bodies**) come to nothing, but the fourth is the mature ovum or egg, now ready for fertilisation by union with a spermatozoön.

What is Meiosis? Write an Account of the Process of Meiotic Division.

A special kind of nuclear division, a form of mitosis, known as "**Meiotic or Reduction Division**," which occurs only in the maturation of the gametes or sex cells; and in which the number of the chromosomes is reduced to half the normal number present in the nuclei of the somatic or body cells of the same animal. In reduction division there is a prolonged skein (spireme) stage. The chromatin threads unite in pairs (syndesis). There may be contraction and a clumping together (synzesis) which may be followed by loosening out again and further synzesis.

By shortening and thickening the paired threads become segmented and isolated as bivalents, twin-bodies or gemini. They may be incompletely separated and widened out in a sort of ring form, or separate rod-like segments in close association.

The bivalent chromosomes are then scattered further apart, and this is the stage termed **diakinesis**. The nuclear membrane disappears, the spindle is formed, and to its fibres the bivalent chromosomes become attached in the equatorial position. The bivalents are divided across the point of junction of the constituent chromosomes, and each of these passes towards the poles. Each separate constituent often has a \succ form, the limbs of which may be lying parallel, as it nears the pole, thus giving it a double appearance. Because of that peculiarity of form, this first meiotic division is often termed **heterotype**. The formation of the daughter-nuclei is completed as in ordinary mitotic division and the two resulting daughter cells are separated. It is plain, therefore, that while the cells of the earlier generations have $2n$ chromosomes, the cells in which the heterotype division takes place have n bivalents or gemini, and the resulting daughter cells n single or univalent chromosomes.

The second division (of the nuclei of the two daughter cells) which promptly follows is called **homotype**, because it presents no peculiarities and in process resembles ordin-

ary somatic mitosis. The chromosomes divide longitudinally and the halves become the chromosomes of the resulting grand-daughter nuclei.

In some cases (e.g., *Ascaris*) each constituent of the bivalent divides transversely into two, making the bivalents tetrapartite and thus forming what are known as tetrads. The two bivalents which separate in heterotype division, being thus divided across, are double and therefore dyads. In homotype each dyad becomes two monads by dividing across at the point of transverse constriction, which therefore corresponds to the longitudinal division described in the preceding paragraph.

The meiotic (heterotype) division separates the chromosomes which united in syndesis.

In meiotic or reducing division the daughter nuclei get dissimilar univalents, whereas in ordinary mitotic division they get similar halves of univalents. This is the process in spermatogenesis, and in oögenesis it is practically the same.

(Meiosis and Maturation are equivalent. See answer to preceding question.)

Define Fertilisation. Describe the Process.

Penetration of the female gamete or ovum by the male gamete or spermatozoön, followed by fusion of pronuclei, and giving that "developmental stimulus" which causes segmentation or cleavage to begin.

The spermatozoön enters the ovum, sometimes at a special opening, the micropyle, as e.g., in insect ova with "shells." The pronucleus (nucleus reduced by meiotic division) of the sperm fuses with the pronucleus of the ovum to form the segmentation nucleus, and thus the full number of chromosomes characteristic of the species is restored. Segmentation or cleavage and the further development of the ovum then proceeds.

In Protozoa the gametes may be only slightly different or not different; and conjugation may only be temporary, fertilisation being effected after exchange of pronuclei.

Explain the Terms Syngamy and Plastogamy.

Syngamy is a fusion of the nuclei of two distinct individuals in reproduction.

In the sexual union of a male with a female gamete (sperm with ovum) there is fusion of cells as well as pronuclei. In certain Protozoa there is fusion only of nuclei or nuclear substance, which takes place after temporary conjugation of the individuals.

Plastogamy is not a reproductive process; it is a union of two or more individuals without fusion of nuclei.

Plastogamic union may be temporary or permanent. When permanent, the result is a composite of cell-individuals, a plasmodium.

Define Sexual and Asexual Reproduction.

In sexual reproduction, which is characteristic of Metazoa, two dimorphic reproductive cells, the female ovum and male spermatozoön, are liberated and unite. The result of this union (syngamy) is fertilisation of the ovum by the spermatozoön, involving amphimixis and followed by the development of an individual from the fertilised egg or zygote.

These sex cells are produced by two different individuals (male and female), or by one individual either in different organs (testis and ovary) or in one organ at different times (hermaphroditism).

Asexual reproduction is not preceded by conjugation. It is a method of propagation by fission or by vegetative budding (gemination). The fission may be binary (as in *Amœba*) resulting in two individuals, or it may be multiple (e.g., the spore formation known as schizogony in Sporozoa) resulting in many. In *Volvox* it is multiple but restricted to special cells of the colony called parthenogonidia. Budding occurs in *Sponges*, in *Hydra* (which liberates its daughter-buds), and in *Obelia* and other hydroids which form colonies by budding.

Give the Meaning of the Terms Dichogamy and Amphimixis.

Dichogamy is a form of hermaphroditism. Sperms and ova produced by the same animal but at different times.

Amphimixis is "a mingling of different hereditary tendencies in one and the same individual." It is the result of fertilisation, of the fusion of a male and a female pronucleus.

What is Parthenogenesis?

In some exceptional instances individuals are developed from ova which have not been fertilised by sperms. A good example is that of the male or drone hive bee which arises from an unfertilised egg. This phenomenon also occurs among Rotifers, Aphides, and certain Crustaceans. In the malaria parasite (*Plasmodium vivax*) of tertian ague the female gametocytes are believed by some to reproduce by a sort of parthenogenesis, and in this way give rise to fresh schizogonous generations.

Explain what is meant by Metagenesis or "Alternation of Generations." Describe the Life-cycle of any Animal which exhibits this Phenomenon.

In the life-history of certain animals reproduction is asexual at one time and sexual at another, asexual generations (there may be several) intervene between sexual generations. That is "Alternation of generations" or Metagenesis, which has been defined as "the alternate occurrence in one life-cycle of two (or more) differently-formed organisms differently produced." It is seen in the life-histories of the Malaria parasites and other Hæmosporidia, where several asexual generations (by schizogony) alternate with sexual generations (by sporogony). It is also characteristic of the life-cycles of *Polystomella*, *Spongilla*, Hydroids (e.g., *Obelia*), *Aurelia*, *Distomum* syn. *Fasciola* (the Liver Fluke), *Tunicates*, etc. In those instances (e.g., *Distomum* and certain Nematodes) in which two different sexual generations (e.g., a parthenogenetic and a true sexual) alternate, it is known as heterogamy.

NOTE.—For answer to second part of question see descriptions of the above-mentioned life-histories.

Describe the different Kinds of Segmentation (Cleavage), and give Examples of the Animals in which each occurs.

1. Eggs with little yolk divide completely and equally (holoblastic and equal). This is seen in some Sponges, *Hydra*, Echinoderms, certain Molluscs, *Amphioxus* (nearly equal), and most Mammals (e.g., *Lepus*).

2. Eggs with a considerable quantity of yolk at one pole divide completely but unequally (holoblastic but unequal). This is seen in some Sponges, in *Lumbricus* and other Worms, in Molluscs, in Dipnoi, and in *Rana*.

3. Eggs with a great quantity of yolk, with the small formative disc at one pole, divide partially and discoidally (meroblastic and discoidal). This is seen in Cuttlefishes, in Elasmobranch fishes (e.g., *Raia* and *Scyllium*), in Birds (e.g., *Columba*) and in Monotreme Mammals.

4. Eggs with a large quantity of yolk, accumulated in the centre, divide partially and superficially (meroblastic and peripheral). This is seen in Arthropods (e.g., *Astacus*).

What is a Blastula?

A blastula is a hollow developmental stage which has one layer of cells. One hemisphere (the animal pole) consists of small cells, and the other (the vegetal hemisphere) has much larger ones more or less yolk-laden. The cavity is the blastocoele or segmentation cavity. The blastula is the first stage after cleavage or segmentation.

Describe a Morula.

A blastula which is practically a solid mass of cells and in which the segmentation cavity is slight or absent.

How is the Gastrula formed?

From the blastula by intucking (invagination) of one hemisphere. The segmentation cavity becomes obliterated and a new cavity (the archenteron or future food canal) is formed, its opening being the blastopore.

The infolded inner layer (lining the archenteron) is the **hypoblast or endoderm**, and the outer layer is the **epiblast or ectoderm**.

When the blastula contains many yolk-laden cells, the gastrula is mainly formed by an overgrowth (**epiboly**) of animal-pole cells; or it may be formed by a process of **delamination**, by division of the blastula cells into two layers:

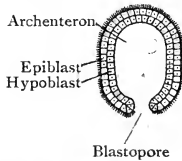


FIG. 2.—**Section of Gastrula.** (Diagrammatic.)

How is the Mesoblast or Mesoderm formed?

From the archenteron, dorso-laterally, two folds arise each of which contains a groove (primary body cavity). These are the **mesoblast pouches**. They grow out and become shut off from the archenteron. They meet and unite and gradually extend so that ultimately the archenteron (now the enteron or food canal) is covered on the outside (**splanchnopleure**) and the ectoderm on the inside (**somatopleure**) by mesoderm; and the extended cavity between is the **coelome or body cavity**. That is one way; another is, from mesoderm cells separated off from the endoderm which subsequently divide to form a structure that is hollowed out; the hollow being the coelome or body cavity.

Which Structures or Organs are formed from (1) Epiblast (Ectoderm), (2) Hypoblast (Endoderm), and (3) Mesoblast (Mesoderm)?

1. The Epiblast forms the epidermis, nervous system, sense organs (partly), infoldings at either end of the gut (fore-gut or stomodæum and hind-gut or proctodæum).
2. The Endoderm forms the mid-gut (mesenteron), the

epithelial lining of the gut, and the associated organs (e.g., lungs, liver, etc.), and also the foundation of the endoskeleton, the notochord.

3. The Mesoderm forms the dermis, the reproductive organs and ducts (which arise from its coelomic wall), the principal parts of the muscular system, and the coats of the blood-vessels.

Connective tissue, cartilage, and bone are derived from the mesenchyme (which is formed from immigrant cells budded off from the epiblast or the hypoblast of the gastrula), i.e., from mesoderm in which the cells are at first discrete and amoeboid.

What are (a) Homologous, (b) Analagous Organs? Give Examples.

Organs in the same or in different animals which are structurally similar and which are of similar origin are homologous. Such are the various appendages of a crayfish. The pectoral fin of a fish, the fore-limb of a frog, the wing of a bird, the flipper of a whale, and the arm of a man are all homologous.

Analagous organs have the same function but not the same structure, e.g., wing of insect and wing of bird.

The wing of a bird and the wing of a bat are both homologous and analogous.

Explain Convergence or Homoplasy.

When two or more animals, not closely related, have a marked outward resemblance due to adaptation to environment, or to habit, they are said to exhibit convergence, e.g., a burrowing amphibian (*Ichthyophis*), a burrowing lizard (*Sloworm*), and a burrowing snake (*Typhlops*).

Distinguish between a Unicellular and a Multicellular Animal.

A unicellular animal is one in which the body consists of a single cell or unit of living matter (protoplasm) which performs all the functions of life, namely movement,

breathing, digestion, excretion, growth, reproduction. Most Protozoa are unicellular.

A multicellular animal is one in which the body is composed of many cells, differentiated and grouped to form layers or special tissues with distinct functions. This specialisation for particular function is physiological division of labour. All animals, except Protozoa, are multicellular (Metazoa) when fully developed.

Explain the Terms Symbiosis and Commensalism.

Symbiosis means "living together for mutual benefit." It is an intimate association of two organisms interdependent for discharge of vital functions (e.g., *Radiolarians* and "*Yellow Cells*."

Commensalism means "eating at the same table." It is a partnership beneficial to both, but of a less intimate nature than symbiosis (e.g., *Sea-Anemone* and *Hermit Crab*).

What is meant by the Term Invertebrate ?

It is a collective name used to distinguish all animals which do not belong to the Phylum Vertebrata. It signifies "backboneless." Invertebrates have no internal supporting notochord or backbone. In the Invertebrata the main nervous system is typically ventral, the eyes (when present) are skin-derived, and the heart (when present) is dorsal.

PHYLUM PROTOZOA.

What are Protozoa ?

Organisms in which the individual or body consists of a single cell or a colony of independent cells which are not differentiated into layers or tissues.

Certain Protozoa show structural complexity, but many are of the simplest morphological type.

A CLASSIFICATION OF *THE INVERTEBRATA*.
(PRINCIPAL PHyla AND CLASSES.)

PROTOZOA	{	Phylum Protozoa.	{	Gymnomyxa	{	Rhizopods	Class Proteomyxa.	.. Mycetozoa (Fungus Animals).		
		.. Lobosa (Amœba, etc.).								
		.. Heliozoa (Sun Animalcules).								
		.. Foraminifera.								
		.. Radiolaria.								
		Corticata		{	Infusorians	.. Flagellata or Mastigophora.				
						.. Ciliata.				
						.. Acinetaria.				
						.. Sporozoa (Gregarines).				
						.. Calcarea (Limy).				
METAZOA	{	Phylum Porifera (Sponges).	{	.. Hexactinellidæ (Siliceous).	.. Demospongiæ (Silica and Spongin).					
		Phylum Cœlenterata.		.. Hydrozoa (<u>Hydra</u> , Hydroids, and Jelly-fish.).	.. Actinozœa (Alcyonium, Sea Anemones, Corals).	.. Ctenophora (Cydippe, Cestum).				
		Phylum Platyhelminthes (Flat Worms).		} Unsegmented	.. Trematoda (Flukes).	.. Cestoda (Tapeworms).				
		Phylum Nematoda (Round Worms).								
		CELOMATA		{	Phylum Annelida (Segmented Worms).	{	.. Chætopoda (Worms with bristles or Chætæ).	.. Hirudinea or Discophora (Leeches).		
							Phylum Arthropoda.	.. Crustacea (Crayfish, Crab, etc).	.. Prototracheata (Peripatus).	.. Myriapoda (Centipedes and Millipedes).	.. Insecta (Insects).	.. Arachnida (Scorpions, Spiders, Mites, Ticks, etc.).
					Phylum Echinodermata.	.. Asteroidea (Starfishes).	.. Echinoidea (Sea-Urchins).	.. Holothuroidea (Sea Cucumbers).		
						Phylum Mollusca.	.. Gasteropoda (Snails, Slugs, etc.).	.. Lamellibranchiata or Pelecypoda (Bivalves).	.. Cephalopoda (Cuttlefishes).	

The general method of reproduction is by simple fission.

The Protozoa are the lowest group in the Animal Kingdom ; they are the first animals, as their name implies, and among them are the most primitive forms of animal life known.

Describe the General Features of the Protozoa.

The cell may be naked or may have a firm envelope. The outer portion (ectoplasm) is clearer and of a firmer consistency than the inner mass (endoplasm), which is opaque, granular, and more or less fluid. There may be only one nucleus, or two, or more; food vacuoles and contractile vacuoles are generally present.

The structure of the cell is often complex ; for instance, the ectoplasm forms special locomotor cilia and flagella, trichocysts with eversible stinging threads, muscle fibrillæ, and tests or skeletons often wonderfully intricate.

A remarkable feature is the specialisation of the nuclear structure into separate nuclei with distinct functions.

The mode of feeding may be holozoic, holophytic, saprophytic, or parasitic; some species are both holozoic and holophytic or saprophytic.

Reproduction is asexual by fission, either simple division into two individuals or multiple resulting in many (e.g., schizogony in Sporozoa). A sexual method, temporary union or permanent conjugation of two individuals (gametes), also occurs.

In several instances the life history shows alternation of generations.

There are four chief types of Protozoa :—

1. The Rhizopod or Amœba Type.—Body naked. Temporary protrusions of the protoplasm (blunt lobopods or thread-like pseudopodia) serving for slow movement and for securing food.

2. The Flagellate type.—Body naked or covered with a cuticle, and provided with one or more flagella for active movement.

PHYLUM PROTOZOA.

A Classification showing the systematic position of the examples dealt with in the following pages.
Those marked * are parasitic forms.

	(Naked-celled Protozoa)				
PROTOZOA GYMNOMYXA		RHIZOPODS.			
Class Proteomyxa.				Example, *Plasmodiophora.	
" Mycetozoa (Fungus Animals).				" Fuligo ("Flowers of Tan").	
" Lobosa.				Examples, *Entamoeba.	
" Heliozoa (Sun Animalcules).				Diffugia (test of adventitious material).	
" Foraminifera.				Actinophrys (one nucleus).	
" Radiolaria.				Actinosphaerium (numerous nuclei).	
" Flagellata or Mastigophora.				Acanthocystis (forms a skeleton).	
				Gromia (a smooth test of chitin).	
				Haliphysema (adventitious test of sponge spicules).	
				Globigerina (the test a chambered shell).	
				Polystomella (the test a chambered shell).	
				Example, Thalassicolla.	
				Examples, Mastigamoeba (has pseudopodia).	
				Euglena.	
				*Copromonas.	
				Volvox (forms colonies).	
				Proterospongia (a Choanoflagellate).	
				Noctiluca.	
				*Trypanosomes or Haemoflagellates (e.g., *Trypanosoma, *Trypano- plasma).	
				*Leishmania.	
				Spirochaetes (e.g., *Spirochaeta, *Treponema).	

PROTOZOA CORTICATA.
 (Cell has an enclosing wall. Ectoplasm is usually a cortex, i.e., it contains contractile fibrillae, or myonemes.)

INFUSORIANS.

Class Ciliata, Order Holotricha (Cilia all over the body).
 Order Heterotricha.
 Order Hypotricha.
 Order Peritricha (Cilia restricted to one end).
 „ Acinetaria (Sedentary Infusoria with tentacles or suckers).

Examples, *Paramecium.
 *Opalina.

Example, *Balantidium.
 Examples, Kerona.
 Stylonychia.

„ *Trichodina (ectoparasitic).
 Vorticella.

Example, Acineta.

Class *Sporozoa, Order Gregarinida.

Order Coccidiidae (Cell parasites of tissue and epithelial cells, *never attacking blood cells*. Life-cycles show *Alternation of Generations*).

Order Hemosporidia (Usually *parasites of the red blood corpuscles*. Life-cycles show *Alternation of Generations*).

Order Myxosporidia (Parasites of Arthropods and Fishes).

Order Sarcosporidia (Parasites of the striped muscles of Birds and Mammals, especially sheep, pig, ox, and horse).

Examples, *Monocystis.
 *Gregarina.

*Coccidium.

*Lankesterella (syn. Drepanidium).
 *Plasmodium (syn. Hæmameba).
 Do. (syn. Laverania).
 *Piroplasma (syn. Babesia).

*Myxidium.
 *Glugea (syn. Nosema) of “*la pebrine*” in Silkworms.

*Sarcocystis.

GREGARINES.

3. The Parasitic Gregarine Type.—A thick cuticle. No special structures (in the adult phase) for locomotion, ingestion and digestion of food. Encystation and the formation of tough-coated spores are characteristic of Gregarines.

4. The Infusorian or Ciliate Type.—A cuticle and numerous small vibratile cilia for active locomotion and for securing food. A definite mouth and a gullet, and specialised nuclei. The more complex nature of the cell distinguishes the ciliate Infusorians as the highest group of Protozoa.

The amœboid, the flagellate or ciliate, and the encysted types may, and often do, occur in the life-history of one species.

The parasitic Protozoa are of great importance in relation to disease in man and the lower animals.

Name some Examples of Protozoa, and state where each is found.

<i>Fuligo</i>	(“ <i>Flowers of Tan</i> ”)	A yellow plasmodium upon bark in tan-yards.
<i>Amœba</i>	... ..	Some species frequent the mud of ponds; others are found amongst wet <i>Sphagnum</i> moss.
<i>Entamœba</i>	... ..	A parasitic Amœba, of the intestine of Man.
<i>Globigerina</i>	... ..	One of the marine Foraminifera. Floating on the surface of the sea.
<i>Thalassicolla</i>	... ..	A Radiolarian. Occurs in swarms floating at the surface in the warmer waters of the great oceans.
<i>Euglena</i>	... ..	A common Flagellate which swarms in stagnant puddles and ditches forming a green scum on the surface.

- Volvox* A colonial Flagellate. The colony spheres are commonly found rolling about in the water in ponds.
- Noctiluca* A marine Flagellate. It often occurs in great numbers on the surface of the sea in coastal waters and contributes to the phenomenon of phosphorescence.
- Trypanosoma* One of the Hæmoflagellates which are important blood parasites in Man and the lower animals.
- Spirochætes* Parasitic flagellate forms which are important blood parasites in Man and the lower animals.
- Paramecium* A common Ciliate Infusorian. In stagnant ditches and pools among decaying organic matter.
- Opalina*. A parasitic Ciliate. An internal parasite in the rectum of the frog.
- Vorticella* A stalked Ciliate found attached to water-weeds, etc., in ponds.
- Acineta* A marine and sedentary Infusorian of the Class Acinetaria. It is found on Hydroids.
- Monocystis* One of the Sporozoa. A Gregarine parasite found in the reproductive organs of the Earthworm.
- Coccidium* One of the Sporozoa. *Coccidium oviforme* is an internal parasite in the liver of the rabbit.
- Plasmodium*
(syn. *Hæmamæba*) { One of the Sporozoa belonging to the group Hæmosporidia. An important blood parasite in Man.
- Piroplasma*
(syn. *Babesia*) { One of the Hæmosporidia. An important blood parasite in cattle, horses, etc.

What are Mycetozoa ?

The *Mycetozoa* or *Fungus animals* (also known as *Myxomycetes* or *Slime Fungi*) are Protozoa which, at one stage of their life-history, have the form of a **plasmodium**. They move slowly by outflowings of the protoplasmic mass, which is often of great size. They are semi-terrestrial and are found in damp situations in humus, on decaying leaves, under bark, in rotting tree-trunks, upon fungi, etc. Their mode of nutrition is both fungus-like (**saprophytic**) and animal-like (**holozoic**). In their saprophytic mode of feeding and in their reproduction (by formation of **sporangia** and liberation of **spores**) they show affinity with the lower plants.

Describe a Plasmodium.

A naked composite body formed by the mutual attraction, massing together and fusion of a number of amœboid individuals (**plastogamy**). Their outward form is lost, but their nuclei remain distinct.

A plasmodium may, however, be formed by repeated nuclear division without subsequent fusion of the cell-body.

Write an Account of the Life-history of the Mycetozoa, with special reference to Fuligo septica.

Large plasmodia (of *Fuligo*), several inches in width and like spreads of slime are often seen upon the oak-bark in tan-yards. Under dry conditions these encrust, passing into the resting state known as the **sclerotium**; but with a return of moisture resume activity. The bright yellow **plasmodium** creeps out to the light and air. This is the familiar phenomenon known as "**the flowering of the tan-heaps.**" When about to reproduce, it seeks a dry situation. The protoplasm breaks up into masses, each containing one or more nuclei. These masses encyst. Each cyst has a coat composed largely of lime, and inside there is a network of threads (the **capillitium**). Division of the contained nuclei is followed by multiple fission, and a number of cellulose-coated spores are thus formed

within the cyst or sporangium. In *Fuligo* the sporangia are not separated but combined together (an æthaliium). In other instances the sporangia are separated and raised off on stalks. The wall of the sporangium becomes friable and breaks down, and the spores, lightly hanging on the capillitium threads, are scattered around. The spores germinate in moisture, their coats rupture and they come out. They are at first amœboid, but soon become pear-shaped (swarm-spores or flagellulæ), with a fine whip-like flagellum at the narrow end. They are active for a time; then, withdrawing their flagella, they become rounded and undergo division by karyokinesis. There may be several successive generations, but ultimately they become amœbulæ which exhibit mutual attraction. A few come together and coalesce, others draw near and "join up," and in this way the composite mass, the plasmodium, is formed.

Briefly describe the Structure of the Plasmodium in the Mycetozoa.

The peripheral portion is firmer and clearer than the inner mass, which is very granular and traversed by branching vein-like thickenings, within which there is a constant streaming of the protoplasm. Some species (e.g., *Fuligo*) have granules of lime. There are numerous nuclei, and contractile vacuoles are seen near the periphery. The plasmodium creeps by outpushings of the protoplasm (pseudopodia).

To which Class of Protozoa does Plasmodiophora brassicæ belong? State its Importance, and briefly describe its Life-history.

To the primitive Class, **Proteomyxa**. It causes a disease, called "Fingers and Toes," or "Club-root," in turnips, cabbages, etc. In the root cells the plasmodium is seen as "a yellow stringy slime." Its nuclei break up, are reconstituted, then divide by karyokinesis, and numerous gametes are formed. These conjugate in pairs and form zygotes which give rise to spores. When the roots of the

plant decay, the spores pass into the soil. Flagellulæ issue from the spores, and, entering the roots of a healthy plant, become amœbulæ. Feeding on the sap, the amœbulæ swell and unite together (plastogamy) to form the plasmodium.

A M C E B A.

(AN EXAMPLE OF THE CLASS LOBOSA.)

Where is Amœba found? Describe its Appearance and general Structure.

Certain kinds of Amœba frequent the mud of ponds and ditches, other sorts are found amongst wet *Sphagnum* moss. A large Amœba may be visible to the naked eye

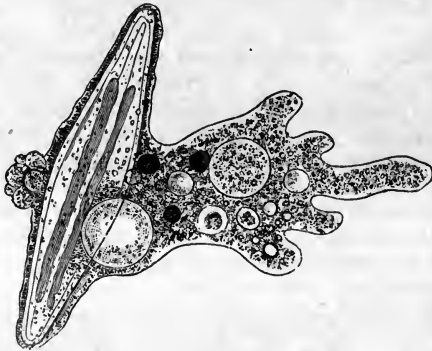


FIG. 3.—*Amœba*. (Magnified.)

On the left is a large diatom which has been engulfed. The largest sphere is the contractile vacuole; the smaller sphere is the nucleus.

as a whitish speck. Irregular in form, like a tiny spot of cloudy jelly, very finely mottled, such is its outward appearance under the microscope. The shape is always changing. The protoplasm is in constant streaming motion

and is not uniform throughout; the inner mass (the endoplasm or endosarc) is coarsely granular and more opaque than the outer film (the ectoplasm or ectosarc) which is finely granular, clearer, and of a firmer consistency. The granules are mostly food reserves and waste materials. Grains of sand, globules of fat, green vegetable organisms, and other conspicuous foreign bodies are often present in the endoplasm. Some of these are surrounded by fluid, and are termed **food-vacuoles**. A large, rounded, solid-looking body, more or less visible in the endoplasm, is the **nucleus**. Near the ectoplasm an opening, the **contractile vacuole**, appears at intervals; at first very small, it rapidly expands into a large, clear sphere, and then suddenly vanishes.

How would you explain the Change of Shape?

The cell or body of the Amœba is naked; there is no rigid or limiting wall. Localised changes in the tension of the elastic outer film may partly explain the outflowings of the protoplasm which cause the irregularity of form.

How does the Amœba move?

Slowly by blunt outflowings or outpushings of the protoplasm called lobopods or pseudopodia. As the pseudopodia flow out, a slime is secreted without which progression would be impossible.

What is the Function of a Contractile Vacuole?

It is apparently a sort of drain in which the finer wastes of the protoplasm are collected. Its formation is supposed to be due to a constituent substance of the protoplasm that has a strong affinity for water. The effete fluid gathers into a droplet which, as it swells, is moved to the surface, and there suddenly expelled by contraction.

How does the Amœba feed? State what you know about the Process of Digestion.

When it moves near to a diatom or other edible object, it protrudes pseudopodia. These flow out until they

meet and coalesce. The food is thus enclosed and engulfed ; and in this way a food vacuole is formed. It may contain a little water ; but most of the liquid is a digestive ferment secreted by the surrounding protoplasm. The ferment has a solvent action on proteid matter, but not on starches and fats. Ultimately, when nothing remains but a residue of waste, the food vacuole is moved to the surface where it bursts and discharges.

How does the Amœba breathe ?

It takes in oxygen and gives off carbon dioxide all over the body.

Describe its Method of Reproduction.

The normal mode of reproduction, when the limit of growth has been attained, is by division into two daughter individuals (simple fission). Fission is preceded by division of the nucleus. *Amœba proteus* sometimes encysts, a process involving complex changes and divisions of the nucleus followed by division of the cytoplasm, and resulting in the formation of numerous small amœbæ.

OTHER EXAMPLES OF THE CLASS LOBOSA.

Indicate the Importance of Entamœba coli and Entamœba histolytica. Where are they found ?

They are internal parasites of Man. *Entamœba coli* is found in the upper portion of the large intestine. It occurs in normal and healthy individuals, and is not (so far as is known) associated with any particular form of disease.

Entamœba histolytica is the cause of certain forms of tropical dysentery. It occurs in the mucous membrane of the intestine, and in the liver where it produces abscesses.

Briefly describe ARCELLA and DIFFLUGIA, and show how they differ from Amœba.

ARCELLA is found in moor pools amongst wet moss (especially Sphagnum). It is an amœboid form with a

protective shell secreted by the animal itself. The shell is shaped like a watch-glass and made of chitin. It has a hole (the pylome) in the centre through which the few pseudopodia are protruded. A peculiar feature is the presence of gas vacuoles which give a certain buoyancy and probably help to balance the shell. There are two distinct nuclei and numerous nuclear particles.

Reproduction is by fission (the protoplasm streams out, another shell is formed, and then division takes place), or by spore formation in which there is conjugation of the gametes.

DIFFLUGIA is common in ponds creeping on the surface of the mud or amongst the tangled masses of Confervæ. It forms a pear-shaped shell of grains of sand glued together with a secretion of the protoplasm. It has several nuclei; otherwise, in its structure and mode of reproduction, it resembles *Arcella*.

The shell and the consequent restriction of pseudopodia, the number of nuclei, and the gas vacuoles in *Arcella*, are the chief differences between these forms and *Amœba*.

CLASS HELIOZOA (SUN-ANIMALCULES).

What are the General Features of the Heliozoa?

The body is spheroidal and only to a slight extent shows amœboid change of shape. The protoplasm is full of non-contractile vacuoles, more especially the outer portion (ectoplasm), and this may be associated with the habit of floating passively in the water.

The numerous pseudopodia are long, slender, and project stiffly like radii from the body. Each consists of a thin layer of protoplasm around an elastic axial filament, the base of which is (in *Actinophrys*, but not in *Actinosphærium*) in contact with the nuclear membrane. There may be only one nucleus (e.g., *Actinophrys*) or many (e.g., *Actinosphærium* which has at least 200). Besides the non-contractile vacuoles mentioned, there are food vacuoles and

contractile vacuoles (seen at the periphery). Some (e.g., *Acanthocystis*) form siliceous skeletons. Green unicellular Algae are often found living in the endoplasm, e.g., a species of *Zoochlorella* lives in intimate partnership (symbiosis) with certain kinds of *Actinosphærium*. Reproduction is asexual by binary fission, or sexual by a process of encystment, involving reduction of nuclei and followed by spore-formation and conjugation of gametes. The Heliozoans are freshwater forms. *Actinophrys* and *Actinosphærium* are common in ditches, ponds, and moor pools.

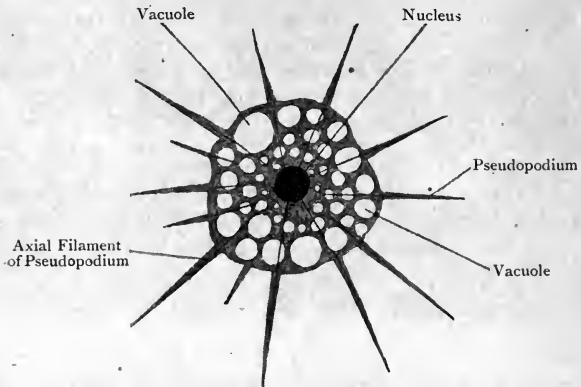


FIG. 4 — *Actinophrys*. (Magnified.)

How does Actinosphærium feed?

It preys on active infusorians. When one touches the pseudopodia, these suddenly bend inwards and the creature is trapped. As the bending goes on, swellings appear upon the pseudopodia and these, moving down, push the captive closer in. When it has been brought quite near the body, blunt amœba-like pseudopodia are protruded, and it is then engulfed and passed into the endoplasm.

Write a short Account of the Mode of Reproduction in Actinosphærium.

Asexual reproduction by binary fission is the normal method; but there is also a sexual process, the chief phases of which are as follows:—The individual withdraws its pseudopodia, the non-contractile vacuoles disappear, and it sinks to the bottom of the pond, becomes amœboid, and soon encloses itself in a soft cyst. Food reserves called “yolk-plates” are formed, and simultaneously the number of nuclei is greatly reduced. The body then divides up. Each segment has a nucleus and is enclosed in a siliceous “primary cyst.” Each primary cyst divides into two “secondary cysts,” and these become gametocytes which undergo nuclear division and extrude polar bodies. The two cells behave like gametes, they conjugate and form a zygote which is the spore. Its nucleus undergoes mitotic division, and the spore then emerges from the cyst as a young *Actinosphærium* with several nuclei.

CLASS FORAMINIFERA.

What are the Special Features of the Foraminifera? State where they are found and give Examples.

The protoplasm is uniform (not differentiated into ectoplasm and endoplasm). The viscid pseudopodia are long and thread-like, branch freely, and often anastomose to form networks; they serve for attachment as well as for locomotion and for securing food.

A test or shell, usually limy and chambered, is secreted by the protoplasm. In certain forms the shell has one or more large apertures; in most it is also perforated with numerous minute holes (hence the name Foraminifera). The protoplasm may pass out from the large apertures (e.g., *Gromia*), or through the numerous perforations, and form a thin layer covering the shell; from this layer pseudopodia are given off (e.g., *Polystomella*).

There is either one nucleus or many. The multinucleate

condition is often a phase in the life-history of one species. Contractile vacuoles are absent in the marine forms.

In several instances two distinct kinds of individuals occur (dimorphism) in the course of a life-cycle (e.g., *Polystomella*). Some "Forams" occur in moor-pools, but most are marine. Most of the marine forms frequent the shallow inshore waters (e.g., *Polystomella*); but some are found in the deep sea, and many are pelagic (e.g., *Globigerina*).

Write a short Description of the Structure of Polystomella, and state where it is found.

The shell is biconvex. Its chambers are formed in a close spiral; each convolution bestrides the one preceding and overlaps it at the sides, so that only the last whorl is seen from the outside. A V-shaped row of holes on the end of the last chamber represents the principal aperture. The pores of the chamber walls are very minute.

The shell is covered by a thin outer layer of protoplasm, and from it the pseudopodia are given off, some also issuing from the V-shaped pores. The viscid pseudopodia are slender and thread-like, some are grouped together like sheaves, others are fused or interlaced at places.

When a number of specimens (apparently similar) are placed in acidulated solution of corrosive sublimate, the shell is dissolved and the protoplasmic body is preserved. The body is in portions, corresponding to the chambers. These portions are united by little bridges of protoplasm and each has a posterior row of pocket-like or retral processes. But the specimens are not all the same. Most of them have a large central and initial chamber (i.e., megalospheric); but, perhaps, one (one in about thirty) is found which has a very small central chamber (i.e., microspheric).

In the megalospheric type the retral processes are present on all the portions except the megalosphere; but in the microspheric type they are absent from the portions of the first convolution. Further, when the specimens are stained (to show the nuclei), it is then seen that the megalospheric form has only one large nucleus and numerous

chromidia (scattered granules of nuclear chromatin), whereas the microspheric has a number of small nuclei scattered throughout. **Dimorphism** of individuals is therefore characteristic of *Polystomella*.

It is an abundant littoral form, found upon *Zostera* and seaweeds (e.g., *Laminaria*).

Describe the Life-history of Polystomella.

When the microspheric form is about to reproduce, there is a multiplication of nuclei by division, and the pseudopodia become so very numerous that they form a sort of halo around the shell. The entire body then comes out of the shell, and (in the halo) breaks up (by fission) into a number of small round pieces. Each secretes a tiny shell with one aperture; it soon forms a second chamber, and is then seen to be a two-chambered young megalo-spheric individual. When it is fully grown and about to reproduce, the nucleus disappears and is replaced by a number of minute nuclei. Then the body breaks up into rounded portions each with a nucleus. These embodied nuclei now divide by karyokinesis; and this is followed by a further division into rounded bodies each containing one of the daughter nuclei. That is the process of sporulation.

The hosts of little units have flagella, and they issue (as gametes or zoöspores) from the shell (now empty). They conjugate in pairs (a gamete of one brood with one from a different brood) to form zygotes; and from these zygotes the microspheric forms are developed. This life-cycle illustrates alternation of generations.

Point out the Special Interest of (a) Globigerina, (b) Haliphysema.

GLOBIGERINA has much more protoplasm outside the shell than inside it, and the outer mass is full of vacuoles, enabling the animal to float at the surface of the sea. Amongst the outspread net-like pseudopodia there are long and delicate, hollow limy spines (set on the shell) which have an axis of protoplasm. The important chalky

deposit on the sea floor known as Atlantic or Globigerina "Ooze" consists largely of the accumulated remains of Globigerina shells.

The test of *Haliphysema* is made of sponge spicules, and it is shaped like a wine-glass, the disc-like base serving for attachment.

CLASS RADIOLARIA:

What are Radiolarians? Give an Example.

Marine naked Protozoa which have thread-like pseudopodia, and which are specially adapted for pelagic life. The body consists of an inner portion which contains

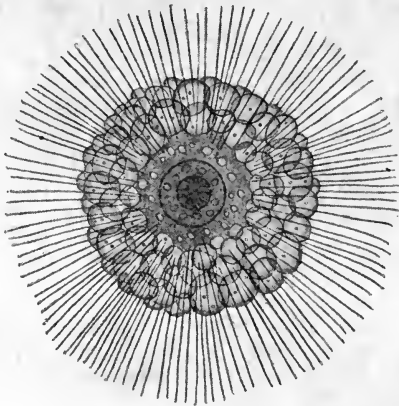


FIG. 5.—*Thalassicolla*. (A Radiolarian.)

After Haeckel.

Note the thread-like pseudopodia, the vacuolated protoplasm, and the central capsule.

the nucleus or nuclei and is the centre of reproduction, and an outer voluminous mass which is highly specialised and has three distinct parts—(1) the innermost, being assimilative and excretory; (2) the outermost, forming

the pseudopodia; and (3) the vacuolated portion between called the "calymma" which is concerned with flotation.

The inner (intracapsular) endoplasm is encased by a perforated "central capsule," and thus separated from the outer (extracapsular) mass or ectoplasm, which is often supported by an additional skeletal framework of silica or by loose radiating spicules. The flinty skeletons are often of exquisite construction; and the accumulated remains form the well-known "Radiolarian Ooze" of the deep sea.

Peculiar "yellow cells" (*zooxanthellæ* and *zoochlorellæ*) are found in most Radiolarians (in the "calymma"), and the association appears to be that of symbiosis.

Binary fission occurs in the forms that have not complex skeletons; but the more frequent mode of reproduction is by formation of flagellated swarm-spores. An example is *Thalassicolla*, which is found floating in swarms in the warmer seas.

Write a Note descriptive of the Skeleton in Radiolarians.

The Radiolarian test or skeleton is frequently a double formation consisting of an inner chitinous central capsule and an outer skeleton of silica or of acanthin or strontium sulphate, either in the form of a lattice framework or a loosely woven arrangement of spicules. It exhibits diversity of form and is often very complex. By the union of a number of skeletal rods in various ways or by the modification of a single skeletal ring or tetrad, a stellate, spherical, or helmet-shaped openwork case may be formed; and these cases are often multiple, one inside another.

The chief function of the skeleton is hydrostatic, it serves as a support for holding out the outer ectoplasm; for instance, the twenty radial spines of *Acanthometra* serve like so many tent-poles upon which the vacuolated ectoplasm is hoisted and held stretched out.

Explain the Association between Zooxanthellæ ("yellow cells") and Radiolarians, and show in what ways it is advantageous to both.

The ZOOXANTHELLÆ are pelagic like the Radiolarians. The stores of nitrogenous waste in the mucilaginous bodies

of the Radiolarians are attractive to the *Zooxanthellæ* as a rich and ready source of nutrition. They enter the ectoplasm of the Radiolarian and live there permanently, consuming the nitrogen and carbon dioxide and supplying free oxygen and starch. Protected by their cellulose coats they are able to resist the digestive ferment of their host, until degeneration of the nuclei (through repeated reproduction by fission) weakens their coats, and then many of them become food for their host. After their entrance, the Radiolarian ceases to prey on Infusorians, etc., and no longer ingests solid food; it relies on its reserves and on the *Zooxanthellæ*. When the endoplasm of the Radiolarian is broken up for sporulation, the dying ectoplasm is used by the *Zooxanthellæ*, which then divide up into free-living spores which begin a new free life.

The partnership would appear to be one of mutual advantage (symbiosis); but it is rather one in which the Radiolarian is predominant, ultimately becoming parasitic on the *Zooxanthellæ*.

CLASS FLAGELLATA, OR MASTIGOPHORA.

State the Characteristic Features of the Flagellata and name some Examples.

The body usually has a definite rind or cuticle and is provided (at or near the anterior end) with one or more whip-like processes or flagella for locomotion. There is generally only one nucleus; when two are present, one (the kintonus) is situated near the base of the flagellum and controls its activity. Many Flagellates have chromatophores containing chlorophyll, and are (holophytic) able to utilise carbon dioxide like plants; some are (saprophytic) capable of absorbing nutrient matter in solution like fungi; others are holozoic (ingesting solid food as true animals do), and several are parasitic. In many instances their mode of living is both plant-like and animal-like. They exhibit a varying metabolism

according to environment, and are therefore properly termed mixotrophic organisms. Certain Flagellates, notably *Mastigamœba*, are amœboid at one period and flagellate at another. Some have siliceous shells. There are fresh-water and marine forms. A number are free-living (e.g., *Euglena*, *Volvox* which forms colonies, and the marine *Noctiluca* which lives at the surface of the sea), and many are parasitic (e.g., *Copromonas*) and pathogenic, causing disease (e.g., *Trypanosomes*).

Their general mode of reproduction is asexual, by longitudinal fission; but a sexual process (formation of gametes followed by conjugation) is also frequent.

Give a short Description of Euglena.

EUGLENA swarms in ditches and puddles, often in profusion, forming a green scum on the surface. It is minute in size and elongate in shape, pointed at one end and blunt at the other. At the blunt end is a tiny opening, the funnel, and a long flagellum arises from its wall inside. Acting like a ship propeller, but in a spiral way, the flagellum pulls *Euglena* swiftly along. At times it slows down and goes through curious changes of form—swells out in the middle, rounds itself off, becomes oval, bends, and so on—expressive of a very elastic cuticle, and all so peculiarly characteristic that they are termed “euglenoid.” These changes are effected by the contractile myoneme fibrils of the ectoplasm. Not clearly visible, except when stained, is the nucleus in the middle of the body. Beside the funnel is the clear reservoir into which several small contractile vacuoles discharge. On the side of the reservoir is a small red spot (the stigma) sensitive to light. Throughout the endoplasm there are green chromatophores and grains of paramylum, a substance allied to starch, formed by decomposing carbonic acid through the action of the chromatophores. *Euglena* multiplies by longitudinal binary fission, and it also encysts, undergoing successive longitudinal divisions.

What is Copromonas and where is it found?

One of the Flagellates. It differs from *Euglena* in shape, in the attachment of the flagellum, and chromatophores are absent. It is a parasite in the intestine of the Frog and the Toad.

Write an Account of Volvox.

Pond water in summer often contains revolving green spheres each about as big as the head of a small pin; these are the colonies of *Volvox*. The *Volvox* colony (a hollow sphere) is an aggregate of perhaps 10,000 biflagellate individuals closely connected together. Each cell body does not fill its capsule, there is a gelatinous matrix between; and the capsule is hexagonal, since each cell is pressed close against six surrounding cells. Further, each cell body is connected to the six adjoining ones by six delicate strands which pass through its capsule wall.

The colony is physiologically an individual organism, exhibiting unified locomotor activities of its constituent units. It also shows structural differentiation; for while most of its units are nutritive or somatic, a few are specialised for reproduction. Each of these units or cells has a nucleus, a contractile vacuole, a chromatophore, a pyrenoid with paramylum granules, and two flagella. Projecting from the colony surface, the flagella by combined action propel the colony which rolls forward, sometimes to the right, more often to the left.

The reproductive cells are larger than the others and have no flagella; and they are called parthenogonidia. By repeated binary fission each gives rise to a new spherical colony. These, at first small, pass into the cavity of the mother colony, and are set free by rupture of the mother colony. This asexual method is continued for several generations, and then colonies appear which have a number of cells like parthenogonidia; but they (gametocytes) behave differently. Some (macrogametocytes) grow large and pass into the cavity; these are female cells or macrogametes. Others (microgametocytes) by repeated division

give rise to aggregates of small elongated flagellate male cells or microgametes, which are set free and pass into the cavity. The microgamete swims towards a macrogamete, enters it and fuses with it (syngamy), and the result is a fertilised egg or zygote. The zygotes have thick envelopes with spines. They remain unchanged through the winter, and in spring develop new colonies (asexually) by repeated fission.

On what Grounds may Volvox be regarded as intermediate between (a) Animals and Plants, (b) Protozoa and Metazoa?

VOLVOX has chlorophyll (chromatophores). By means of these it decomposes CO_2 and forms a starch; therefore it is holophytic like a plant. It is also plant-like in having pyrenoids with paramylum granules. But it moves actively in search of food, and it has flagella and contractile vacuoles, and these are animal features. It is therefore intermediate between Plants and Animals.

The Volvox individuals are unicellular protozoans; but their differentiation (somatic cells and reproductive cells of two distinct kinds) and the grouping together as a colony appear to indicate transition and approach to many-celled Metazoa. Volvox may therefore be regarded as intermediate between Protozoa and Metazoa.

What is Proterospongia and what is its Zoological Interest?

One of the Choanoflagellata. It forms colonies composed of two structurally distinct kinds of cells, amœbocytes and choanocytes. The choanocyte has a flagellum surrounded by a collar-like extension of the cytoplasm. The collar is retractile, and to it adhere the food-particles brought by the water currents caused by the activity of the flagellum. Similar choanocytes are characteristic of Sponges. (See page 67.)

HÆMOFLAGELLATES, OR TRYPANOSOMES.

Describe the Structural Features of the Hæmoflagellates.

The body of a typical Trypanosome is spindle-shaped and usually somewhat sinuous, and it has a delicate fin-like undulating membrane along one side. The flagellum arises at the anterior end where the undulating membrane begins; but instead of projecting in front, it is turned back and is attached along the free border of the undulating membrane, and its free terminal portion (when present) projects posteriorly. When there are two flagella (as e.g., *Trypanoplasma* of Fishes) the other one is entirely free and projects anteriorly. The protoplasm of the body is finely granular. Sometimes there is a distinct oval vacuole, and there are two nuclei, a large trophonucleus situated about the centre, and a small accessory kinetonucleus near which the flagellum arises and which controls the locomotor activities.

The following are important types:—

1. *Trypanosoma* with a single flagellum and a well-developed undulating membrane along the body.
2. *Crithidia* with a single flagellum, arising near the kinetonucleus which is situated beside the trophonucleus, and with a short or rudimentary undulating membrane.
3. *Herpetomonas* with a single flagellum, arising at anterior end of body, and without an undulating membrane.
4. *Trypanoplasma* with two flagella, one free and the other united, for a part of its length, to the undulating membrane.
5. *Leishmania* which is non-flagellate at one stage.

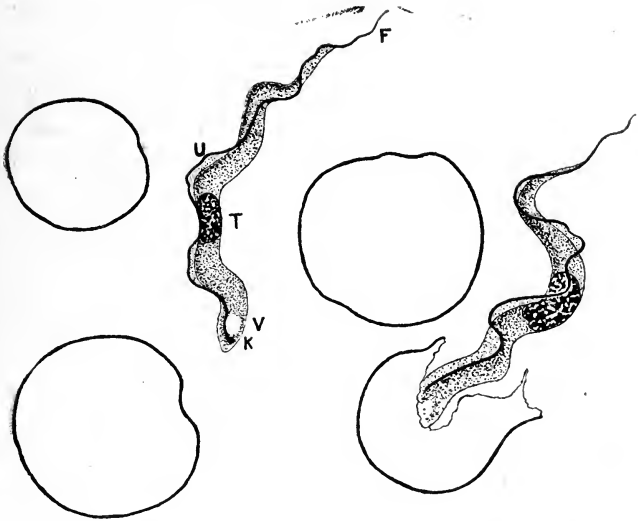


FIG. 6.—The Nagana parasite (*Trypanosoma brucei*), and four blood corpuscles. (Highly magnified.)

From a photo-micrograph by J. A. Ballantyne.

- T. Trophonucleus.
- K. Kinetonucleus.
- V. Vacuole.
- F. Flagellum.
- U. Undulating membrane.

How do Trypanosomes move?

Movement may be swift and dashing, wriggling, or sluggish (as in *Trypanosoma brucei*). In active movement the free portion of the flagellum rapidly propels the trypanosome and is aided by the vibratile undulating membrane, which exhibits wavy motion. Slow slithering movement is by flexion and “euglenoid” contraction of the body.

Where are Trypanosomes found and what is their Importance?

They are internal parasites in the blood of vertebrates including Man. Many of them are pathogenic, causing disease which is often fatal (e.g., Sleeping sickness in Man, and Nagana or Tsetse-fly disease in cattle and horses).

They also occur in certain invertebrates which are their alternate hosts.

How are Trypanosomes transmitted to the Blood of Vertebrates?

Those which occur in warm-blooded vertebrates are transmitted by certain species of blood-sucking insects (usually Diptera, or two-winged flies) when these "bite" a healthy individual. In one instance (among horses) they are transmitted during coitus. Those which occur in cold-blooded vertebrates are transmitted in Fishes by Léeches, and in Reptiles probably by Ticks.

In which Part of the Blood are the Trypanosomes found?

In the fluid plasma among the blood corpuscles.

In what Part of the Body are they found in their Invertebrate Hosts?

In the food (alimentary) canal.

How do Trypanosomes reproduce?

The general method is asexual by binary longitudinal fission. Multiple division by repeated fission without separation results in rosette-like groups of the parasites.

Write an Account of Asexual Reproduction in Trypanosomes.

The ordinary way in asexual reproduction is by binary longitudinal fission (preceded by division of the two nuclei) in which both body and flagellum are split equally. In *Trypanosoma lewisi* (of the Rat), however, this process

results in two unequal individuals, and is therefore more like the budding of a smaller daughter individual from the larger parent. Further division of both results in an aggregate of individuals (the parent always distinct) which remain for a time grouped side by side in a ring, their non-flagellate ends towards the centre. That kind of fission seems to be intermediate between ordinary equal division and another kind, called **segmentation** by rosette formation, which is also characteristic of *T. lewisi*. The process is as follows:—the double nucleus divides into a number of small double nuclei; the body cytoplasm having been rounded, the paired nuclei move to the periphery which now becomes lobulated; the splits are extended inwards and the lobes thus become distinct segments or daughter trypanosomes (each with a trophonucleus, a kinetonucleus and a flagellum); they remain for a time connected together at the centre. In this way a rosette of small equal-sized Trypanosomes is formed and the identity of the parent lost.

What is the Importance of Trypanosoma Gambiense and Trypanosoma Rhodesiense?

They are internal parasites in the blood of Man. The presence of *T. gambiense* in the blood is the cause of **Trypanosome Fever** (in West and Central Africa). When, at a later stage, it occurs in the cerebro-spinal fluid, it causes the deadly malady known as "**Sleeping Sickness.**" *T. rhodesiense* causes a form of "sleeping sickness" in Nyassaland and North-east Rhodesia.

How are Trypanosoma Gambiense and Rhodesiense transmitted to Man?

By two-winged blood-sucking flies of the Genus *Glossina* (Tsetse flies). When the infected insect "bites," i.e., pierces the skin with its proboscis, it introduces the trypanosomes while sucking the blood.

T. gambiense is transmitted principally by *Glossina palpalis*, and *T. rhodesiense* by *Glossina morsitans*.

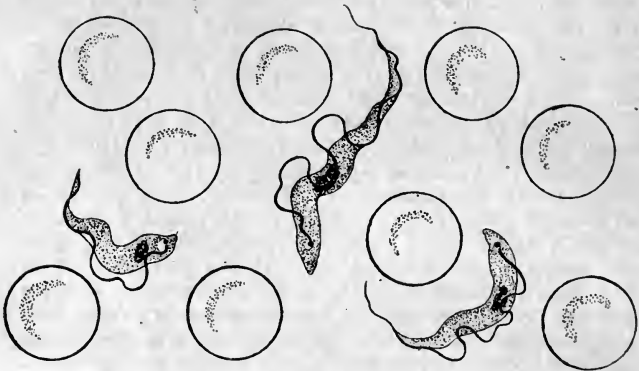


FIG. 7.—Organisms of Sleeping Sickness (*Trypanosoma gambiense*), and red blood corpuscles. (Highly magnified.)

With permission, from "British Museum (Natural History) Special Guide No. 7."

What Disease is caused by Trypanosoma Cruzi, and how is it conveyed?

The fatal disease, **Barbeiro**, in Man (especially children) in South America (Brazil). The parasite is conveyed by a bug (*Conorhinus*, syn. *Lamus megistus*), which is found in the houses of the poorer people. It attacks at night, biting the face.

Name some Trypanosomes which are of importance in relation to Domesticated Animals. State which diseases they cause, and how they are spread.

Trypanosoma brucei is the cause of the deadly disease **Nagana** in horses, cattle, etc., in Africa. It is spread by *Glossina morsitans*, one of the tsetse flies.

T. equinum causes "**mal de caderas**" of horses in South America (Paraguay, Argentine, and other parts). The mode of transmission is not known.

T. evansi causes "Surra" in horses in Indo-Burmah, and is said to be conveyed by the fly, *Tabanus lineola*.

T. theileri has been suspected as the possible cause of gall-sickness among cattle in the Transvaal. It is perhaps spread by the fly, *Hippobosca rufipes*.

T. equiperdum is the parasite of dourine or horse-syphilis in the countries around the Mediterranean. It is conveyed by coitus.

How would you explain the Occurrence of Nagana in a Dog or a Horse in a wild Tract of Africa where there were no other Domesticated Animals?

As being due to transmission of *Trypanosoma brucei* by tsetse-flies infected from a natural alternate host, e.g., a buffalo, or a species of antelope.

What is Leishmania? Where is it found, and what is its importance?

There are three known species of *Leishmania*. They are minute and round or pear-shaped parasites found in the blood of Man. They are intracellular, occurring in the leucocytes or white blood corpuscles and also (more abundantly) in the vascular endothelium (i.e., the flattened cells which form the lining of the heart and blood-vessels).

Leishmania donovani (the Leishman-Donovan body) is the cause of the Tropical Fevers, Dum-dum, Kala-azar, prevalent throughout Indo-Burmah, and usually fatal.

Leishmania tropica (Wright's bodies) produces "Oriental sore" or "Delhi boil," a localised skin disease.

How do the Leishmania parasites reproduce?

They multiply by fission equal and unequal. A remarkable feature of the unequal longitudinal fission method is, that very thin portions are segmented off from one side of the body, and neither of the two nuclei nor the flagellum are involved in the process.

How is Leishmania donovani transmitted to Man?

Probably by the bed-bug, *Cimex rotundatus*, in which the flagellate stages of this parasite have been found.

What are Spirochætes?

Active minute filamentous organisms with pliant flexuous bodies. The nuclear substance is diffuse, in the form of chromidia rodlets. Some forms have a membrane called the crista which is not, however, an undulating membrane. Certain species are important blood parasites.

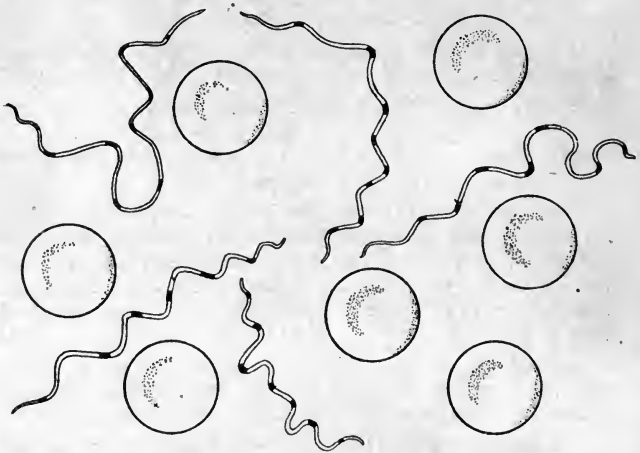


FIG. 8.—Organisms of African Relapsing Fever (*Spirochæta duttoni*), and red blood corpuscles. (Highly magnified.)

With permission, from "British Museum (Natural History) Special Guide No. 7."

What Disease is caused by (a) Treponema pallidum, (b) Treponema pertenuè, (c) Spirochæta recurrentis, (d) Spirochæta duttoni?

Treponema pallidum is the spirochæte of syphilis.

Treponema pertenuis is the spirochæte of yaws or fram-
bœsia.

Spirochæta recurrentis causes European relapsing fever.

Spirochæta duttoni is the cause of human tick-fever or relapsing fever of Tropical Africa, prevalent in the Congo State and other parts.

How are the Spirochæte parasites conveyed from one person to another?

By lice or by ticks. *Spirochæta recurrentis* is transmitted by bed-bugs and by lice. Infection from lice is commonly brought about by scratching the skin, and thus crushing the lice containing the spirochætes which then enter by the abrasions.

Spirochæta duttoni is transmitted by a tick, *Ornithodoros moubata*, which frequents the ground of camping sites and places where the natives have built their huts. The parasites are taken up by the tick when it sucks the blood of an infected individual. The tick remains infective for some time. The parasites also penetrate the ovaries of the tick and enter the immature eggs; so that the nymphs which arise from these eggs also transmit the germs to healthy individuals.

While the tick is feeding, it voids excrement containing the parasites and they find their way into the wound. That is the mode of infection.

CLASS CILIATA (INFUSORIANS).

State briefly the General Characters of the Ciliata.

The body has a definite shape and has short, vibratile, hair-like cilia which act like oars for locomotion. The cilia may be all over the body (e.g., *Paramecium*), or may be restricted to one area (e.g., *Vorticella*). Stinging hairs or trichocysts are (in one order) present among the cilia.

There are two nuclei (a large macro- or meganucleus and a small micronucleus which differ also in structure

and in mode of division, the division of the meganucleus being amitotic, and of the micronucleus, mitotic).

In some instances (e.g., *Opalina*) there are many nuclei. There is usually a definite mouth which may be at the surface or insunk at the bottom of a funnel, the vestibule. There may be one contractile vacuole or many. The modes of reproduction are transverse and longitudinal fission, gemmation or budding, and spore formation. Some Ciliates form colonies (e.g., *Epistylis*, *Carchesium*). There are freshwater and marine forms, free-swimming or fixed (often with a stalk), and others are entozoic, i.e., living inside other animals, e.g., *Opalina*, *Balantidium*.

PARAMECIUM.

(A type of Infusoria and an example of the Class Ciliata.)

Describe the General Appearance and Structure of Paramecium.

The *Slipper Animalcule* is visible to the naked eye. It has a definite long oval shape. It is rounded at one (anterior) end and is sharper at the other (posterior) end. The body is covered uniformly with short and delicate cilia (holotrichous). The greater bulk of the body is the endoplasm or medulla, which is full of granules, food vacuoles, and foreign bodies (e.g., symbiotic algæ). Around the endoplasm is the thin ectoplasm or cortex which has an outer pellicle or cuticle, and in which are the contractile myoneme threads and the trichocysts. On one side about the middle is the opening of the funnel (vestibule or peristome) which is richly ciliated. At the bottom of this funnel is the true mouth or cytostome, opening into a short gullet which has a delicate undulating membrane. Two contractile vacuoles are seen at intervals. At first there appears a ring of tiny tributary vacuoles, and these form the large spherical vacuole. It expands (diastole) until it comes in contact with the surface of the pellicle; then it suddenly contracts (systole) and vanishes. Staining with

picocarmine shows clearly the two nuclei situated in the middle of the body, the small micronucleus alongside the large oval macro- or meganucleus.

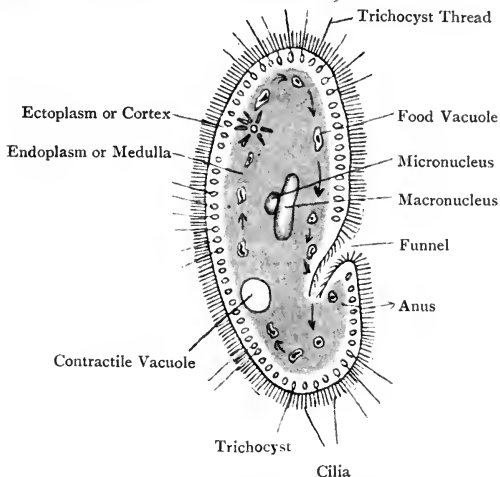


FIG. 9.—*Paramecium*. (Magnified.)

Where is Paramecium found, and how does it move and feed?

In stagnant water and in infusions of decaying organic matter.

It moves actively by means of the cilia.

Food particles are inwafted by the numerous cilia lining the peristome and passed to the mouth, which opens into the gullet, through which the particles are driven by the action of the undulating membrane. At the bottom of the gullet a food vacuole is formed and carried into the endoplasm.

How does Paramecium excrete?

It gets rid of solid matter through the temporary anus which is situated a little way behind the mouth. The

finer soluble wastes are discharged by the contractile vacuoles.

What happens when a Drop of Corrosive Sublimate Solution is added to the Water containing Paramecium?

The trichocysts (in the cortex or ectoplasm) suddenly extrude their long stinging threads, which are then seen amongst the cilia.

What is the special Importance of the Micronucleus in Paramecium?

It is the nucleus chiefly concerned in reproduction.

How does Paramecium reproduce?

When full grown, it reproduces by simple transverse binary fission. After a succession of generations by that method, temporary conjugation occurs between two individuals and an exchange of micronuclear substance takes place.

Write a short Account of the Process of Conjugation in Paramecium.

Two Parameciums, which have degenerated in size and in other respects, approach each other and, side by side, partly unite, their oral regions becoming fused and indistinguishable. In each the micronucleus undergoes great change, increases in size, divides into two, then into four. The four then proceed to divide again; but three are absorbed and only one completes the process, dividing into two pronuclei. Each Paramecium has now two pronuclei and one meganucleus (as yet unchanged). The Parameciums now exchange each a pronucleus, and thus an interchange of micronuclear substance is brought about. The exchanged or migratory pronucleus fuses with the stationary or retained one to form the zygote nucleus (syngamy). Then the Parameciums separate. In each the large meganucleus breaks up and disappears, and the zygote nucleus undergoes three successive mitotic divisions,

with the result that two groups of four are formed, one group being new meganuclei and the other being new micronuclei. But three of the micronuclei disappear; only one remains, and it divides into two.

The *Paramecium* now divides into two daughter-*Parameciums*, and each has two meganuclei and one micronucleus which divides into two. The two daughter-*Parameciums* each divide, and the final result is therefore four *Parameciums*, each with a meganucleus and a micronucleus derived from the original zygote or combination nucleus.

This is the process in *P. caudatum*. In *P. aurelia*, which has two micronuclei, it is a little more complicated.

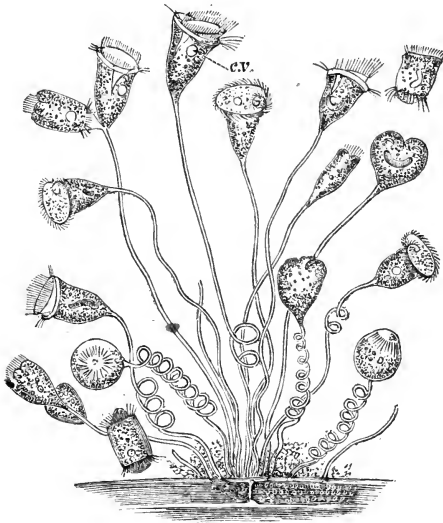


FIG. 10.—*Vorticella*. (A colony magnified.)

C.V. Contractile Vacuole.

Note the detached free-swimming individuals.

Contrast Paramecium with Vorticella, and state the Main Points of Difference.

(The main points of difference are printed in bold type.)

Paramecium (Slipper Animalcule).

In shape a **long oval**.

A cortex with an outer pellicle.

Free-swimming in water.

Cilia not restricted, and covering body uniformly (**Holotricha**).

Actively moving by means of cilia.

Numerous trichocysts (stinging hairs).

A mouth within peristome and an anal spot near.

Food particles inwafted by cilia into mouth *via* the peristome.

Food vacuoles formed.

A large **oval meganucleus** and one small micronucleus (or two) alongside it.

Two Contractile Vacuoles.

Reproduction by—

(a) Simple division (**transverse binary fission**).

(b) **Temporary conjugation**, with exchange of micronuclei.

Vorticella (Bell Animalcule).

In shape like a **bell with a long handle**. A disc on top of the bell.

A cortex with an outer pellicle.

Fixed by a stalk to water-weeds.

Stalk has an axial contractile fibre or "**myophan**" thread.

Cilia restricted to lip of bell, disc, and peristome (**Peritricha**).

Although fixed, **contracts its stalk freely**; and **bell may swim free** when detached from stalk.

A mouth within peristome and an anal spot near. A ciliated groove between disc and lip of bell.

Cilia of disc and groove cause vortex currents which inwaft food particles into mouth *via* the peristome.

Food vacuoles formed.

A large **horse-shoe-shaped meganucleus**, and close to it one small micronucleus.

One Contractile Vacuole.

Reproduction by—

(a) Simple division (**longitudinal fission**)—one half being separated off as one or more microzooids which swim free, and

(b) **completely conjugate** with ordinary stalked individuals.

Give a short-Description of Opalina.

One of the Ciliata. It occurs as a parasite in the rectum and bladder of the Frog. The body is oval and uniformly ciliated (Holotricha). There is no mouth and no contractile vacuole. There are numerous nuclei. In summer and autumn multiplication is by fission into two, and serves for increase within the host; but in spring the process is multiple fission, resulting in numbers, each containing a few nuclei. These encyst and pass out from the frog into the water. If one is swallowed by a tadpole, the cyst wall is dissolved, setting free ciliated uninucleate bodies (the gametes) which conjugate in pairs to form zygotes from which multinucleate *Opalinas* are developed.

Write a short Note on Balantidium coli.

Balantidium coli is a ciliate of the order Heterotricha. It generally multiplies by transverse division; but conjugation and encystment also occur. It is found in the large intestine of man, in the rectum of the pig and other animals. In Man it causes a form of dysentery known as balantidiasis.

What do you know about Kerona and Trichodina?

They are Ciliates, and they are both found upon the body of *Hydra*, the one (*Kerona*) actively creeping over the cuticle and the other (*Trichodina*) sometimes attached thereto, sometimes moving. *Kerona* is probably a commensal (i.e., a harmless or beneficial associate "eating at the same table"). *Trichodina*, which is a cylindrical Vorticellid, with an adhesive disc instead of a stalk, is an ectoparasite.

CLASS ACINETARIA.

Describe the Acinetaria. Give an Example.

They are Infusorians which, in their adult state, are of fixed sedentary habit and have retractile suckers or tentacles instead of cilia. In the early or larval period of their life they have cilia and are free-swimming.

Some Acinetarians have a stalk or peduncle. Their way of feeding is remarkable. They have no mouths; they fasten on to their prey or food by the suckers and by means of these extract the nutrient substance. Many of them are parasitic. Reproduction is by fission and gemmation (budding). *Acineta*, a well-known freshwater and marine genus, is found attached to Hydroids.

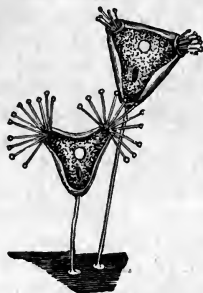


FIG. 11.—*Acineta*. (Magnified.)

CLASS SPOROZOA (GREGARINES).

Indicate the Characteristic Features of the Sporozoa and their Importance.

They are parasitic Protozoa which infest the tissues and internal organs of almost all animals, from worms up to and including Man. Many are minute in size, some are as long as half an inch. Being internal parasites, and feeding by osmosis, simply absorbing through their cuticle the juices of their hosts, they have no special structures for ingesting and digesting food. There are no food vacuoles and no contractile vacuoles; only a nucleus is present in the body. The body has finely granular endoplasm (the medulla) with a thin border of ectoplasm (the cortex) which contains contractile fibrillæ. Movement is amœboid or euglenoid, and the shape of the body alters little.

Characteristic is their prodigious procreativeness, their profuse multiplication by sporulation, i.e., by fragmentation of the body into numerous minute nucleated reproductive germs or spores. These spores may serve for further increase within a host or for infecting fresh hosts, thus ensuring the spread of the species. The spores are either grouped within tough-walled cysts, or separate and each provided with a tough resistant coat. While many of the Sporozoa are little more than inconveniences, others produce disease often fatal in result. The Hæmosporidia are the cause of malaria in Man.

ORDER GREGARINIDA.

Structure and Life History of Monocystis.

Where is Monocystis magna found?

In the reproductive organs of the Earthworm (*Lumbricus*), either free in the seminal vesicles or attached to the internal funnel openings of the vasa deferentia.

Describe the Appearance and Structure of Monocystis magna.

It is worm-like, a quarter of an inch long more or less, and its body consists of a clear thin outer cortex or ectoplasm and an inner medulla or endoplasm, finely granular, in which there is a conspicuous oval and fluid nucleus. This description is that of the trophozoite stage of the parasite.

*Where is the Trophozoite of Monocystis agilis found?
Does it differ in any way when compared with the
Trophozoite of Monocystis magna?*

In the fluid contents of the seminal vesicles of the Earthworm. It is of minute size and oval shape (varying, however, when contracted during "euglenoid" movement). The body structure is similar to that of *Monocystis magna*.

How would you proceed to examine an Earthworm for Monocystis agilis?

Open the earthworm (under salt solution) from the *ventral* side. Slit open a seminal vesicle, remove some of the fluid contents with a pipette, place a drop (diluted with salt solution) on a microscope slide, and, placing a coverslip on top, examine under the microscope.

Having mounted a Drop of the Earthworm's Seminal Vesicle Fluid, describe what you would probably see.

The fluid would consist chiefly of countless minute hair-like spermatozoa, and many floating mulberry-like clumps called sperm-morulæ, each a cluster of developing spermatozoa attached by their heads to a central piece of protoplasm. Amongst the sperms and sperm-morulæ, there would probably be some trophozoites with or without furry coats composed of the tails of destroyed sperms; and almost certainly large spherical cysts would be seen, full of small ovate spores (pseudonavicellæ), also numbers of these spores scattered about from burst cysts. Possibly a cyst of another kind would be noticed, one containing two large oval masses (gametocytes) joined together; and also perhaps gametocytes in associated pairs but not yet encysted.

KEY TO FIG. 12

- A. Three trophozoites.
- B. Cyst containing two gametocytes.
- C. Stage prior to formation of gametes. Note the numerous small nuclei.
- D. Gametocytes broken up and gametes formed. Some of the gametes are conjugating in pairs; some pairs have fused to form zygotes.
- E. Cyst containing ripe spores or pseudonavicellæ.
- F. A single spore or pseudonavicella containing falciform sporozoites.
- G. A sporozoite inside a sperm-morula.
- H. A young trophozoite coated with tails of destroyed sperms.

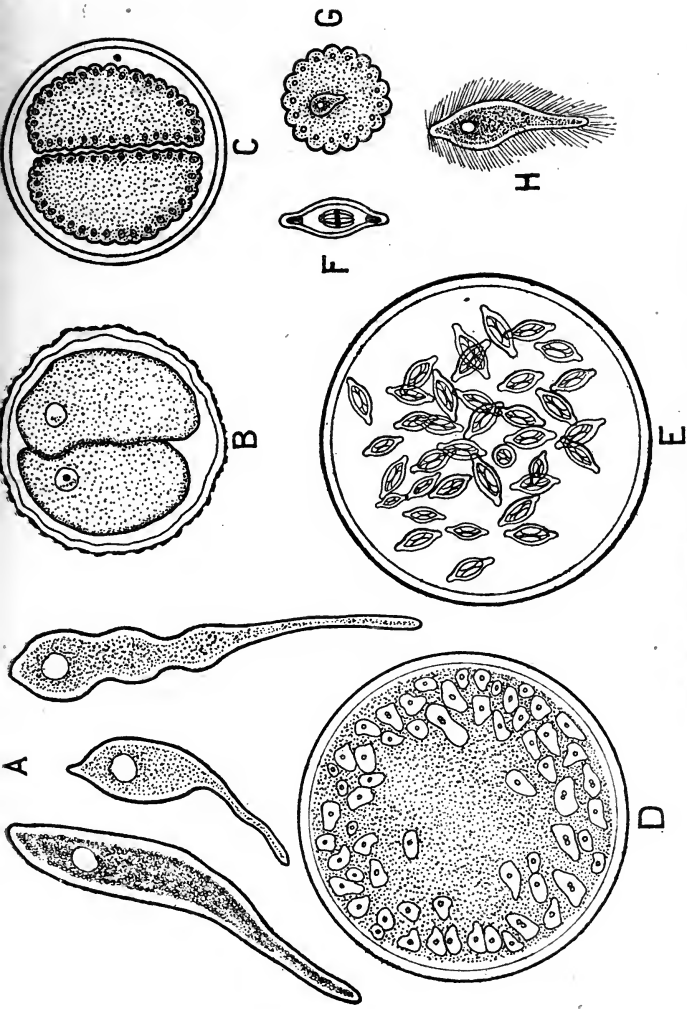


FIG. 12.—Life-History Stages of *Monocystis agilis*. (Magnified.)
 With permission, from Parker & Haswell's Text-book of Zoology.

Where is the young Trophozoite found?

In the sperm-morula, where it feeds and grows, ultimately destroying the sperm-cluster.

Give the subsequent History of the Trophozoite.

When the trophic or vegetative stage has been completed and the limit of growth attained, the trophozoite is adult and ripe for reproduction, and is then known as a gametocyte (or sporont).

What is the next Event?

Two gametocytes associate together side by side. They secrete a double-walled enclosing cyst. Their nuclei undergo changes and divide by karyokinesis. There are further repeated divisions which do not occur at the same time in each gametocyte. As the nuclei multiply, they decrease in size, and when the limit has been reached and division ceases, they move towards the surface of the body. The body of each gametocyte now breaks up into small portions, each containing a little nucleus; and these are the gametes. A certain amount of surplus or residual protoplasm serves for their nourishment. The body-wall of each gametocyte is dissolved, the gametes are set free and mix together. The cyst now contains a crowd of lively gametes and conjugation follows. It is likely that each pair represents a gamete from each gametocyte. The union results in the formation of a zygote (or sporoblast).

How does the Zygote or Sporoblast become a Spore?

It becomes oval and secretes a tough chitinous coat. Its nucleus (by three successive amitotic divisions) divides into eight and its protoplasm is segmented correspondingly, with the result that the spore contains eight sickle-shaped or falciform sporozoites and a little residual protoplasm. By the time the sporozoites have been formed the spore has become boat-shaped, rather like a diatom of the genus *Navicula*, and so these spores are also known as pseudonavicellæ.

Can these Spores or Pseudonavicellæ develop further in the Earthworm ?

No ; they require to be transmitted to another host.

How is transmission to another Earthworm effected ?

Probably the earthworm is eaten by a bird. The resistant-coated spores (undigested) are thus set free, and passing out through the food canal they are scattered over the ground. The spore may be swallowed by an earthworm along with its food ; and the coat being dissolved by the digestive juice, the contained sporozoites are consequently liberated.

How would the Sporozoite get into the Reproductive Organs ?

It is active and can bore through tissues. It might pass through the intestine wall and *via* the body cavity, or more likely by some blood channel, reach its objective, the seminal vesicles.

When the Sporozoite gets inside a Seminal Vesicle, what does it do ?

It enters a sperm-mother-cell (sperm-morula) and there develops into a young trophozoite.

Conjugation is said to be Anisogamous in Monocystis.

What do you understand by the Terms Isogamous and Anisogamous ?

Isogamous means that the conjugating gametes are not different. **Isogamy** is common among Flagellates, e.g., *Copromonas*. Isogamous conjugation may be temporary ; in which case no zygote is formed, but an exchange of nuclear substance is effected. This is seen in Ciliata, e.g., *Paramecium*.

When the gametes are distinct (male and female), the conjugation is described as **anisogamous**, e.g., *Volvox*, many Sporozoa, and all Metazoa.

What is (a) *Exogenous*, (b) *Endogenous* Generation?

When the life-cycle is adapted for spreading the species to new hosts, the generation is termed **exogenous** (**cross-infective**).

When it is adapted for further multiplication within one host, the generation is called **endogenous** (**self-infective**). In many Sporozoa both generations occur. In *Monocystis* there is only exogenous generation.

Explain the Terms Sporogony and Schizogony.

Many Protozoa (especially Sporozoa) reproduce by a process of multiple fission, and the result is a numerous brood of spores. When this multiple fission is preceded by conjugation of gametes with subsequent formation of spores (the sporozoites), usually with resistant coats, for dissemination outside the host, the process is called **Sporogony**; and it is characteristic of exogenous generation.

When the multiple fission is not preceded by conjugation of gametes, and the result is formation of spores (the merozoites), which are naked, for further multiplication within the host, the process is called **Schizogony**; and it is characteristic of endogenous generation.

In *Monocystis* sporogony is the only process.

In which ways (in Sporozoa) may the Infection of a New Host be brought about?

In most instances (e.g., *Monocystis*) the mode of infection is direct and casual; the spores or germs are taken up accidentally by the new host. In certain instances (especially Sporozoa parasites of the blood) it is indirect and inoculative, through an intermediate host; e.g., the malaria germs are taken up by a mosquito, a blood-sucking insect which, when it "bites," transmits the germs. There is a third but exceptional way, by hereditary infection. It is known to occur in *Glugea* (syn. *Nosema*), the parasite which causes the destructive "pébrine" in silkworms. The parasites enter the eggs and give rise to spores which infect the succeeding generation.

ORDER HÆMOSPORIDIA.

(Sporozoa parasites of the red blood corpuscles.)

Structure and Life History of the Malaria Parasites of Man.

Name the Three Kinds of Malaria Parasite which occur in the Blood of Man, and state the form of Malaria Fever which each causes.

Plasmodium falciparum (syn. *Laverania malaricæ*) is the parasite of pernicious or æstivo-autumnal malarial fever.

Plasmodium malaricæ is the parasite of quartan ague.

Plasmodium vivax is the parasite of tertian ague.

How is Malaria transmitted from Man to Man?

By the "bite" of female mosquitoes or gnats of the genus *Anopheles* (e.g., *Anopheles maculipennis*, which is the carrier of malaria in Southern Europe).

How is the Malaria Germ introduced into the Blood of Man?

When an infected mosquito "bites" (i.e., pierces the skin with its proboscis), the germ (the sporozoite) is conveyed in the salivary secretion which passes into the wound.

Describe the Sporozoite.

It is a minute filamentous organism. It tapers to a sharp point at each end; and in the thicker middle portion there is a nucleus.

State the subsequent History of the Sporozoite, giving a brief Account of the Schizogonous Cycle.

The Sporozoite enters a red blood corpuscle, becomes rounded, enlarges, and a conspicuous vacuole appears in position so close to the nucleus that the parasite resembles a signet-ring (the so-called "signet-ring" stage). Then the vacuole disappears and the parasite becomes an amœboid trophozoite. Black pigment (melanin) collects

in grains around its nucleus. Feeding on the blood corpuscle, it now almost fills it. It is now ripe for reproduction, asexual by schizogony; the nucleus divides up, and the protoplasm is segmented. The result is a number of nucleated merozoites around a small portion of residual protoplasm, where all the melanin has accumulated. This is the rosette stage. The blood corpuscle now breaks up, the merozoites are set free in the blood plasma, and the melanin is scattered. This completes the Schizogony cycle.

KEY TO FIG. 13.

A combined diagram (the figures are not all from the same species). Figures above the dotted line represent stages passed in human blood; those below are stages found in the mosquito.

- I. to V. and 6 to 10, Schizogony of tertian parasite, *Plasmodium vivax*. After Schaudinn, and magnified about 1500 diameters.
- VI., VIIa., and VIIb. Formation of gametocytes of pernicious malaria (*Plasmodium falciparum*).
- VIII. to XIII. Stages of sexual generation of *Plasmodium vivax* in stomach of mosquito. After Schaudinn. The sign ♂ signifies male, ♀ female.
- XIV. to XVIII. Sporogony. Diagrammatic.
- XIX. Germs or Sporozoites.
- IV. "Signet-ring" stage.
- V. Amoeboid trophozoite.
9. Rosette stage and .
10. Free merozoites.
- VIIa. Male gametocyte or "e. rescent."
- VIIb. Female gametocyte or "e. rescent." One is shown free.
- Xa. Formation of microgametes. rtion of nucleus.
- Xb. Macrogametocyte extruding po. nete ("sperm") is shown
- XI. Process of Syngamy. A microga. "ovum"). penetrating the macrogamete (side it is a cluster of
- XII. A zygote which is elongating. B. s"). degenerating microgametes ("sperm")
- XIII. Motile ookinete.
- XIV. Oöcyst or spore-cyst.
- XVI. Sporoblasts formed.
- XVII. Formation of sporozoites.
- XVIII. Ripe cyst containing numerous sporozoites and residual protoplasm.

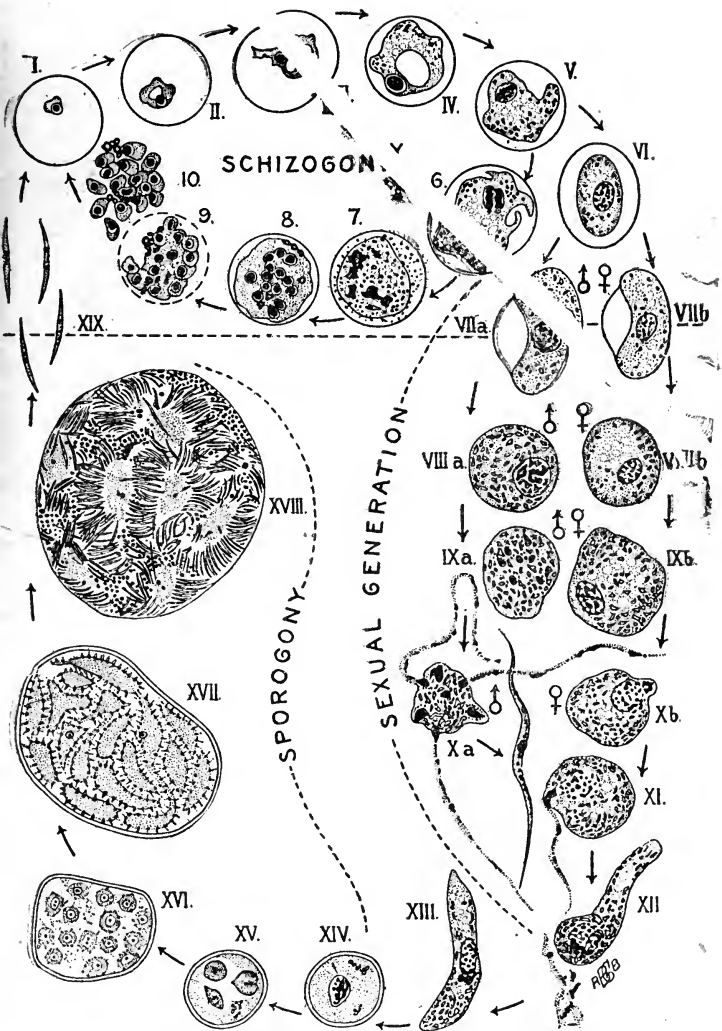


FIG. 13.—Life-cycle of a Malaria parasite.
 ((With permission, from Minchin's Protozoa.)

What happens when the Merozoites go free in the Blood Plasma?

They enter the blood corpuscles, and, behaving as sporozoites, go through the whole schizogony cycle, which in that way is repeated for many generations.

This prolific multiplication means great destruction of blood corpuscles, checked only by the leucocytes which attack the germs, and the result is onset of fever in the infected individual, followed by anæmia and general vitiation which may end fatally.

Do all the Merozoites give rise to Sporozoites?

There is a limit to the repetition of schizogonous (asexual) generations, and so ultimately there is the generation in which some of the merozoites become sexually different gametocytes. In *Plasmodium falciparum* these have a characteristic sausage-like form, are known as "crescents," and are therefore diagnostic of pernicious malaria.

The gametocytes cannot, however, develop much further in the human host; they require to be transferred to the intermediate host, the mosquito.

When a Female Mosquito "bites" a Man suffering from Malaria, what happens to the Germs sucked in with the Blood?

Probably germs of various stages will be sucked in. All are destroyed except the gametocytes, which alone can resist digestion.

Point out the difference between the Male and the Female Gametocyte.

The nucleus of the male is larger than that of the female; and the melanin granules are scattered in the male, but in the female surround the nucleus.

Give the subsequent History of the Gametocytes (the Sexual Generation).

In *Plasmodium falciparum* the crescentic gametocytes become rounded and free from the remains of their containing blood corpuscles. They undergo maturation in the stomach of the mosquito. In the male or microgametocyte the nucleus breaks up, and its chromatin substance passes into four or six slender processes, like flagella, which grow out from the body and are detached as active microgametes ("sperms").

The female or macrogametocyte, after extruding a portion of the nucleus at the surface, becomes a macrogamete ("ovum") ready for fertilisation. Conjugation takes place; the minute active microgamete enters the larger macrogamete and loses its thread-like form. The two nuclei fuse, and the result is a zygote that elongates into an oökinete, which bores its way through to the outside of the stomach and there encysts (an oöcyst or spore-cyst).

Describe the further Development of the Oöcyst.

Segmentation of the nucleus and protoplasm results in a number of irregular-shaped sporoblasts. In each sporoblast the nucleus divides up into numerous small nuclei which pass to the periphery. Then a number of slender processes grow out from the surface of the sporoblast and each contains one of the little nuclei. Thus, by sporogony, a great number of minute sporozoites are formed which soon go free from the residual protoplasm. There may be hundreds or even as many as ten thousand of these motile germs within the cyst. In one instance a mosquito was found with more than 500 cysts on the outside of its stomach.

How do the Sporozoites get into the Proboscis of the Mosquito?

When the cysts burst they are free in the hæmocoel or body cavity. They travel to the salivary glands; and when the mosquito "bites," they pass in swarms into the proboscis along with the saliva.

What is the Importance of Piroplasma?

Piroplasma (syn. *Babesia bigeminum*) is the parasite of Redwater or Texas cattle-fever.

How is Babesia transmitted from an Infected Ox to a Healthy One?

By one of the Ticks, *Rhipicephalus annulatus* (syn. *Boöphilus bovis*).

What is the History of the Tick, Boöphilus, in relation to Texas Cattle-fever?

The ticks feed on the blood of the ox. After their last moult they pair. The fertilised females, gorged with blood, drop off the ox. About 2000 eggs may be laid by one female. Along with the egg in the egg-case there is a supply of blood for the developing larva. When the young tick hatches out, it has some of this blood in reserve within its abdomen. It crawls up a grass blade, and if it fails to attach itself to the skin of an ox before "the remains of its share of its mother's last meal" are exhausted, it dies. If the mother drew the blood from an infected ox, the young ticks are infected, and so healthy cattle "bitten" by them become infected.

What are the Chief Features of the Hæmosporidia?

They are intracellular parasites of the blood of Amphibians, Reptiles, Birds, and Mammals, including Man.

The life-cycle shows alternation of generations—repeated generations asexual by schizogony, which serve to multiply the parasite within its host, are followed by sexual generation (formation of gametes which conjugate to form the zygote or sporont).

The sporont, at first motile, encysts, becomes an oöcyst from which by sporogony numerous minute naked sporozoites are developed. The sexual cycle occurs in the intermediate host, an invertebrate animal of blood-sucking habit which inoculates new vertebrate hosts.

The parasites cause fevers of various kinds. In Man

three sorts of fever are caused by three distinct species of parasite; the benign and intermittent tertian and quartan ague are produced respectively by *Plasmodium* (syn. *Hæmamoeba*) *vivax* and *malariae*, and the pernicious æstivo-autumnal fever or Tropical Malaria is caused by *Plasmodium falciparum*. In these fevers the parasite is transmitted by mosquitoes of or allied to the genus *Anopheles*. Similar fevers occur in other animals, e.g., the rapidly-fatal Texas Cattle-fever caused by *Piroplasma* (syn. *Babesia*).

PHYLUM PORIFERA (SPONGES).

What are Sponges?

They are (in the adult state) fixed sedentary animals of plant-like appearance and aquatic habit. Most are marine.

The general structure of the body is a branching internal system of canals or waterways with numerous openings on the outside. The water passes in through countless minute inhalent pores (hence the term Porifera) and, circulating freely throughout the body, passes out at one or several large exhalent openings, the oscula.

Sponges are two-layered (diploblastic) Metazoa. The outer or dermal layer consists of flattened (epithelial) cells, and there is a middle jelly between it and the inner or gastral layer, which is composed of flagellate collar-cells or choanocytes that keep the water currents going and secure the food.

Spicule formation is a feature of most Sponges. The spicules may be limy or siliceous and of various forms. In the Hexactinellidæ the glassy spicules are felted together into a supporting skeletal framework of exquisite beauty (e.g., the "Venus Flower-basket" of *Euplectella*).

A CLASSIFICATION OF THE PHYLUM PORIFERA.

Class CALCAREA (Sponges with spicules of lime).

Order Homocœla (the internal cavity lined throughout with Choanocytes—Ascon type.)

Examples, Leucosolenia.
Clathrina.

Order Heterocœla (Choanocytes restricted to chambers of internal cavity—Sycon type).

Example, Sycon (Grantia).

Class HEXACTINELLIDÆ (Sponges with a skeletal framework of siliceous spicules).

Examples, Euplectella (Venus Flower-basket).

Hyalonema (Glass-rope Sponge).

Class DEMOSPONGIÆ (Sponges without spicules, or with a skeleton of siliceous spicules combined with horny spongin in flexible fibrous cords).

Examples, Euspongia (the Bath sponge of commerce). Has an elastic skeleton of spongin only.

Spongilla (the freshwater Sponge).

Halichondria (Crumb-of-bread Sponge). A common encrusting Sponge of the sea-shore.

Cliona (a boring Sponge).

Halisarca (without spicules)‡

LEUCOSOLENIA.

A simple Sponge of the Ascon type, and an example of the Class Calcarea.

What is the General Appearance of Leucosolenia, and where is it found?

It is a small white tubular sponge. The wall of the tube is perforated by numberless minute inhalent pores, and at the top of the tube there is a large exhalent aperture (the osculum). The cavity is cut across a little way below the osculum by a thin porous membrane.

These tubes are massed together in colonies; they arise in numbers from a creeping stolon which grows and branches, forming a horizontal network basis attached to seaweeds, stones, and rock-surfaces. The upright tubes by vegetative budding also branch to some extent.

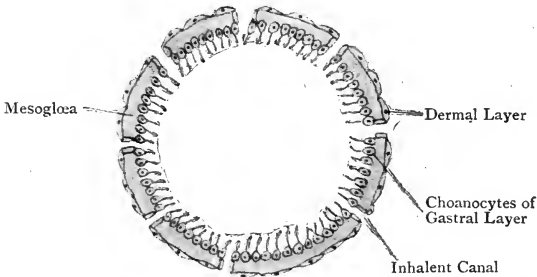


FIG. 14.—**Transverse Section of an Ascon Sponge (*Leucosolenia*).**
(Diagrammatic.)

*Describe the Structure of an Ascon Sponge (*Leucosolenia*) as seen in a Transverse Section of the Body.*

The wall consists of an outer **dermal layer** and an inner **gastral layer** with a middle jelly between these layers.

The breaks in the wall are the short **inhalent canals**

which open direct into the internal cavity of the tube. The internal or gastral cavity is lined by the gastral layer which is entirely composed of collar-cells or choanocytes.

The outer dermal layer is composed of flattened cells (dermal epithelium) and amœboid cells called amœbocytes. Besides these there are loose spicules. There are usually some wandering amœbocytes in the middle jelly.

What is the Structure of a Collar-cell or Choanocyte, and what is its Function?

It is a rounded cell with a delicate projecting funnel or collar which surrounds the lower portion of the long flagellum. Both collar and flagellum can be withdrawn.

By their action, the flagella draw the water in through the inhalent pores; and the food particles, caught in the swirl inside the collar, are engulfed by the cell. The main function of the choanocyte is to keep up the water currents; but by means of its collar it also secures the food which is afterwards ingested and digested by the cell (intracellular digestion).

Indicate the Functions of the Amœbocytes.

Some of them probably serve to transfer food and wastes from layer to layer. Some become scleroblasts, spicule-forming cells. Each triradiate spicule is made by three scleroblasts. Other amœbocytes develop into genital cells, which give rise to spermatozoa and ova.

What are Porocytes?

Large specialised cells of the outer dermal layer which pass through the wall and become hollowed out, and thus form the inhalent openings or pores.

GRANTIA.

A Sponge of the Sycon type.

Write a short Description of the Sycon Sponge (Grantia), showing the Structural Difference between it and one of the Ascon Type.

Grantia is sac-shaped but flattened. The wall is perforated by numerous minute inhalent pores, and there is a large exhalent osculum. The base of the cup has sometimes a short stalk which serves for attachment to seaweeds and rock-surfaces.

The internal gastral cavity of this sycon sponge is lined with thin flat epithelial cells, and it has a number of pouches formed by infoldings of the wall. These are called radiating chambers and the choanocytes are confined to them.

The inhalent canals are in communication with these radiating chambers, and the opening of communication between a canal and a chamber is termed the prosopyle.

In the ascon type (e.g., *Leucosolenia*) the wall is not folded, there are no radiating chambers, and the internal gastral cavity is lined throughout with choanocytes.

The short inhalent canals are in direct communication with the internal gastral cavity, and the opening of an inhalent canal into the central cavity is the prosopyle.

Sponge Development.

How do Sponges multiply?

By vegetative budding the individual or colony is increased; but the mode of reproduction of the species is sexual, the sperms and ova being developed (both in the same sponge, in some instances) from genital cells (amœbocytes).

In the freshwater sponge, *Spongilla*, unfavourable conditions are tided over by the development of gemmules or statoblasts, which are formed by the grouping together of food-laden cells.

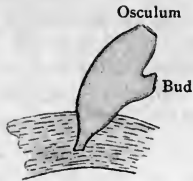


FIG. 15.—*Grania*. (Natural size.)

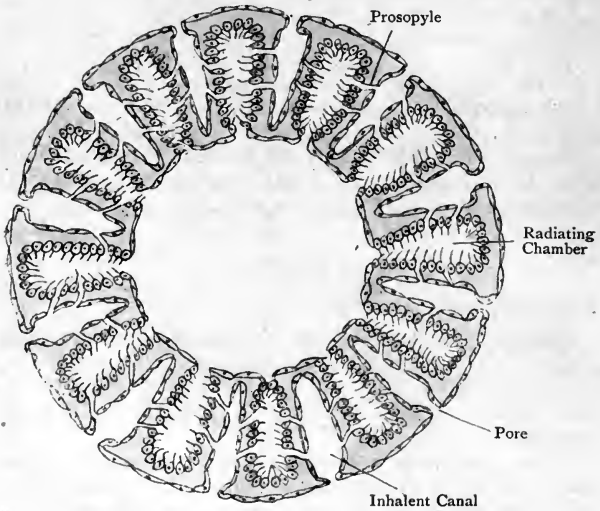


FIG. 16.—**Transverse Section of a Sycon Sponge.**
The central space is the internal gastric cavity.

Describe the Development of a Simple Ascon Sponge (e.g., Leucosolenia).

Segmentation results in an oval blastula of elongate flagellate cells, all similar except two, which are large and not flagellate. A number of the cells lose their flagella, become amœboid, and pass into the central cavity. This larval form, with three kinds of cells, is the free-swimming parenchymula. It becomes attached and flattened out, and most of the inner amœboid cells pass between the flagellate ones to the outside and there form the outer dermal layer. Of those that remain, some become porocytes and pass to the outside where they hollow out to form the inhalent openings of the wall, while the others (which are archæocytes developed from the two exceptional large non-flagellate cells) remain and become the genital amœbocytes.

Some of the cells of the dermal layer migrate inwards, and are specialised as scleroblasts; they group in threes to form the triradiate spicules.

The central cavity, lined by the flagellate cells, which are now choanocytes, enlarges, and the adult form, with an osculum at the free end, is attained.

How does the Sycon Sponge differ in Development from the simple Ascon Type?

The blastula has an upper hemisphere of small flagellate cells and a lower hemisphere of large rounded archæocytes. The flagellate cells increase rapidly by division and soon completely surround the archæocytes, now in the segmentation cavity. This is the pseudogastrula stage.

Then the flagellate cells of the lower hemisphere lose their flagella and become large and rounded; and this larval stage (with an upper hemisphere of flagellate cells and a lower one of large round non-flagellate cells) is the amphiblastula which swims free from the parent sponge and then becomes fixed.

The flagellate cells are overgrown by the large rounded ones. The former become the choanocytes, and from the

latter the dermal layer is developed. The wall is thickened by growth of the middle jelly, and the radial chambers are formed by infolding.

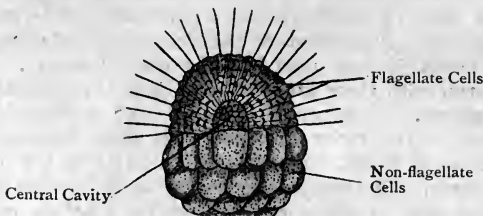


FIG. 17.—**Amphiblastula larva.** (After Schulze.)

Describe the Life-history of the Freshwater Sponge (Spongilla).

In autumn gemmules are formed within the sponge. The gemmule is a group of food-laden cells enclosed in a protective envelope of capstan-like spicules made by the scleroblasts. The rest of the sponge decays, but the gemmules remain alive. In spring these develop into new sponges, some producing spermatozoa, others ova. From the fertilised ova a summer generation of sponges is developed. These produce gemmules in autumn and then perish.

This life-history shows alternations of generations.

PHYLUM COELENTERATA.

Give an Account of the General Characters of the Coelenterata.

The body is radially symmetrical. The body-wall consists of two layers, outer ectoderm and inner endoderm, with mesogloea between. The central space of the body is the coelenteron, and its opening is the mouth.

The layers show differentiation into special contractile and nervous tissues. Cnidoblasts or stinging cells are a

A CLASSIFICATION OF THE PHYLUM CÖLENTERATA.

Class HYDROZOA (the cœlenteron is a plain tube).

Order Hydrida (Polyps only. The buds set free).

Order Hydromedusæ (Polyps by budding form colonies. Sexual medusoids developed and set free).

Sub-order Calyptoblastea (a cup-like extension of the horny perisarc surrounds head of polyp. Medusoids have "otocysts." Gonads on the under surface of the bell).

Sub-order Gymnoblastea (no cup-like extension of perisarc. Medusoids have ocelli. Gonads are on the manubrium).

JELLY-FISH (formerly Class SCYPHOZOA).

Sub-order Hydrocorallinæ (Hydroid colonies with the perisarc thick and limy, forming a coral).

Order Siphonophora. Free-swimming colonies composed of hydroid and medusoid individuals and exhibiting polymorphism. The colony may have a special float or pneumatophore (*e.g.*, Physalia, the "Portuguese Man-of-War," and Porpita) or some of the medusoids may be modified for swimming (*e.g.*, Diphyes), or both float and swimming bells (nectocalyces) may be present (*e.g.*, Halistemma).

Class ACTINOZOA or ANTHOZOA (the cœlenteron has a stomodæum or gullet and mesenteries).

Order Alcyonaria (eight mesenteries).

Order Zoantharia (twelve or more mesenteries, in pairs).

Class CTENOPHORA (Comb-bearers). Free-swimming globular or ribbon-like Cœlenterates with only two tentacles, and with bands or plates of cilia in comb-like rows. They have adhesive cells instead of stinging cells.

Example, Hydra (the Freshwater Polype).

Example, Obelia.

Examples, Tubularia.
Hydractinia.

Examples, Aurelia (the common Jelly-fish).
Lucernaria (a sedentary form).

Example, Millepora.

Examples, Alcyonium ('Dead men's fingers').
Corallium (Red Coral).

Examples, Sea-Anemones (*e.g.*, Actinia,
Peachia), Madrepora and other
coral-forming species.

Examples, Cydippe.

Cestum (Venus's Girdle), which is
ribbon-like.

characteristic feature. The mesogloea may be a thin supporting lamella, or it may form an extensive mass, and it often contains migratory cells. In the simpler types (e.g., *Hydra*) the coelenteron is a plain tube; in higher forms (e.g., *Sea-Anemone*) it has a gullet or stomodæum, formed by an intucking of ectoderm at the oral end, and it is also divided into compartments by radial septa or mesenteries, folds of the wall which extend towards the centre.

There are two chief structural types, the tubular polyp and the expansive bell-like medusa. Both types are often present in the course of a life-history and illustrate alternation of generations.

In the polypoid types the ectoderm often secretes a horny protective covering, the perisarc, and in certain forms a deposition of lime results in the formation of corals.

Multiplication by budding (gemmation) is common and results in colonies which show division of labour which in certain instances amounts to polymorphism, more than two different kinds of "persons" being produced. The mode of reproduction is sexual.

Most Cœlenterates are marine, a few (e.g., *Hydra*) occur in freshwater. Commensalism is frequent (e.g., *Sea-Anemone* and *Hermit-Crab*).

- CLASS HYDROZOA.

Hydra (the Freshwater Polype).

Where is Hydra found? Describe it.

Upon water weeds in ponds. It has a thin tubular body with six or more hollow prolongations, the tentacles, at one end and a disc or "foot" at the other. The tentacles surround an oral cone at the top of which is the mouth. The body is about a quarter of an inch in length, the tentacles are often longer; and the colour is green, brown, or white according to the species.

From time to time it shifts its position, detaching its "foot" and moving along on its "head" by means of its tentacles, the outermost cells of which extrude little pseudopodia. It is continually drawing in and lengthening out again, waving and curving its tentacles.

It often has a replica bud, a small daughter-hydra attached to its body. Sometimes a bulging (the testis) is seen just below the tentacles; or nearer the "foot" (the ovary).

Two infusorians are often found on its skin, namely, *Kerona*, which is probably commensal, and *Trichodina*, which is ectoparasitic.

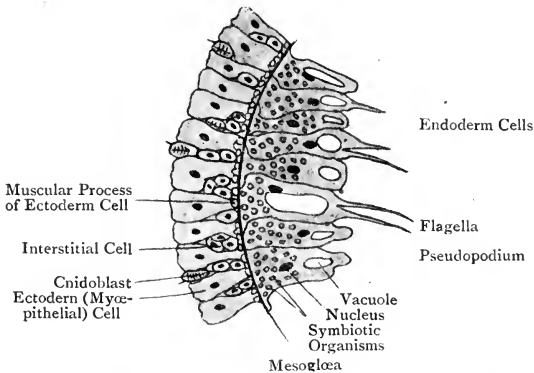


FIG. 18.—Portion of a transverse section of body-wall of *Hydra*.
(Highly magnified.)

Describe the various kinds of Cells in Hydra. and state the Parts of the Body to which they belong.

The endoderm layer which lines the coelenteron is composed of large cells and some of them are T-shaped. The crosspiece is a thin contractile portion of the cytoplasm; the stem or main part of the cell is large and pear-shaped, and has a nucleus, a big vacuole, green symbiotic organisms which give the Hydra its colour, and also either pseudopodia

or two or three flagella which project from the thicker end into the cœlenteron.

Between the inner endoderm and the outer ectoderm there is a thin supporting lamella, the mesogloea.

The ectoderm cells are shorter than the endoderm cells, but they have a similar shape, and their contractile processes are longer. Since they have muscular processes and are arranged in a layer, they are therefore termed myoepithelial cells.

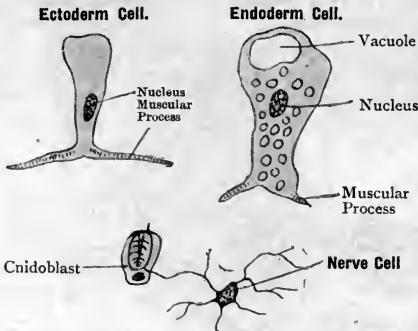


FIG. 19.—An Ectoderm cell, Endoderm cell, and a Nerve cell connected with a Nematocyst. (After Jickeli.)

Between the thinner parts of the ectoderm cells, adjoining the mesogloea, there are small round interstitial cells.

Embedded in the ectoderm of the tentacles are the cnidoblasts or stinging cells which are seen in clumps studing the tentacles.

Throughout the ectoderm there are minute nerve cells with ray-like processes, which form a connected nervous network.

*Hydra shortens and lengthens its Body, and it also creeps.
How are these Movements effected?*

The ectoderm (myoepithelial) cells have crosspiece processes which contain muscular fibrils lying alongside

the mesogloea and parallel with the body. When these contract the body is shortened.

The endoderm cells have similar processes; but they are circular in position. When these contract the diameter of the body is reduced and it lengthens out.

Creeping is accomplished by using the tentacles, by the small pseudopodia of their ectoderm cells.

Explain the Structure and Action of the Hydra Stinging Cell.

Embedded in the ectoderm there are cnidoblast cells. Each has a small projecting barb, the **cnidocil**, and contains a sac called the **nematocyst** which has inside it fluid and a long stinging thread coiled up.

When, for instance, a water-flea comes in contact with the barb, cnidocil, or touch point, the cnidoblast suddenly contracts and the pressure on the nematocyst causes the contained stinging thread to be instantly shot forth into the body of the flea with a poisonous paralysing effect.

How does Hydra feed?

It captures its prey by means of its tentacles. The tentacles are tightly turned in, and the food is thus brought to the mouth and passed in. Within the cœlenteron portions of it are digested by a ferment secreted by those endoderm cells near the mouth which are specialised **gland cells**.

The ordinary endoderm cells simply absorb the digested substance; and by means of their pseudopodia they engulf the more resistant portions, digesting these in food vacuoles. Digestion in Hydra is therefore partly intercellular, partly intracellular.

The residue or waste is passed out at the mouth. This is accomplished by the activities of the flagella, which sustain the circulation of the watery fluid within the cœlenteron.

What is the Function of the Interstitial Cells?

Some of them are specialised for reproduction and produce the male and female gametes. Others move towards

the outside and develop into cnidoblasts or stinging cells. A number of them are probably latent ectoderm cells, ultimately becoming such.

How does Hydra reproduce?

In spring and during summer it usually multiplies by gemmation or budding. On the body a pouch-like outgrowth appears, and as it lengthens, the free end branches out as a crown of tentacles. This daughter-hydra remains attached for a time and then goes free.

In autumn the mode of reproduction is sexual. Certain interstitial cells give rise to the testis (one or several swellings beneath the tentacles) and the ovary (usually a single swelling near the "foot"); both being produced by one Hydra.

The ovary contains several potential egg-cells, but only one becomes the large ripe ovum (the macrogamete).

The ectoderm ruptures and the ovum protrudes. Minute motile sperms (microgametes) are liberated from the testis. When one of these enters an ovum, the result of the conjugation is a fertilised egg-cell or zygote.

Write a brief Account of the Development of Hydra.

After fertilisation the egg begins to segment. Segmentation is total (holoblastic) and equal, and the result is a blastula.

The cells of the wall, by division, give rise to cells which pass into the cavity of the blastula, filling it up; and thus, by multipolar ingression, the endoderm layer is formed, and there is now a two-layered embryo.

The ectoderm secretes a protective spiny spherical envelope or shell; and the enveloped embryo then drops off and remains in the pond mud throughout the winter. After a resting stage the interstitial cells are developed, then the mesogloea; and finally, when the shell bursts and the elongate embryo emerges, the coelenteron appears as a space in the endoderm at the upper end, a mouth is formed by splitting, and tentacles are budded out.

Order Hydromedusæ.

What are the chief Differences between the Hydromedusæ and Hydra?

The hydroid buds of the *Hydromedusæ* are not liberated, and the result is that colonies (simple or complicated) are formed. There are two principal types of individuals, namely, the fixed hydroid or polyp, which resembles *Hydra*, and the free-swimming medusoid.

The tentacles of the hydroid are usually solid, and the ectoderm of the body secretes a horny protective covering known as the perisarc. The medusoid is morphologically a modified polyp. In many instances, it is developed asexually as a bud from a specialised reproductive polyp; and it gives rise to the polyp or hydroid type.

The life-history frequently shows alternation of generations.

What is a Zoophyte? Give two Examples.

Hydroid colonies are termed Zoophytes because their formation is by budding and their appearance plant-like. *Obelia* and *Sertularia* are well-known examples. (The Polyzoa are also known as Zoophytes.)

Write an Account of Obelia geniculata, its Structure and Life-history.

It is found abundantly on the shore at low-water mark on the fronds of seaweed (*Laminaria*). Each colony is about an inch in length, thread-like and zig-zag, the little polyps arising at intervals aslant the main stem.

The ordinary nutritive polyps of the colony have numerous solid tentacles, but otherwise resemble *Hydra*. From their flower-like appearance they are called hydranths. Each is surrounded by a cup-like extension of the horny perisarc which invests the colony stem. This protective cup, inside which the polyp can be withdrawn, is called the hydrotheca. Where these polyps arise from the stem, another kind of short-stalked polyp is often seen, a tubular

one without mouth and tentacles but specialised for asexual reproduction and called a blastostyle. It is completely enclosed in a vase-shaped extension of the perisarc termed the gonotheca, which has a small opening at the top.

The blastostyle develops small buds. These are liberated, swim free, and become little medusæ; some of them produce ova, others produce sperms. The result of the development of the egg is a larva called a planula from which a new *Obelia* colony is developed.

What is (a) a Larva, (b) a Planula. How does the Planula become a Hydroid?

When the young stage of an animal is different from the adult and is free-living it is termed a larva.

A planula is an oval, ciliated, free-swimming larval form which consists of a layer of ectoderm cells around a central space, which space is subsequently filled more or less completely with endoderm cells.

The free-swimming planula settles down and attaches itself by the broader end. This end spreads out as a disc from which creeping root-like stolons are budded. The coat of cilia is cast off. The distal end becomes swollen, the body space is enlarged, a mouth is formed, tentacles grow out around it, and the ectoderm secretes a tubular investment of horny perisarc.

Describe the Medusa of Obelia.

The medusa and the polyp are homologous. In essentials the structure is the same in both.

The medusa may be regarded as a squat polyp. By flattening out and rounding it has become like a bell without a handle but with a clapper. The dome represents the base of the polyp, the clapper represents the oral cone which is a pendant manubrium with a four-sided mouth at the end; and the tentacles, removed from the oral cone, form the fringe of the dome.

The manubrium opens into the cœlenteron which is lined with endoderm. Between the endoderm and the

ectoderm, which forms the outer surface of the medusa, is an extensive mesogloea. The greater bulk of the medusa consists of mesogloea jelly.

The cœlenteron gives off four radial canals, channels of endoderm, which run at right angles through the mesogloea and open into the circular canal of the margin. By means of these canals food is distributed throughout.

The tentacles have ocelli ("eyes") at their bases; and eight of them (two in each quadrant) have also "otocysts." These are sense organs by which the medusa changes or corrects its position in the water. Each is a sac lined by ectoderm cells, some of which develop fine sensing hairs, while others secrete the limy concretions in the sac.

There are four gonads (reproductive organs) on the underside of the medusa, one below each radial canal.

The ectoderm cells of the margin and underside have contractile processes, and by this means the medusa swims, by rhythmic contractions of the bell.

What is a Velum or Craspedon?

A narrow fold of the margin of the medusa bell produced inwards like a shelf. Medusæ with a velum are described as craspedote, those without a velum as acraspedote.

Give the Meaning of the Terms Leptomedusæ and Anthomedusæ.

Medusæ which have "otocysts," and which have gonads in connection with the radial canals, are termed Leptomedusæ (e.g., *Obelia*).

Medusæ which are without "otocysts," and which have the gonads on the manubrium, are called Anthomedusæ.

In what ways does Tubularia differ from Obelia?

It is a gymnoblastic hydroid, i.e., one which has no cup-like extension of perisarc around the polyp. It has two sets of tentacles, long ones round the oral cone and short ones encircling the mouth. The medusæ are not set free, they remain attached as gonophores.

What is the Interest of Hydractinia?

It is hydra-like and forms unbranched colonies, often upon the whelk shells tenanted by hermit-crabs (commensalism).

These colonies exhibit polymorphism and division of labour. Some of the polyps are ordinary nutritive individuals, some (the tactile palpons) are longer and without mouths, others with rudimentary tentacles and with or without mouths are specialised for reproduction; and a number are abortive "persons," functioning as the protective spines of the colony.

*Aurelia (The common Jelly-fish).**What are the chief Structural Features of the common Jelly-fish?*

✓ It is acraspedote; there is no velum. The mouth has four long and frilled lips. The coelenteron is a wide four-lobed space, and on the floor of the lobes are the four semicircular gonads which are developed from the endoderm. Each gonad has, on its inner side, a row of gastral filaments. There are eight straight radial canals and eight which branch. There is no nerve ring, and the eight sense organs are tentaculocysts or rhopalialia.

How does Aurelia reproduce?

The method of reproduction is sexual. Aurelia is dioecious, i.e., the sexes are separate.

Write a short Account of the Life-history of Aurelia.

In early summer the developing embryos are carried about in pockets of the manubrium. Later they go free. The free-swimming planula soon attaches itself to a frond of seaweed and becomes a little hydra-like polyp called a hydra-tuba. Others, like itself, arise as buds from its creeping stolon.

In late autumn the hydra-tuba loses its tentacles, the edge of the oral disc becomes lobed, and an oral cone is developed. It elongates and annular constrictions appear

on its body. The result is a series of lobed discs like a pile of saucers. This process is termed **strobilisation**, and the hydra-tuba is now called a **scyphistoma**.

In December these "saucers" are liberated in succession. Each is a free-swimming **ephyra**; it turns over and becomes a jelly-fish.

The life-history illustrates alternation of generations or **metagenesis**.

CLASS ACTINOZOA OR ANTHOZOA.

ORDER ALCYONARIA.

Alcyonium.

Describe the general Appearance of an Alcyonium Colony.

The colony basis is a whitish, more or less lobed and pulpy mass (the **cœnenchyme**) from which the numerous polyps project. It consists largely of dense **mesogloea** jelly which is developed extensively from the bases of the polyps.

The polyps have **pinnate tentacles**; they are deeply embedded in the mass, and arise from **stolons** or **endodermal tubes** within the mass.

Describe the Structure seen in a Section cut through the Colony Mass of Alcyonium.

The **cœnenchyme jelly** (**mesogloea**) has a honeycombed appearance; it is traversed by the large **cœlentera** of the polyps and by the smaller **endodermal tubes** and **corals** connecting them. Each **cœlenteron** shows the eight **mesenteries** of the polyp. Numerous **spicules** are scattered throughout the jelly substance. The spicules are most abundant about the colony surface and around the polyps.

When the projecting Part of an expanded Alcyonium Polyp is examined under a Lens, what Structures are seen?

Eight pinnate and hollow tentacles surrounding the mouth, the gullet (**stomodæum**), the eight mesenteries

(free below the gullet), and the mesenterial filaments or folds of the free edges of the mesenteries.

Explain the Structures seen in a transverse Section of the Polyp of Alcyonium (a) through the Stomodæum Region, (b) below the Stomodæum.

(a) The wall of the polyp tube consists of outer ectoderm and inner endoderm with a thickened mesogloea between.

Outgrowths of the wall, the eight mesenteries, pass across to the central gullet or stomodæum, and thus the coelenteron cavity is partitioned into eight chambers.

The gullet has (at the so-called ventral side) a deep ciliated groove called the siphonoglyph.

On the ventral sides of the eight mesenteries (i.e., the sides facing towards the siphonoglyph) there are powerful longitudinal muscles. The two mesenteries at the siphonoglyph side are the directive mesenteries.

(b) The mesenteries are free, and upon their free edges are the mesenterial filaments. Otherwise the structure is similar in both sections.

What is the Function of (a) the Siphonoglyph, (b) the longitudinal Muscles?

The siphonoglyph, by means of its powerful cilia, keeps up the water current when the outer part of the gullet is choked with food and thus ensures respiration.

By means of the longitudinal or retractor muscles the polyp can suddenly draw in.

Order Zoantharia.

Comparing a Sea-anemone (e.g., Actinia or Peachia) with Alcyonium, what are the chief Structural Differences?

Ordinary sea-anemones do not form colonies, Their hollow tentacles are not pinnate and are numerous (*Peachia* has twelve). There are six or more pairs of primary mesen-

teries (six pairs in *Actinia* and *Peachia*), and besides these there may be secondary and tertiary mesenteries which are shorter and do not join the gullet (*Actinia* has both, *Peachia* has secondaries only).

The gullet has usually two siphonoglyphs (*Peachia* has one). The pair of primary mesenteries opposite each siphonoglyph are directive, and the muscles are on their outer surfaces, not facing. The other mesenteries have the muscles facing, on their inner surfaces.

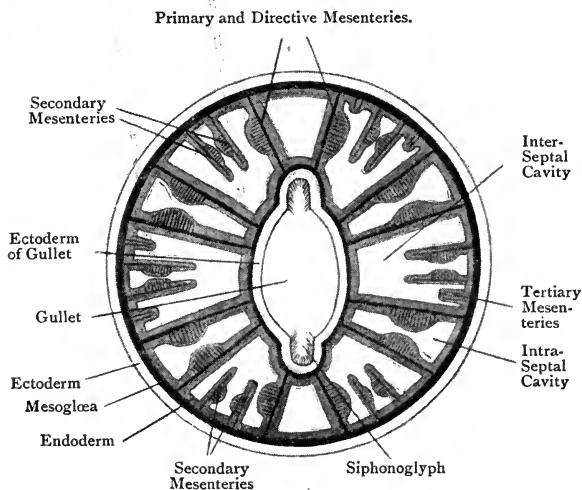


FIG. 20.—Transverse Section of a Sea-Anemone.

The mesenteries often have special stinging threads (acontia) which are protruded through openings in the body-wall. (*Peachia* is without acontia.)

There is a circular sphincter muscle around the oral margin, and by its constricting action the oral region can be completely closed in. There are no sense organs.

How are Corals formed? Give some Examples.

By felting together of the spicules to form tubes (e.g., *Tubipora*, the Organ-pipe coral), by fusion of the spicules to form a supporting axis (e.g., *Corallium*, the Red Coral), and by an accretion of lime about the base of the body (e.g., the colonial sea-anemones of the Order Madreporaria form the well-known hard cup-shaped corals of the coral reefs).

ZOOLOGY.

THE INVERTEBRATA.

PHYLUM PLATYHELMINTHES (FLAT WORMS).

State the principal distinctive features of the Platyhelminthes.

The body, flattened dorso-ventrally, is usually either leaf-like or tape-like; in some instances it approaches a cylindrical shape. Between the ectoderm and the endoderm there is a mesenchyme tissue, the parenchyma, certain cells of which have muscular processes and form strands of unstriped muscle. There is no coelomic body-cavity.

The alimentary canal, when present, has only one opening, the mouth. The central nervous system consists of two united ganglia (cerebral ganglia) formed from the massing together of nerve cells, and giving off lateral nerves. There is a definite and ramifying excretory system (flame-cells with tubules leading into larger canals) for removing the body wastes. The reproductive organs communicate with the exterior by genital ducts. There are accessory yolk and shell glands for providing the eggs with nutrient food-yolk and with tough resistant shells. Nearly all the Platyhelminthes are hermaphrodite. Reproduction is sexual and asexual (by budding or by segmentation); both modes occur in the life-history of certain species.

Many Platyhelminthes are parasites in or on other animals; but there are free-living forms (e.g., Planarians).

*Describe the Excretory System of the Platyhelminthes.
What is a Flame-Cell?*

Certain cells grow from the ectoderm into the parenchyma; these have tubular processes and form a ramifying

A Classification of the PHYLUM PLATYHELMINTHES (FLAT WORMS).

Class TURBELLARIA (Planarians, Eddy Worms). The body soft and generally leaf-like in form; the integument a ciliated epithelium. Certain cells of the ectoderm secrete small rod-like bodies (rhabdites) which are extruded under irritation. The gut or food canal is often branched and has a protrusible muscular pharynx. Sense organs ("eyes") are present. Most are free-living; a few are parasitic.

Class TREMATODA (Flukes). Usually leaf-like, and with one or more adhesive suckers which sometimes have chitinous hooks. The body integument a thick elastic and resistant cuticle. The gut forked; the forks often branching freely (caeca). Reproductive system complex and frequently diffuse. Most are hermaphrodite; self-fertilisation normal. External or internal parasites causing disease in Man and animals.

Order Monogenea. A posterior sucker, and the anterior sucker (when present) double. Excretory system opens by two dorsal pores. Development (in one host only) direct, only one larval form (monogenetic). Chiefly external parasites.

Order Digenea. Two suckers. Excretory system opens by a posterior pore. Development (involving two hosts) indirect, different larval forms (digenetic). Internal parasites.

Class CESTODA (Tapeworms). The body of the adult tape-like, and composed of one or numerous joints (proglottides). Adhesive organs on "head" or scolex. The body integument a thick elastic and resistant cuticle. There is neither a mouth nor an alimentary canal. Most are hermaphrodite; self-fertilisation normal. The larva a "bladder-worm". Internal parasites causing taeniosis and hydatid disease in Man and animals.

Examples, Convoluta. Marine.
Planaria and Polycelis. Freshwater.
Bipalium. A large land planarian.
Leptoplana. Marine.

Example, Polystomum of Frog.

Examples, Fasciola, syn. Distomum. (the Liver-fluke of the Sheep). An incidental parasite in Man.
Paragonimus. A pulmonary fluke of Man.
Schistosoma, syn. Bilharzia (the Blood-fluke of Man).

Examples, Bothriocephalus (the Broad Tapeworm of Man).
Taenia. Various species parasitic in Man and animals.

system of extremely fine excretory tubules. The tubules join to form larger canals that unite together into one or more main canals (collecting tubes) which open to the exterior by one, two, or many pores.

The flame-cell is the first portion of an excretory tubule, the slightly dilated part with the blind end. It has delicate protoplasmic processes extending into the parenchyma, a nucleus at the blind end, and a somewhat conical cavity continuous with that of the tubule. At the base of the cavity there is a bunch of cilia which in vibratile action resembles a flickering flame.

CLASS TREMATODA (FLUKES).

What is the general course of development in a Monogenetic Trematode?

The ectoparasitic Monogenea affect one host only (e.g., a fish or a frog), the development is direct. The eggs are developed outside the parent. The ciliated embryos or larvæ are often free-swimming. After a simple metamorphosis, the adult state is attained.

Structure and Life-History of Fasciola, syn. Distomum (the Liver-fluke).

Where is the Liver-fluke (Fasciola hepatica) found? Which diseases does it cause?

The adult Liver-fluke commonly infests the bile-ducts of the sheep and other herbivorous mammals in many parts of the world, and produces the wasting disease known as "liver rot." In Man it is a rare incidental parasite.

N. B. — When a parasite occurs occasionally in a host which is not its usual or specific host, it is then said to be incidental to that host.

What is the General Appearance of the Adult Liver-fluke?

It is about an inch long, flat and oval, and has at the broader "shoulder" end a characteristic blunt triangular

projection (the cephalic cone), at the tip of which is the mouth, within the small anterior sucker. On the mid-ventral surface, near the "shoulder," there is a large and blind sucker; and between the two suckers there is a small opening, the genital outlet, through which the penis may be protruded. The cuticle has transverse rows of minute spines.

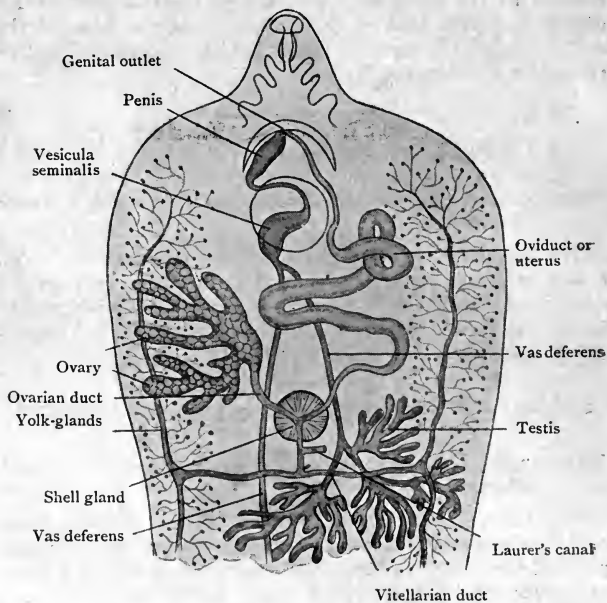


FIG. 21.—The Liver-Fluke (*Fasciola hepatica*). After SOMMER.
Showing the Reproductive Organs.

Describe the Alimentary System of the Liver-fluke.

The mouth leads into a short muscular pharynx which opens into the blind intestine. The intestine immediately bifurcates into two long tubes which are near together,

one on each side of the middle line; they extend the whole length of the body and give off numerous diverticula (caeca) short ones from their inner sides, long and branching ones from their outer sides.

NOTE.—For main features of Nervous and Excretory Systems of the Liver-fluke, see *Platyhelminthes*, page 89.

Give an Account of the Reproductive System of the Liver-fluke.

The Liver-fluke is hermaphrodite, each individual having two sets of organs (male and female).

Male organs.—There are two (tubular and branching) testes, one behind the other in the central area of the body. Each has a long duct, the vas deferens. The spermatozoa pass by the vasa deferentia into the short vesicula seminalis which is situated in front of the ventral sucker, and which leads into a thin ejaculatory duct that opens into a muscular cirrus or penis. The penis opens into the genital outlet. The vesicula seminalis, ejaculatory duct, and penis occupy a slight cavity, the cirrus sac, between the ventral sucker and the genital outlet.

When expulsion of the sperms is about to take place, the penis is protruded by evagination; the ejaculatory duct is then telescoped inside the penis, and the openings are correspondingly transposed.

Female organs.—On the right side, in front of the anterior testis, is the ovary; it resembles the testis, but is less extensive, and a short narrow ovarian duct issues from it. Along the whole length of the body, on both sides, numerous yolk-glands and their ducts form a diffuse branched system opening into two transverse yolk or vitellarian ducts which meet together in a small median reservoir. This reservoir gives off a small median vitellarian duct which joins the ovarian duct to form the wide and convoluted oviduct or uterus. The uterus narrows as it nears the genital outlet where it opens beside the penis.

The eggs are fertilised before they reach the uterus; and each egg, along with some nutrient yolk from the yolk-glands, is enclosed in a tough "shell" secreted by

the shell gland which surrounds the junction of the ovarian and vitellarian ducts. From an opening on the dorsal surface a short Laurer's Canal (with a sperm reservoir) passes to the aforementioned junction: its significance is not clearly understood.

Describe the Life-History of the Liver-fluke, Fasciola (syn. Distomum) hepatica.

The eggs passed out in the faeces of the sheep, are spread about the pastures; and after a few weeks, in wet situations, the miracidia hatch out. The miracidium is a minute conical ciliated embryo with a simple gut, a cerebral ganglion with two simple eyes, and two flame-cells with excretory vessels. It swims about for a time; then it enters a freshwater snail (*Limnaeus truncatulus*) which is common in pools and marshy fields; and, in the snail's mantle cavity, it becomes a sac-like sporocyst (without internal organs).

Germ cells, which were formed from the internal lining of the body wall of the miracidium, develop in the sporocyst (paedogenesis) into germ balls or morulae; and these develop into rediae, forms with a simple gut and a "birth-pore." About six rediae emerge from each sporocyst; they bore into the liver or other parts of the snail, and they produce (paedogenesis) the cercariae. In the summer months, the rediae develop a second generation of rediae from which the cercariae are produced. About fifteen cercariae emerge (by the "birth-pore") from a redia.

The cercaria has the internal organisation of the adult fluke; it has also a tail for active locomotion. It leaves the intermediate host (*Limnaeus*) and attaches itself to some plant or blade of grass, then casts off the tail and encysts. This stage is attained about the end of summer. When the grass is eaten by the sheep, the young flukes escape from their cysts and force their way into the bile-ducts where they become adult.

This life-history illustrates metagenesis or alternation of generations; but it is an alternation of a true sexual generation, not with asexual but with sexual generations

of the parthenogenetic type, i.e., heterogamy (see page 13 of "Catechism" Zoology, Part I.). Further, the parthenogenesis here exhibited is strictly paedogenesis, i.e., development of young by a sexual (parthenogenetic) process from individuals not adult.

Name three Trematodes which are Parasites of Man, and state what you know about them.

Fasciola (syn. *Distomum*) *hepatica*, the Liver-fluke of the sheep, is a rare incidental parasite in the liver of Man. It appears to be frequent in North Lebanon as a parasite in the pharynx, causing the illness known as "Halzoun."

Paragonimus ringeri, a pulmonary fluke, in Japan and China, is found in the lungs and bronchi.

Schistosoma (syn. *Bilharzia*) *haematobium*, the Blood-fluke of Man, is common in Egypt and occurs frequently in other parts of Africa. It is a parasite of the blood vessels, particularly the portal vein and its tributaries, and is the cause of endemic haematuria.

The sexes are separate. The male *Schistosoma* is about half an inch long and has a rounded appearance, the edges of the body being rolled in ventrally to form the gynae-cophoric canal in which the longer and thread-like female is carried about. The egg has a peculiar terminal spine. The natural intermediate host is a freshwater snail, *Bullinus*.

CLASS CESTODA (TAPEWORMS).

Write a general Description of a typical Tapeworm, e.g., Taenia solium.

The so-called head and the thin neck together form the scolex, the small vegetative portion of the body. The succeeding generative portion is a tape-like series of about 800 flat joints or proglottides, varying in length from two to three metres.

The scolex is globular: it has four hemispherical suckers round the base, and a crown or rostellum with a circlet of recurved hooks.

Each proglottis is budded from the neck of the scolex; as the number increases, the one first formed is pushed further and further away and is the hindmost of the "chain." The result of this intercalary mode of growth is a regular gradation in size, shape and internal development. The proglottids of the anterior portion of the "chain," being the youngest, are narrow and short; those of the middle portion are larger, progressively square in shape and approaching maturity; while those of the terminal portion, the oldest, have attained the lengthened rectangular

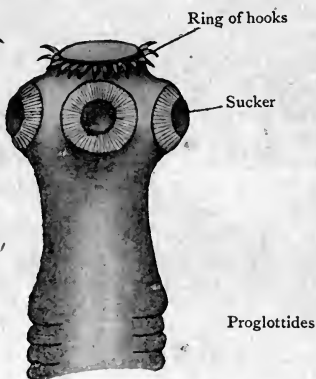


FIG. 22.—**Scolex of *Taenia solium*.** (Highly magnified.)
After LEUCKART.

form and are, most of them, ripe or gravid, ready to detach themselves from the "chain."

The tapeworm has no mouth and no alimentary canal; nourishment is obtained from the gut contents of the host by absorption through the whole body surface (endosmosis). The main nervous system consists of a commissural plexus in the scolex, and two longitudinal nerve-strands with accessory nerves which pass through the whole series of proglottides. The branching excretory system (flame-cells, tubules and collecting tubes) is also continuous throughout the entire worm.

The hermaphrodite reproductive system is repeated in each proglottis. The male organs are formed first. The male and female sexual orifices open together into a **genital atrium** or external opening which is situated (in rough alternation) on the right or on the left side of the proglottis.

Describe the Structure of a Mature Proglottis.

The outer cortex consists of thick cuticle and longitudinal muscles. Underlying this is a layer of circular muscles surrounding the inner parenchyma in which the reproductive organs are embedded.

At each side of the proglottis are the portions of the longitudinal nerves and the excretory canals. Connecting the latter, is a transverse vessel, across the posterior end. The greater part (of the mature proglottis) is occupied by the fully-developed hermaphrodite reproductive system. The male organs, small pear-shaped testes, are numerous throughout, but more towards the surface which is regarded as dorsal. The ducts (*vasa efferentia*) unite and lead into the convoluted male duct or *vas deferens* which opens into the external **genital atrium**, on the right or the left side. The end of the *vas deferens* is surrounded by a protrusible cirrus or penis. The female organs are in the compact form of a paired ovary or **germarium**, lying in the posterior half of the proglottis and towards the surface regarded as ventral. The female orifice is beside the male opening; and leading from it is the **vagina**, which ends in a dilatation, the **receptaculum seminis**. A short continuation from this joins the oviduct from the ovaries, and the continuation of the oviduct from that junction is called the **fertilisation canal** (within which the eggs are fertilised); it receives the vitelline duct from the **yolk gland** (which supplies the food yolk for the nourishment of the developing embryo), also numerous ducts from the **shell gland** (the secretion of which forms the egg "shell"); and it is further continued as the **uterine canal** which enters the expansive and blind uterus proper.

What is a Ripe or Gravid Proglottis?

One in which only traces of the reproductive organs remain, excepting the uterus which is greatly distended and full of developing eggs or embryos (onchospheres) within their tough "shells." The embryo, oval or spheroidal, has six chitinous hooks (hexacanth embryo).

Describe the Life-History of Taenia solium, and state how this Parasite is transmitted to Man.

The Pork Tapeworm lives attached to the mucosa of the small intestine of Man. It is white, and frequently attains a length of from six to ten feet.

The gravid proglottids are detached and pass out in the faeces; and (in places where unsanitary conditions exist) the encapsuled embryos (or the proglottids containing them) are swallowed by the omnivorous pig. The capsules are dissolved by the digestive juices, and the hexacanth embryos are liberated; they bore into the wall of the intestine and, entering the blood vessels, pass to the connective tissue between the muscles. There they increase in size and develop into hollow cysts filled with fluid. The wall of the cyst or bladder becomes invaginated at one point, and the bottom of this pouch is formed into a scolex which is everted within the pouch. This is the asexual stage, a "bladder-worm" of the kind called a *Cysticercus*. In the pig, *Cysticercus cellulosae* causes the disease known as "measles."

When diseased or "measly" pork (i.e., pork infested with *Cysticercus cellulosae*) is eaten by Man, the bladder-worms are then transmitted. In the small intestine the scolex is everted, and by its hooks and suckers it becomes attached to the mucous membrane; the bladder is dissolved, and, by budding out a chain of proglottides, the tapeworm is formed.

Taenia solium is also transmitted in the embryo stage to Man, by drinking water or eating vegetables (e.g., salads) contaminated with the onchospheres, and, frequently, through habits of personal uncleanness in defaecation. The resulting *Cysticercus* is generally developed in the

brain and the sub-cutaneous tissue; and it is the more dangerous stage of this parasite.

State briefly the Life-Histories of Taenia serrata and Taenia canina or cucumerina (syn. Dipylidium caninum).

Taenia serrata is a common tapeworm of the dog. The shed proglottids are swallowed by rabbits and hares while feeding. Via the stomach wall and the portal vein, the embryo enters the liver and passes to the omentum, where it attaches itself and becomes a bladder-worm, *Cysticercus pisiformis*. When the viscera of an infected rabbit or hare are eaten by a dog, the bladder-worms are introduced into the gut and the tapeworm is then developed.

Taenia canina (syn. *Dipylidium caninum*) is the commonest tapeworm in the dog. It is also recorded as occurring occasionally in Man (in children). Its larva is a Cysticercoid (i.e., a bladder-worm which has a small bladder with a slight or obliterated cavity and a solid tail-like portion that is ultimately cast off) and it lives in the dog louse (*Trichodectes canis*), the dog flea (*Ctenocephalus canis*), and the flea of Man (*Pulex irritans*). The infection of dogs and cats is brought about by biting or swallowing their own lice and fleas; transmission to human beings may be effected if an infested dog or cat happens to lick the face or hands of a child.

Give short Accounts of Taenia saginata and Taenia coenurus.

The Beef Tapeworm (*Taenia saginata*, syn. *T. medio-canellata*) lives exclusively in Man, in the small intestine. It attains an average length of from 4 to 10 metres. The scolex is cubical and has four suckers; and, instead of a rostellum, there is an unarmed sucker-like organ. The larval stage, *Cysticercus bovis*, lives in the ox, and it is transmitted to Man when "measly" beef is eaten raw or under-cooked. This is the commonest tapeworm of Man; its growth is exceptionally rapid, and the proglottids have the power of independent movement.

Taenia coenurus is a common tapeworm in sheep-dogs. When mature its average length is about twelve inches.

The ripe proglottids are passed out in the dog's faeces and soon decay. The embryos, scattered about the pasture, are swallowed by lambs or sheep while grazing; and, penetrating the intestine wall, they enter the blood-vessels, and in that way reach the brain or spinal cord. In the brain, the embryo becomes a big bladder-worm of the *coenurus* type, *Coenurus cerebralis*, which is sometimes as large as a hen's egg; and as many as three or four hundred scolices (potential tapeworms) may be formed within it.

These hydatids in the brain of the sheep cause the malady known as "sturdie" or "staggers," generally fatal; and when they occur in the spinal cord, the result is "lumbar-gid," a paralysis of the hindquarters. The dogs become infested with the tapeworms by eating the heads of the dead sheep.

Describe Taenia echinococcus, its Larva and its Life-History.

Taenia echinococcus is, in some parts of the world (e.g., Iceland, and parts of Australia), a common tapeworm in dogs. It is very small, rarely longer than five millimetres, and has only three or four proglottides, the terminal one being the largest.

The larva, an *Echinococcus*, lives in the liver, lungs, and other organs of cattle, dogs and other domesticated animals; it also frequently occurs in Man. This hydatid "may (in Man) attain the size of a child's head." The rounded bladder or cyst, which contains fluid, is enclosed in a sac of connective tissue ("spurious capsule"); and the bladder wall, which is thin, consists of an outer cuticle (ectocyst) and an inner germinal or proligerous layer (endocyst).

In domesticated animals (e.g., cattle) the bladder sometimes remains barren, producing no scolices (an acephalocyst). Usually, however, a great number of brood capsules arise from the germinal layer, and within these many scolices are formed. The brood capsules may go free and may rupture, liberating the scolices. Free brood capsules and scolices in the bladder-cavity fluid are known as "hydatid sand."

In Man, secondary cysts are formed in the cuticle (from detached germinal parts); and these pass into the cavity,

or to the outside, between the bladder and the sac enclosing it. Some of them are barren (acephalocysts), many of them form scolices or produce brood capsules, while others give rise to a third generation of productive cysts. The original primary bladder or cyst may decay; and the whole brood of cysts is then enclosed by the "spurious capsule."

By this prolific multiplication of scolex-forming cysts, thousands of potential tapeworms result from one Echinococcus. The eggs or embryos, from the ripe proglottids voided by dogs, get spread about everywhere, into water, on food (*N.B.*, water-cress), etc.; and being commonly upon the lips, tongue, and coat of the dog, they are also transmitted directly to human beings through contact (e.g., handling and fondling dogs). Gaining entry to the stomach, they reach the liver and other parts *via* the blood system.

The tapeworm stage does not occur in Man; the larva, the echinococcus, produces dangerous disease.

What is a Multilocular Echinococcus?

A large composite mass of small cysts united together by connective tissue, some of which contain one or more scolices. *Echinococcus multilocularis* occurs in the ox and other ruminants, and in Man. It is most frequent in the liver; and it produces disease invariably fatal.

Write a short Description of Bothriocephalus latus, its Distinguishing Features and its Life-History.

Bothriocephalus or *Dibothriocephalus latus* (the Broad Tapeworm) is a parasite in the small intestine of Man. It is frequent in Russia, Germany, and other parts of Europe. It varies in length from about ten to thirty feet. The scolex is club-shaped and has, instead of suckers, two elongated grooves (bothria). It has no hooklets, therefore it is an unarmed tapeworm.

Ripe portions, consisting of several proglottids, are evacuated; but before that occurs, most of the eggs escape into the intestine (the uterus has an external opening), and they are voided with the faeces.

The embryos hatch out in water, and, having ciliated coats, they swim about for a time. In the intermediate host (a perch or some other freshwater fish) the embryo becomes a plerocercoid larva (i.e., a solid elongated larva, simply a scolex telescoped within its neck). If the fish, raw or underdone, is eaten by dog, cat, or man, the larva then develops (direct) into a tapeworm.

Bothriocephalus latus causes gastric trouble, sometimes anaemia.

PHYLUM NEMATODA (ROUND WORMS).

Mention the Distinctive Characters of the Nematoda.

The smooth white body is cylindrical in shape and usually tapered more or less at both ends. The body-wall consists of a tough outer cuticle, a syncytial ectoderm (i.e., one in which the boundaries of the cells cannot be distinguished, a matrix of protoplasm with scattered nuclei), and a layer of longitudinal muscles divided into quadrants by four thickenings of the ectoderm which project inwards. The muscle cells are remarkable; they consist in greater part of unaltered protoplasm, only their outer borders have contractile fibrils.

The cavity of the body is not a true coelome. The alimentary canal consists of a mouth, a short gullet or oesophagus (stomodaeum), a long mid-intestine, and a short rectum (proctodaeum) with a terminal anus. The main nervous system is a nerve ring round the oesophagus, with associated ganglion cells and a number of anterior and posterior nerves. The excretory system is variable; in many instances there are two lateral vessels which unite anteriorly in a small bladder which opens to the outside behind the mouth.

The sexes are generally separate. The males, which are smaller than the females, often have the terminal portion of the body ventrally incurved. The reproductive organs are simple, tubular, and sinuous. The spermatozoa are amoeboid.

A noteworthy feature of the body tissues of Nematodes

is the absence of cilia ; this is also characteristic of Arthropods. Nematodes move by wriggling ; some are free-living, but most are parasitic during part or the whole of their life, and many of these are important parasites which cause disease in plants, animals and Man.

Structure and Life-History of Ascaris.

Where are the Round Worms, Ascaris lumbricoides and Ascaris megaloccephala, found? What is the effect of these Parasites on their Hosts?

Ascaris lumbricoides is a frequent parasite of Man in all parts of the world ; it is common also in the pig and other animals, and it lives in the small intestine and stomach. The effect is digestive disorder with toxic symptoms.

Ascaris megaloccephala is a large species common in the small intestine of the horse. When numerous, the worms cause intestinal obstruction and death may ensue.

Describe the External Features of Ascaris lumbricoides.

The triangular mouth has three lips bearing sensory papillae. Four lines, which mark the corresponding ectoderm thickenings, may be noticed along the body ; the more prominent two are the lateral lines, the other two are dorsal and ventral. On the ventral line, about 2 mm. from the mouth, is the excretory pore ; and about the same distance from the posterior end is the anus (of female) or cloaca (of male).

The male measures from four to eight inches in length, and about a tenth of an inch in diameter ; the terminal portion of its body is incurved, and two minute genital chaetae or copulatory spicules may be seen projecting from the cloaca. The anal and genital apertures are within the cloaca.

The female is nearly twice the size of the male. The female genital aperture is situated ventrally in a groove encircling the body about two or three inches from the mouth.

How would you dissect Ascaris? Give a description of its Internal Structure.

Cut the specimen along each lateral line; carefully remove the dorsal portion of the body-wall, and pin down the ventral portion. Then proceed to unravel the sinuous tubular reproductive organ or organs, using pins to keep them in position separate from the alimentary canal.

The mouth opens into a short bottle-shaped gullet or oesophagus. This is followed by a long and flattened mid-gut or intestine which passes straight to the posterior end where it narrows to form a short rectum ending in the anus.

In the male the reproductive apparatus is a single coiled tube. The first part, the testis, is long and thin; the succeeding wider portion is the vesicula seminalis, and it ends in a short and thin ejaculatory duct which opens into the cloaca close beside the anus. Two small chaeta sacs, opening into the cloaca, contain the copulatory spicules.

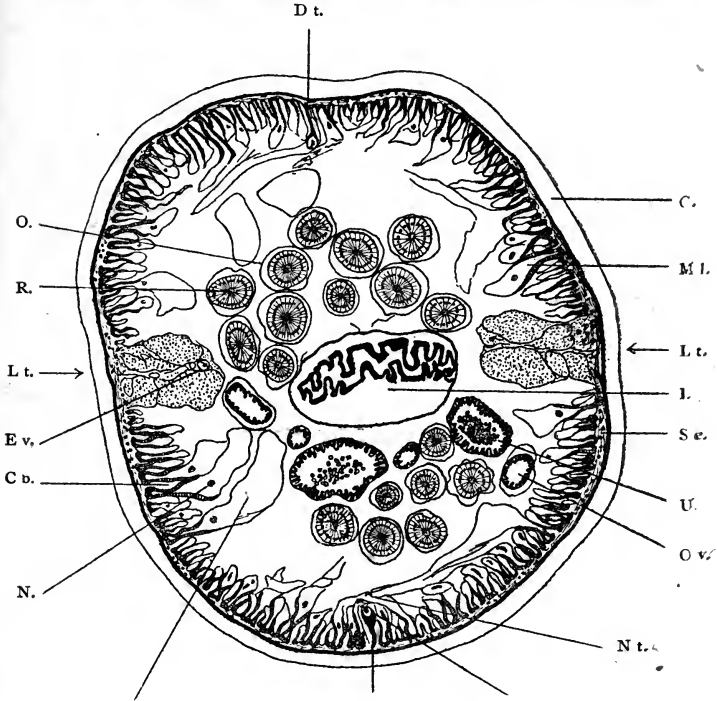
In the female the reproductive organs are double. The first and thinnest portions of the two coiled tubes are the ovaries; the continuous wider portions are the oviducts, and these pass into still wider uteri. The uteri unite to form the short and narrow vagina which opens to the outside by the genital aperture.

In the anterior region, adhering to the body-wall, are four small brown tufts (two on each side), the phagocytic organs.

Explain the Structure of Ascaris as seen in a Transverse Section of the Body, through the Intestinal Region.

Beneath the cuticle is the syncytial ectoderm with two slight (dorsal and ventral) thickenings and two prominent lateral thickenings. Each lateral thickening shows in section an excretory vessel and two nerves. Underlying the ectoderm is the muscle layer. The muscle cells have an elongated form, and chiefly consist of unaltered protoplasm, the contractile substance being restricted to their outer borders. Some of them show the protoplasm drawn out into a nervous tail connected with the nerve trunk of the dorsal or the ventral thickening.

The intestine, large and irregular in outline, is centrally placed. The other structures, of rounded shape, are mostly



D t.	Dorsal thickening	N.	Nucleus.	U.	Uterus
O.	Ovary	P.	Protoplasm	S e.	Syncytial ectoderm
R.	Rachis	V t.	Ventral thickening	I	Intestine
L t.	Lateral thickening	N.	Nerve	L t.	Lateral thickening
E v.	Excretory vessel	N t.	Nervous tails	M l.	Muscle layer
C b.	Contractile border	O v.	Oviduct	C.	Cuticle

FIG. 23.—Transverse Section of *Ascaris* (female). Magnified.

From a photo-micrograph by J. A. BALLANTYNE.

sections of the testis or the ovaries, each showing a more or less compact mass of germ cells around a central rachis

of protoplasm ; but the few larger sections (of vas deferens or of oviducts and uteri) have no rachis. The vas deferens and oviducts contain free gametes ; the uteri contain the fertilised eggs.

State what you know about the Life-History of Ascaris lumbricoides. How does this Parasite gain access to Man ?

The encapsuled eggs are passed out in the faeces of the host and develop in moist conditions (in water or in damp earth). No intermediate host is known. Probably the eggs containing embryos are accidentally swallowed with water or by eating contaminated vegetables.

State briefly what you know about the following Nematodes : Oxyuris vermicularis, Strongylus gigas, Sclerostomum, and Syngamus.

Oxyurus vermicularis (the Pin-worm) is a common parasite of Man (children especially). It occurs in the small intestine (when young) and in the large intestine (when adult). The female is tailed, and about 10 mm. in length ; the male measures 3 or 4 mm.

The movements of these worms, particularly at night, cause intense anal irritation. The eggs may be conveyed (on the fingers) from person to person, or by eating fruit, vegetables, or other articles of food that have been contaminated ; and auto-infection is caused in these ways. Possibly the eggs are carried by flies.

Strongylus gigas (The Giant Palisade Worm) lives as a parasite in the kidneys of the dog, the horse, and other animals ; it rarely occurs in Man. The female is nearly a foot in length.

Various species of *Sclerostomum* (Armed Palisade-worms) are dangerous intestinal parasites of the horse. The embryos of *S. armatum* enter the mesenteric arteries and cause vermiceous aneurisms.

Syngamus trachealis (the Red Gape-worm or Forked-worm) lives in the trachea and bronchi of poultry and game-birds, and is the cause of the devastating disease

known as "gapes." The female is nearly an inch long; the male, which is about a fifth of that size, is generally attached to the female, hence the name "forked-worm." When mature and full of eggs the worms are coughed up; they decay and their eggs, scattered about the ground, are swallowed by healthy birds.

A species of *Syngamus* has been found in Man.

Describe Ancylostoma duodenale and its Life-History.

How does Man become infected with this Parasite, and what is the Result?

Ancylostoma (syn. *Dochmius*) *duodenale*, the "Hook-worm" or Miner's Worm, is a dangerous parasite of Man. It is prevalent among the inhabitants of tropical countries and commonly attacks ground-workers and miners throughout Europe, Africa, China, and other parts of the world. In America it occurs in association with the closely related *Necator americanus*.

The female is about 12 mm. in length; the male measures from 6 to 9 mm. and its body ends in a prominent expansion, the bursa. The mouth is armed with two pairs of cutting teeth, and by this means the worm attaches itself to and feeds on the mucous membrane of the small intestine (jejunum and duodenum). The fertilised eggs are passed out in the faeces and develop in damp soil. The larvae show distinct stages of growth with corresponding moultings of the skin.

There are two ways of infection:—

1. By taking food with dirty hands, or by eating polluted vegetables (a common source of ancylostomiasis in Japan where human faeces are used as manure).
2. Through the skin. The mature larva has a mouth capsule with teeth; it works its way through the skin (of hands or feet) and, via the blood circulation, ultimately reaches the small intestine. "Ground-itch" and other forms of foot-sore in the tropics are attributable to this invasion of the skin.

The ultimate result is severe anaemia of various forms (e.g., Egyptian chlorosis and Miner's cachexia). The marked inertness so characteristic of tropical communities is now associated with life-long infection of these intestinal "hook-worms," which, when numerous, cause a profound grade of anaemia frequently ending in premature death.

How could you distinguish Necator americanus from Ancylostoma? State its Geographical Distribution.

The head of *Necator* is strongly bent upwards; and, instead of cutting teeth, it has two chitinous plates. In America it is found in association with *Ancylostoma*. Their distribution is similar.

Where is Trichocephalus dispar found? Describe its general Appearance.

The Whip-worm (*Trichocephalus dispar*, syn. *Trichuris trichiura*) is a common parasite of Man and monkeys. Its distribution is world-wide. It lives attached to the lining of the caecum and colon. It is seldom dangerous.

The anterior portion of the body is very long and thin, whip-like. The female is about 45 mm. in length; the male is shorter, and has only one copulatory spicule.

Give an Account of Trichina (syn. Trichinella) spiralis, its Life-History, and its effect on Man.

Trichina spiralis is a very small Nematode; the male is little more than a millimetre in length, the female is about three times as long. The natural host is the rat; but *Trichina* also infests other animals, notably the pig; and it is a most dangerous parasite in Man, producing trichinosis, a frequently fatal disease prevalent in many parts of the world, especially North Germany.

The adult worms live in the duodenum and jejunum. After copulation the males die; the viviparous females bore through the mucous membrane and enter the lymph spaces where they bring forth their young, each female giving birth to about 1500 larvae. The larvae are carried by the lymph and blood stream to the heart, and are then

distributed in the blood throughout the body. They penetrate the capillary walls and invade the muscles, particularly those of the tongue, diaphragm, intercostal region, and abdomen. In the muscle tissue the larvae coil themselves up and encyst. The cyst, which may contain one or several larvae, is formed by the inflamed connective tissue; it is oval and membranous, but after a time it becomes limy. There may be many millions of these cysts, and within them the larvae remain quiescent until their host is eaten by a new host. If a rat thus infested is devoured by a pig, the cysts are dissolved in the pig's stomach, and the larvae, thus set free, become sexually mature in two or three days' time. Pigs are also infected when fed with the offal from "trichinosed" pigs.

When the encysted larvae are accidentally swallowed by Man, by eating trichinosed pork undercooked, development follows as already described.

The presence of the adult *Trichinae* in the small intestine causes gastro-intestinal disorder. The invasion of the muscles by the larvae results in degeneration of the fibres, and inflammation, fever, and oedema ensue; later there is marked cachexia.

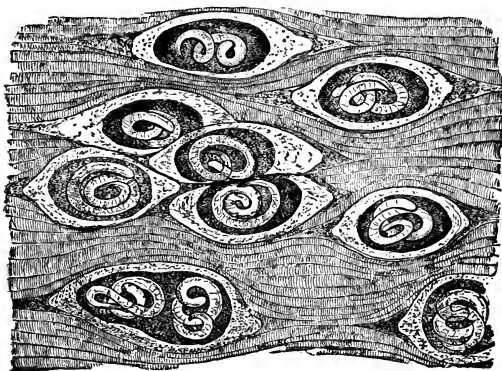


FIG. 24. — "Trichinosed" Pork. (Magnified.)
Showing encysted larvae of *Trichina spiralis*.

Describe *Filaria bancrofti*. How does this Parasite gain access to Man, and what is the Result?

Filaria bancrofti, syn. *Filaria sanguinis hominis nocturna*, is a blood parasite of Man in tropical and sub-tropical countries. It is long and thread-like, and the mouth is without lips and unarmed. The female is from 50 to 65 mm. in length; the male is about half as long, and it has a curved tail with two unequal spicules. The mature females live in the lymphatic glands; the larvae (*Microfilaria bancrofti*) are found in the blood.

The intermediate host is the mosquito (various species, but chiefly *Culex fatigans*) which convey the larvae (or *Microfilariae*) to Man. The larvae escape from the mosquito's labium while it is in the act of "biting"; being too large, they are not introduced directly into the blood, they work their way through the skin.

Culex fatigans "bites" only at night. In connection with this it is noteworthy that these larvae (*Microfilariae*) show a definite periodicity, appearing in the peripheral blood circulation during the night, and retiring during the day to the deeper parts, to the lungs chiefly.

The disease caused by this parasite is filariasis. Haematochyluria and certain forms of elephantiasis are prominent symptoms.

What is "Calabar swelling"? Name the Parasite which causes it, and mention what you know about its Life-History.

"Calabar swelling" is a form of filariasis in Man, prevalent in West Africa, especially in the Congo region. It is a transient oedematous condition (of the arms and other parts of the body) due to the migratory movements of the Nematode, *Filaria loa*, which, in its adult state, lives beneath the skin.

The larvae (*Microfilaria diurna*) occur in the blood, appearing in the peripheral circulation during the day. The larvae develop in the salivary glands of female Tabanid flies of the genus *Chrysops* (e.g., *Chrysops dimidiata*).

Infections of both adults and larvae have not usually been found in the same individual about the same time.

Write a short Account of the Guinea-worm.

The Guinea- or Medina-worm (*Dracunculus*, syn. *Filaria medinensis*) is a subcutaneous parasite of Man in tropical Asia and Africa and certain parts of South America (introduced by negroes). It is also found in oxen, horses and dogs.

The male is rarely seen; the females attain a length of from one to six feet. The mouth has two lips, the alimentary canal is atrophied in greater part, and the body is almost wholly occupied by the uterus which always contains great numbers of young long-tailed larvae.

“The worm can be felt beneath the skin like a bundle of string.” When it is ripe for parturition (at about a year old), it usually moves towards the ankle or foot. A vesicle about the size of a penny is formed on the skin; this ruptures, exposing an ulcer from which the worm partly protrudes, and the young larvae are then set free. In water they enter an intermediate host, a species of *Cyclops*, within which they mature. It is probable that infection occurs when water containing infected *Cyclops* is swallowed.

Inflammatory abscess is the condition produced in dracontiasis or guinea-worm disease.

What are Eel-worms? Mention some Examples.

The Eel-worms or Anguillulidae are mostly small and free-living Nematodes found in water, damp earth, etc. Many live in decaying matter and are saprophytic; some are important parasites. The saprophytic and parasitic forms have a cutting-spine in the mouth.

Anguillula aceti (the Vinegar or Paste-eel), is found in vinegar, etc.

Tylenchus devastatrix (Stem Eel-worm) produces “tulip-root” in oats, etc., and is one of the causes of “clover sickness.”

Tylenchus tritici, syn. *scandens* (Wheat Eel-worm), causes “ear-cockles” in corn.

Strongyloides stercoralis is an intestinal parasite of Man.

What is the Interest and Importance of Strongyloides stercoralis (syn. Rhabdonema intestinale)?

The life-history shows alternation of generations or metagenesis of the type known as heterogamy (see "Catechism," Zoology, Part I., p. 13). A free-living rhabditiform generation (*stercoralis*) in which the sexes are separate alternates with a parasitic generation (*intestinale*), the individuals of which are filariform and are either hermaphrodites or parthenogenetic females.

This parasite is found in the intestine of Man, and it is the cause of a form of endemic diarrhoea in Indo-China, Africa, Brazil, and certain parts of Europe. Infection may be by the mouth or through the skin. The worm has been found in association with *Ancylostoma*.

What is the effect of Parasitism (1) on the Parasite, (2) on the Host?

1. Degeneration: organs essential for free life tend to disappear through disuse; and the body of the creature may have undergone alteration so great that its identity can only be established by reference to its development (e.g., *Sacculina*. See account of its life history, page 127).

The degeneration may be slight or considerable, according to the degree of parasitism. In ectoparasites (temporary or permanent) the changes are generally slight, as, for example, the absence of wings in *Melophagus*, a fly which has become a crawling sheep-parasite. In endoparasites the organic changes are generally striking: locomotor structures (e.g., cilia) are lost, in many instances (e.g. tapeworms) there is no alimentary canal, the nervous system is often poorly developed, eyes are usually absent; the whole body may be reduced to a generative sac.

New features are frequently acquired, e.g., adhesive or clinging organs, modification of mouth-parts (as in blood-sucking insects), hermaphroditism, prolific reproduction ("60,000,000 eggs have been computed in a single Nematode worm").

Shelter and a rich source of nutrition are the chief advantages gained by the parasite.

2. In many instances the effect on the host is negligible ; but serious injury or disease is often caused, for example, by parasites infesting the blood, by a bladder-worm situated in the brain, by toxins which the parasitic worms or Helminthes produce.

COELOMATA.

What is a Coelome ?

Distinct from but generally surrounding the enteron or food canal, there is (in higher Metazoa) a space enclosed by a wall of mesoderm ; it is developed from two pouches of the archenteron which become shut off, or from certain cells which are detached from the endoderm and which, by repeated division, form a hollow structure : that is the coelome or true body-cavity (cf. *Mesoblast or Mesoderm*, page 15, Part I., " *Catechism,*" *Zoology*). Its functions are excretory and generative ; it contains a fluid in which there are wandering amoeboid cells (amœbocytes), and these and the cells of its lining remove waste from the body-tissues.

The renal organs of higher animals are largely derived from its wall ; and the reproductive elements arise from a portion of its lining.

Mention the chief Structural Features which distinguish the Coelomata from the Porifera, the Hydrozoa, and the Actinozoa.

The Coelomata have a coelome or true body-cavity, and a layer of mesoderm between the outer ectoderm and the inner endoderm. The embryos are triploblastic (three-layered).

PHYLUM ANNELIDA (SEGMENTED WORMS).

Give the general Characters of the Annelida.

The elongated body is divided into a series of compartments (segments or metameres), and is marked exter-

A Classification of the PHYLUM ANNELIDA (SEGMENTED WORMS).

Class CHAETOPODA. Annelids with chaetae or bristles, either in pits of the skin or on conspicuous outgrowths termed parapodia.

Order Archiannelida. Marine Chaetopoda without chaetae.

Order Oligochaeta. The "head" without appendages. Gills generally absent. Chaetae usually not numerous. Reproductive organs few but localised. Hermaphrodite. Development direct. Asexual reproduction (fission and budding) occurs, and some (e.g., Nais) show alternation of generations.

Order Polychaeta. Marine Chaetopoda. The head, generally distinct, usually bears dorsal tentacles, palps and tactile cirri; and one or other of these may be modified as gills, and there may be gills along the body. Chaetae numerous and on parapodia. No localised reproductive organs. Sexes usually separate and, in certain instances, exhibiting polymorphism (*see* page 122). Development indirect. Asexual reproduction by fission and budding occurs, and there is alternation of generations (*see* page 122).

Example, *Polygordius*. The pelagic free-swimming larva (Lovén's larva) is a typical trochosphere.

Examples, *Nais* and *Tubifex*. Freshwater. *Lumbricus* (Earthworm).

Examples, *Syllis hyalina*, *Syllis ramosa*. } *See* page 123.
Autolytus.
Myrianida.

Aphrodite (the Sea-mouse). Body oval and flattened. The scales or "elytra" (modified dorsal cirri) on the back are covered in by a feltwork of chitinous threads formed from the notopodia.

Nereis (*see* pages 120, 122). *Nereis diversicolor* is viviparous. *Chaetopterus*. Forms a parchment-like tube in which it lives.

[*Terebella*, syn. *Lanice* (the Sand Mason). Lives in a tube made of sand and small fragments of shells and stones. *Polycirrus*. Has numerous very long tentacles, processes of the prestomium.

Arenicola marina (Common Lugworm or Fisherman's Lobworm). Burrows in the wet sand.

[*Sabella*. The modified palps form a crown of filamentous gills. Lives in a tube made of fine mud.

Serpula. Forms a limy tube attached to shells, rock surfaces, etc.

Spirorbis. A tiny Polychaete which forms a limy tube, a flat coil, commonly attached to seaweed (e.g., *Fucus*).

Examples, *Pontobdella*. A marine leech, ectoparasitic on the Skate and other Elasmobranch fishes.

Glossiphonia, syn. *Clepsine*. A common freshwater leech which carries its young attached to its body.

Hirudo medicinalis (the Medicinal Leech). In swamps, ponds, etc. Europe (Hungary) and North Africa.

Haemopsis (the Horse-leech).
Haemadipsa (the Land-leech of the Tropics). Attacks Man, Asia and South America.

Acanthobdella. Ectoparasitic on Teleostean fishes. Chaetae on anterior part of body. Coelome spacious.

nally by rings which correspond more or less closely with the internal segmentation. The body-wall has layers of muscle; and the skin (of most Annelids) bears chaetae (bristles) which aid in movement. The main nervous system consists of a ventral nerve cord and a ring round the pharynx. The cord generally has distinct ganglia, and there are two cerebral ganglia on the ring. There is a blood circulation. The coelome, generally extensive, communicates with the outside by paired nephridia. The gonads are developed from the coelome lining. Reproduction is usually sexual (the sexes are separate in the marine Chaetopoda; earthworms and leeches are hermaphrodite); and the development is either direct (i.e., without a larval stage) or indirect, involving a trochosphere larva.

Asexual reproduction by fission and budding also occurs (e.g., *Nais*, *Syllis*, *Autolytus*).

CLASS CHAETOPODA.

Lumbricus (The Earthworm).

A Type of Oligochaeta.

Describe the Alimentary Canal of the Earthworm, and indicate the functions of the various Parts.

The small oral cavity opens into a wide muscular pharynx which is connected to the body wall by radiating muscles. When these muscles contract, the pharynx dilates and the soil is sucked in. The next part is the narrow gullet or oesophagus, which has on each side three pouch-like calciferous glands; these probably neutralise the acids of the food (the organic débris in the soil). Behind this is the swollen and thin-walled storing crop; it is separated by a constriction from the thick-walled muscular gizzard in which the food is ground. The intestine, which extends from the gizzard to the anus, is the digestive and absorptive portion of the gut; it is a sacculated tube, and its surface is further increased by a deep dorsal fold, the typhlosole. The intestine is covered by a layer of

yellow cells (coelomic epithelium), which have an excretory function.

The food is forced along the gut by the combined action of the circular and longitudinal muscles of the gut wall, the visible effect being that peculiar wavy contraction known as peristalsis.

Give an Account of the Excretory System of Lumbricus.

The principal organs of excretion are the nephridia; there is a pair in each segment except the first three and the last. Each nephridium is a single tube consisting of a minute ciliated funnel, and a looped main portion which is glandular and solid (the duct passing through the cells) and which ends in a wider, non-glandular, and muscular walled bladder opening to the exterior on the ventral surface of the body. The nephridium traverses the thin wall or septum between two segments; so that its funnel is in one segment and its looped portion in one behind. The opening of the funnel in the body-cavity is the nephrostome.

On the walls of the nephridium there are numerous blood capillaries. The waste from the blood is removed by the glandular cells and passed into the tube; and the current caused by the cilia of the nephrostome flushes it into the bladder which, at intervals, discharges to the outside.

The yellow cells also extract waste from the blood; when laden with it they die, and their remains, in the fluid of the body-cavity, are engulfed by the wandering amoebocytes. The amoebocytes go close to the wall of the nephridium, and the effete matter is then removed by the glandular cells.

The coelomic fluid which is exuded through the dorsal pores (one in each groove behind the tenth segment) helps to keep the skin moist and at the same time destroys bacteria.

Describe (1) the Blood System, and (2) the Nervous System of the Earthworm.

1. There is a ramifying system of capillaries and a number of larger vessels which have contractile walls and are

filled with a circulating fluid containing numerous free cells (blood corpuscles). In the fluid there is a red substance, haemoglobin, which (through the skin circulation) takes up oxygen from the outer air. The earthworm breathes by its skin. The capillary walls are so extremely thin, that transference of food and oxygen from the blood to the body tissues and removal of waste are readily effected.

The principal vessels are the dorsal vessel, along the entire length of the alimentary canal, the ventral vessel below the alimentary canal, and, connecting these there are short half-hoop-like vessels (two in each segment) of which five enlarged pairs (in the region of the gullet) are the contractile "hearts." Below the nerve cord there is a sub-neural vessel and two lateral neural vessels. The blood flows forward in the dorsal vessel, and downward through the five pairs of rhythmically contractile "hearts" into the ventral vessel in which the flow is backwards.

2. Along the ventral body-wall there is a median ventral nerve cord, the two halves of which diverge (in the third segment) and form a ring round the pharynx. In each segment the cord is somewhat swollen; each swelling is an aggregation of nerve cells and is termed a ganglion or nerve centre. The largest of these swellings is the double ganglion of the nerve ring (the supra-pharyngeal or cerebral ganglia) connected with which are the small peripheral nerves of the sensitive prestomium (the lobe overarching the mouth). From the ganglion in each segment three pairs of nerves are given off on each side to the body.

In the ectoderm there are scattered sensory cells. Each has a fine sensitive hair which projects through the cuticle, and a delicate afferent or sensory fibril which is connected with a nerve or ganglion cell. Impressions received from the outside through the sensitive hairs are transmitted to the ganglion cells which then convey impulses through their efferent or motor fibrils to the muscles. A bunch of sensory fibrils forms an afferent peripheral nerve; a motor peripheral nerve is composed of efferent fibrils.

Write an Account of the Reproductive System of Lumbricus.

The Earthworm is hermaphrodite. Under the alimentary canal there are two median seminal vesicles (in segments 10 and 11) and, connected with these, three pairs of lateral seminal vesicles. Inside each median seminal vesicle, and attached to the septum in front of it, there is a pair of small lobed testes. Beside each testis is the funnel-shaped opening of a seminal duct. The two short seminal ducts on each side pass through the posterior septa of their respective segments and unite to form the longer vas deferens; the two vasa deferentia open on the ventral surface of segment 15. The sperm-forming cells pass from the testis into the seminal vesicles, and there the active hair-like spermatozoa are formed.

The female organs are two small pear-shaped ovaries, attached by their broader ends to the septum between segments 12 and 13, one on each side of the nerve cord. Opposite them, on the septum behind, are the funnel-like openings of two very short oviducts which open to the exterior on the ventral surface of segment 14. Two small sacs, the receptacula ovarum, open into the funnels of the oviducts. The ripe eggs from the ovaries pass into the coelome, and thence down the oviducts.

When two worms unite (the head of one beside the tail of the other) one of them acts as male; and the spermatozoa, passed out from the vasa deferentia, are received by the other worm into the spermathecae or receptacula seminis, two pairs of globular pockets in segments 9 and 10.

The worm casts off a membranous sheath secreted by the clitellum (a thickening of the integument from the thirty-second to the thirty-seventh annulus inclusive). This sheath is slipped off forwards; passing over the openings of the oviducts and spermathecae, it carries away some eggs, and sperms are squeezed out. The ends of the cast sheath close in, and thus an elastic cocoon is formed containing eggs and sperms. Conjugation follows (fertilisation is therefore external), and the development is direct.

Explain the Structure of Lumbricus as seen in a Transverse Section of the Body, through the Intestinal Region.

The body-wall consists of a thin cuticle secreted by the underlying ectoderm or epidermis. Beneath this are two layers of muscles, circular and longitudinal. On each side of the body-wall there are two pairs of chaeta-sacs, pockets of the epidermis in which are the four pairs of chaetae or bristles.

The space between the muscles and the intestine is the coelome or body-cavity. The "yellow-cells" form an outer coat around the intestine and occupy its deep dorsal fold (the typhlosole). In the "yellow-cells," and above the typhlosole, is the dorsal blood-vessel. Below the intestine is the ventral nerve cord; and between it and the intestine is the ventral blood-vessel. Just beneath the nerve cord is the sub-neural vessel.

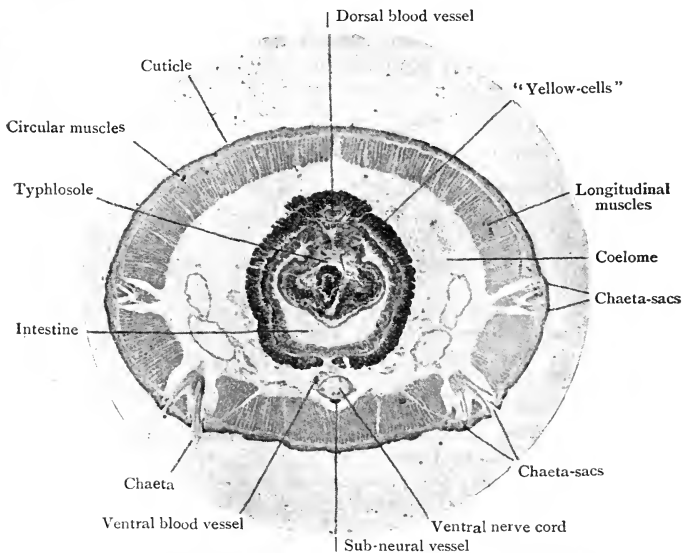


FIG. 25.—Transverse Section of Earthworm (*Lumbricus*).

How does the Earthworm move?

The contraction of the longitudinal muscles shortens the body; the chaetae then project, and stick into the ground, and thus a firm hold is secured. When the circular muscles contract, the body lengthens out and the chaetae are accordingly withdrawn.

Arenicola (The Lobworm).**A Type of Polychaeta.***State briefly the External Features of the Lobworm.*

The body has three distinct regions: an anterior region of seven segments, each of which (except the first) has two lateral tufts of bristles; a middle region of thirteen segments with bristles and also gills or branchiae; and a thin posterior region, which varies in length and number of segments and which has neither bristles nor gills. The mouth is overarched by the prestomium; the anus is terminal.

Describe a typical Parapodium (e.g., of Nereis), and compare with it the Parapodium of Arenicola.

The parapodia, which function as limbs or (when modified) as swimming organs, are hollow lobed outgrowths of the sides of the body-wall. Typically each parapodium consists of two similar halves, a dorsal notopodium and a ventral neuropodium; and each of these has a bunch of chaetae or bristles and a large needle-like bristle called the aciculum. There is also a dorsal tactile cirrus on the notopodium, and a similar ventral cirrus on the neuropodium. The chaetae are lodged in setigerous sacs, and can be pushed out or withdrawn. In many instances the cirri are flattened and leaf-like for swimming; and are sometimes adapted to form gills.

In *Arenicola* the parapodium is reduced. The notopodium is a small process with a tuft of setae; and the neuropodium is a separate flat and narrow pad bearing a row of minute hooks.

Give a short Account of the Food Canal of the Lobworm.

The buccal cavity, which has papillae, opens into a short pharynx. This part of the gut is frequently everted. The next portion, the narrow gullet, has a posterior pair of oesophageal glands. The succeeding gastric portion or "stomach" is wide and is covered with "yellow-cells." The narrower intestine extends from the end of the "stomach" to the terminal anus.

The foremost and hindmost parts of the gut are supported respectively by three anterior septa and numerous posterior septa of the body cavity; in the middle portion of the body, where there are no septa, the gut lies free.

Describe the main Nervous System of Arenicola.

There is, as in *Lumbricus*, a ventral nerve cord and a nerve ring; but there are no ganglia on the cord, and the cerebral ganglia are represented by slight swellings of the ring.

Indicate the General Course of the Blood Circulation of the Lobworm, mentioning the Principal Vessels.

The aerated blood is conveyed from the gills to the body by seven pairs of efferent branchial vessels (from the seven posterior pairs of gills) which enter the dorsal vessel, and by six pairs of efferent branchial vessels (from the six anterior pairs of gills) which enter sub-intestinal vessels. The flow of the purified blood is mainly forwards.

Impure blood is returned *via* the lateral vessels to a pair of contractile "hearts" (above the front end of the "stomach"), each of which consists of a thin-walled auricle and a muscular ventricle. The blood is pumped by the ventricles into a ventral vessel; and, flowing backwards, it is distributed to the gills through the thirteen pairs of afferent branchial vessels.

How does the Lobworm breathe?

By means of its thirteen pairs of external gills or branchiae; small hollow and branched processes, through the delicate walls of which the blood absorbs oxygen from the water.

State what you know about the Reproductive System of *Arenicola*.

The sexes are separate. The reproductive elements or gametes arise from patches of the coelomic epithelium which covers the nephridia. (There are six pairs of nephridia in the anterior region of the body.) The gametes are liberated in the body cavity, and pass through the nephridia to the outside.

Reproduction and Development of Polychaeta.

Write an Account of the Reproduction and Development of *Polychaetes*.

The sexes are generally separate and the sex cells or gametes are always formed from the coelomic epithelium. The development is indirect; the segmentation of the egg results in a pelagic free-swimming larva of the trochosphere type. This trochosphere has the appearance of two small cones attached together at their bases; there is a single or double girdle of cilia around the middle, the mouth is situated at the girdle, and the anus is at the apex of the lower cone which lengthens out and becomes segmented as the body of the future worm. The upper part of the trochosphere becomes the head.

In certain species of the genus *Nereis* (when sexually mature) the posterior (sexual) portion of the body is strikingly different from the unchanged anterior (non-sexual) portion; the parapodia having been transformed into leaf-like swimming appendages. This is called the "Heteronereid" phase.

In many instances (e.g., *Nereis dumerilii*) there are also different forms of both sexes (polymorphism).

In the family Syllidae similar reproductive phenomena occur; but there is also asexual reproduction by fission and budding, a sexless worm producing one or more worms of one sex (i.e., schizogamy, showing alternation of generations). Illustrative of this are the following:—

Syllis hyalina. The posterior sexual half of the "heterosyllid" separates by fission from the anterior non-sexual half, and forms a new head.

- Autolytus* . A chain of individuals of one sex is developed. The hindmost (the first-formed) being the original sexual half of the "**heterosyllid**"; the intervening ones are produced by budding from the zone of fission. All acquire heads *before* separation.
- Myrianida* . A chain of individuals of one sex is developed by budding from the tail of an asexual worm, the hindmost zooid being the one first formed.
- Syllis ramosa*. This worm forms lateral buds, and these in turn form buds, the result being a **much-branched colony**. Some of the individuals develop sexual organs and go free.

CLASS HIRUDINEA, OR DISCOPHORA (LEECHES).

Hirudo medicinalis (The Medicinal Leech).

Describe the External Features of the Leech.

The flattened body, which is regularly marked on the dorsal surface and mottled on the ventral surface, has, at the front end, a small anterior sucker within which is the mouth, and, at the terminal end, a larger blind posterior sucker. The anus is dorsal, in the constriction in front of the posterior sucker. There are about 100 skin rings on the body. Five rings correspond to a segment, except at the ends of the body; and most of the segments are indicated by the large dark spots on every fifth ring. On the dorsal surface at the anterior end there are five pairs of "eyes." On the ventral aspect, between rings 30 and 31, is the male aperture (from which the penis is sometimes seen protruding); and five rings behind it is the female aperture. Also ventral are the openings of the nephridia (seventeen pairs), each pair five rings apart.

How does the Leech move?

In a looping way, by alternately fixing and releasing its suckers.

How does the Leech feed? Describe the Alimentary System.

The leech is a temporary ectoparasite. It presses its sucker-mouth firmly on the skin, and by means of three chitinous toothed plates, it makes a triradiate cut. The blood is then sucked in by the muscular pharynx, into which certain gland cells secrete a ferment that prevents clotting.

The blood is stored in the crop, the largest part of the gut, which has eleven pairs of pockets. The last pair are the longest, and lie one on each side of the narrow terminal rectum. Digestion takes place in the very small stomach which is situated between the last pair of storing pockets and the beginning of the rectum. If the crop has been filled, the process of digestion may occupy many months.

Give a short Account of the Nervous System of Hirudo.

It consists of a ventral nerve cord with ganglia, and a nerve ring round the pharynx with a double ganglion (the supra-pharyngeal ganglia). The nerve cord is within the ventral sinus.

How does the Leech breathe?

By the skin, where the blood is oxygenated.

Describe the Structure of the Nephridium of Hirudo.

The glandular main portion is U-shaped and twisted; it consists of cells traversed by a complex system of fine ducts, and its walls are richly supplied with blood capillaries. It ends internally in a "cauliflower lobe" which has minute pores. This lobe is also known as the "testis-lobe," because it is situated in a sinus above the testis. The terminal portion of the nephridium has a muscular and ciliated bladder communicating with the exterior by a short duct. The Leech has seventeen pairs of excretory nephridia.

Write a short Description of the Reproductive Organs of the Leech.

The Leech is hermaphrodite. The male organs are nine pairs of testes (along the sides of the ventral sinus), com-

municating by short and sinuous ducts (*vasa efferentia*) with two longitudinal *vasa deferentia* which end in two convoluted tubular epididymes or seminal vesicles. From each of these a short duct leads into the swollen base of the penis, where the spermatozoa are formed into packets.

The female organs are two small ovaries enclosed in globular sacs (situated behind the base of the penis). Leading from the sacs are two small oviducts; these

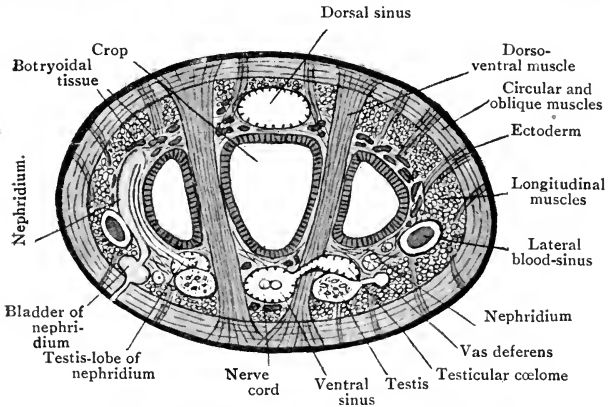


FIG. 26.—Transverse Section of Leech (*Hirudo*).

After BOURNE.

unite to form a convoluted duct which widens out as the “uterus,” opening to the outside. Fertilisation is internal. The eggs are enclosed in a cocoon. Development is direct.

Explain the Structure of Hirudo as seen in a Transverse Section of the Body.

The body cavity or coelome is greatly reduced (cf. trans. sec. of *Lumbricus*), its place being almost entirely occupied by the spongy botryoidal tissue. The dorsal sinus, the ventral sinus surrounding the nerve-cord, the sinus enclosing the testis and testis-lobe, the sacs enclosing the

ovaries, and (probably) the lateral blood sinuses are remnants of the body cavity.

The body integument consists of a thin cuticle secreted by the underlying epidermis, beneath which is the dermis containing a plexus of blood capillaries. The next layer is the circular and oblique muscles; and between that and the botryoidal tissue surrounding the crop, is the more extensive layer of longitudinal muscles. There are also dorso-ventral muscles which pass from the dermis through the circular layer and between the bundles of longitudinal muscles.

The three central spaces are the crop and two pockets; on the outer side of each pocket is a lateral blood-sinus, and between it and the ventral sinus there is, on each side, a vas deferens.

PHYLUM ARTHROPODA.

State the general Characters of Arthropods, and mention the principal Groups.

The body is segmented and has jointed appendages, in pairs. The segments and appendages are variously modified according to use; one or more pairs of the appendages become gnathites or jaws, and these show striking modifications according to the nature of the food. The cuticle, stiffened by the deposit of a waste substance (chitin), forms a tough exoskeleton, often rigid except about the joints; and it is periodically moulted (ecdysis). Ciliated epithelium is generally absent. The coelome is greatly reduced; there is instead a haemocoel (of blood-carrying spaces). The heart is dorsal. There is a double ventral nerve cord with ganglia, and a nerve ring (round the gullet) with cerebral ganglia. The sexes are usually separate. The eggs generally contain a great quantity of yolk. The development frequently shows metamorphosis. The Arthropods show great variation in habits, and there is a remarkable diversity of forms.

NOTE.—For the principal groups of Arthropods, see “Catechism,” Zoology, Part I., page 18.

CLASS CRUSTACEA.

Mention the Distinctive Features of the Crustacea.

The body is usually divided into three distinct regions: head and thorax (frequently consolidated) and abdomen. The head has two pairs of feelers or antennae, and three or more pairs of gnathites or jaws; the thorax bears the principal appendages of locomotion, and the abdomen often has appendages. The appendages are modifications of a common type which has three parts: a two-jointed basal piece (the protopodite) to which gills may be attached and which bears two branches (outer exopodite and inner endopodite). The exoskeleton consists of chitin impregnated with lime salts. Respiration is by gills or through the skin.

The floating population or "plankton" of the sea and fresh waters largely consists of Crustaceans (adults and larvae) which are pelagic, occurring in myriads at or near the surface; and these (especially Copepods) are the principal food of Fishes.

Where is Sacculina found? Give an Account of its Life-History.

Sacculina carcini is a parasite of the Shore-crab (*Carcinus maenas*). It begins life as a free-swimming Nauplius, a tiny oval larva which has three pairs of limbs and a dorsal shield with two "frontal horns." The Nauplius changes into a Cypris, which has a bivalved carapace and two antennae with prehensile hooks. This Cypris fastens on to a young crab, fixing the hook of one antenna into the base of one of the crab's "hairs" or setae. Then it casts off the greater part of its body; and the remaining small nucleus portion passes through the hollow antenna into the body of the crab and is carried by the blood to the outer wall of the intestine: there it becomes attached and sends out ever-spreading "roots." As its bulk increases, this "*Sacculina interna*" moves down the gut; and when it comes to where the abdomen bends abruptly in upon the thorax, it causes a hole in the integument through

A Classification (abridged) of the Crustacea.

Sub-class ENTOMOSTRACA. Mostly small and simple forms. Number of segments and appendages very variable. No teeth in the gizzard. The excretory organ (the "shell-gland") is associated with the second maxillae. The larva is a Nauplius.

Order Phyllopoda. The appendages leaf-like, for swimming. Dorsal part of head forms a shield or carapace extending over greater part of body.

Sub-order Branchiopoda. Segments numerous. Numerous swimming appendages.

Sub-order Cladocera. Segments few. The carapace generally bivalved. Second antennae used for swimming. A brood-pouch. Parthenogenesis frequent. Freshwater and marine.

Order Ostracoda. The carapace bivalved and enclosing the whole of the body. Appendages few. Both pairs of antennae used for swimming. Parthenogenesis. Freshwater and marine.

Order Copepoda. The body pear-shaped; segments few, and terminal segment modified as a caudal or tail-fork. No carapace. A single median eye. Female has a pair of egg-sacs at sides of body. Important as forming the principal food of Fishes. Many are ectoparasites on Fishes ("fish-lice"). Freshwater and marine.

Order Cirripedia. Adult lives attached by the head-end. Body, not distinctly segmented, is enclosed in a mantle strengthened by outer limy plates. Five pairs of biramous thoracic limbs (fringed with setae) used for "kicking" food particles into the mouth. Usually hermaphroditic. Marine.

Example, Apus, Freshwater.

Example, Daphnia (Water-flea). See page 137.

Example, Cypris.

Example, Cyclops.

Examples, Lepas (Ship-barnacle).
Balanus (A corn-shell).
Sacculina. One of the most degenerate parasites known.
See page 127.

Sub-class MALACOSTRACA. The larger Crustacea. Body shows distinct regions and has 19 segments (head 5, thorax 8, abdomen 6 or 7), and 19 pairs of appendages. Teeth in the gizzard (a gastric mill). Excretory organ usually associated with the antennae. Larva, or larval stages, generally higher than a Nauplius.

Order Isopoda. Body flattened dorso-ventrally. Carapace absent. Eyes sessile (i.e., without stalks). Gills on appendages of abdomen. Development direct.

Order Amphipoda. Body compressed at the sides. Carapace absent. Eyes sessile. Gills on appendages of thorax. Development direct.

Order Decapoda. Carapace fused with segments of thorax, forming a cephalothoracic shield. Eyes compound and on movable stalks. The three anterior pairs of thoracic limbs (maxillipedes) modified as secondary jaws, the five posterior pairs used for walking and seizing. Eggs attached to appendages of abdomen. Generally a complex metamorphosis.

Sub-order Macrura. Abdomen long.

Sub-order Brachyura. Abdomen short, and bent in upon undersurface of thorax. Appendages of abdomen reduced.

Examples, Asellus. Freshwater.

Ligia. Marine.

Porcellio. A terrestrial wood-louse.

Example, Gammarus. Freshwater and marine.

Examples, Homarus (Lobster).

Nephrops (Norway Lobster). The "crayfish of the fish-shops.

Astacus (Freshwater Crayfish).

Palaemon (Prawn). Rostrum well developed. Antennae beneath antennules. First two pairs of legs chelate.

Crangon (Shrimp). Rostrum rudimentary. Antennae on outer side of antennules. First pair of legs sub-chelate

Pagurus or Eupagurus (Hermit-crabs). Abdomen soft. Living in empty Gasteropod shells. Frequently associated with sea-anemones (Partnership or Commensalism).

Examples, Dromia. Generally covered by a Sponge (Masking).

Carcinus (Common Shore-crab).

Cancer (Edible Crab)

Portunus (Swimming-crab).

Inachus and Hyas (Spider-crabs). Frequently plant zoophytes, sponges, algae, etc., upon their bodies and limbs (adventitious protective resemblance).

Gecarcinus. A land-crab

which it issues to the outside. Connected by a peduncle with its absorptive "roots," it becomes an ovoid growth partly concealed by the crab's abdomen. It is now an adult "*Sacculina externa*" and consists of a central "visceral mass" which contains hermaphrodite organs and ducts, cement glands, and a nerve ganglion, and which is surrounded by a brood-chamber that opens to the exterior.

Astacus (The Fresh-water Crayfish).

An Example of the Malacostraca.

Describe the External Features of Astacus.

The head and thorax form a rigid cephalothorax covered by the carapace, a saddle-like shield with a frontal spine (the rostrum) at the sides of which are the eyes, on movable stalks. The abdomen has six movable segments and a flat tailpiece or telson, which, with the last pair of appendages, forms the paddle used for swimming backwards.

The transverse cervical or neck groove on the carapace marks the junction of head and thorax. The dorsal portions of the cephalothorax segments have been fused in the carapace; but ventrally the segmentation is distinct. The floor of the cephalothorax is double; the inner framework, the "endophragmal skeleton," is formed by folded ingrowths of cuticle (apodemes) to which the limb muscles are attached. The sides of the carapace shelter the gills on the thoracic walls and thus form branchial plates (branchiostegites).

The exoskeleton of an abdominal segment consists of four parts: a dorsal arched tergum with side extensions (pleura), a ventral crosspiece or sternum and, between each pleuron and the sternum, a small epimeron, at the inner side of which an appendage is attached. The abdomen can be flexed and extended: each segment slightly overlaps the one behind it, and has two little knobs which fit into corresponding sockets on the overlapped segment.

There are nineteen pairs of (serially homologous) appendages, one pair to each segment. The mouth is on the ventral surface of the head; the anus is ventral on the telson.

What is the typical Structure of a Crayfish Appendage?

A basal piece, the protopodite, bearing two branches, an inner endopodite and an outer exopodite.

Which are the Sensory Appendages of Astacus, and where are they situated? Explain their Structure.

The short first antennae or antennules and the long second antennae or feelers. Both pairs project from the fore-part of the head, in front of the mouth.

The antennules have each a three-jointed protopodite bearing a filamentous and many-jointed exopodite and a similar endopodite. On the upper surface of the basal joint of the protopodite there is a minute sac fringed with delicate setae, the *otocyst*, an auditory and balancing organ. Some of the setae fringing the exopodite have an olfactory sense.

The antennae have two-jointed protopodites (basipodite and coxopodite). The exopodite is a short scale (the squame); the endopodite is long and filamentous. On the basal joint of each protopodite there is an opening of a kidney or "green gland."

Name the Appendages of the Crayfish which have a Masticatory Function, and describe their Parts.

APPENDAGES OF HEAD.	}	The mandibles ...	Protopodite is a hard-toothed gnathobase. Endopodite is a small three-jointed palp. Exopodite is absent.
		1st Maxillae ...	Protopodite forms a blade-like bipartite gnathobase. Endopodite is a small filament. Exopodite is absent.
		2nd Maxillae ...	Protopodite forms a blade-like quadripartite gnathobase. Endopodite is filamentous. Exopodite, joined to epipodite, forms the "baler" or scaphognathite (a respiratory organ).

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APPENDAGES OF THORAX (First three pairs).	1st Maxillipedes	Protopodite forms a blade-like bipartite gnathobase. Endopodite reduced. Exopodite filamentous. The base of this appendage has an attached epipodite, i.e., a gill which has lost its respiratory processes.
	2nd Maxillipedes	Endopodite is leg-like and has five joints; the two lower joints have cutting edges, and along with the protopodite form the gnathobase. Exopodite is long and filamentous. To the base of this appendage a gill (podo-branch) is attached.
	3rd Maxillipedes	Endopodite is large and leg-like, and has five joints; the two lower joints have toothed edges, and along with the protopodite form a strong gnathobase. Exopodite is filamentous. To the base of this appendage a gill (podo-branch) is attached.

Note.—The protopodite is two-jointed in all the above appendages except the mandibles.

Indicate the Structure and Function of the Chelae, Thoracic Limbs and Swimmerets of the Crayfish.

APPENDAGES OF THORAX.	The chelae or "nippers." For seizing food and for defence. Protopodite two-jointed. Endopodite large and five-jointed; the second last joint prolonged to form with the last joint a double claw (chelate). Exopodite absent. To the base of each chela a gill (podo-branch) is attached.
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- 1st Walking Legs ... Same as chelae, but smaller. Each bears a gill (podo-branch).
- 2nd " " ... Same as 1st pair. Each bears a gill (podo-branch). The female has an opening on the base of each leg (female genital apertures).
- 3rd " " ... Not chelate. Each bears a gill (podo-branch).
- 4th " " ... Not chelate. Each bears a gill (podo-branch). The male has an opening on the base of each leg (male genital apertures).

- 1st Swimmerets. Exopodite absent. Protopodite and endopodite fused and rolled in male, so that the two appendages form "tubes" for conveying the seminal fluid to the female. These swimmerets are rudimentary in the female.
- 2nd Swimmerets. Same as first pair in male. In the female the protopodite two-jointed and bearing a small filamentous endopodite and exopodite. Aid in swimming, and carry eggs.
- 3rd, 4th, and 5th Swimmerets. Protopodite two-jointed, and bearing a small filamentous endopodite and exopodite (in both sexes). Aid in swimming, and carry eggs in female.
- 6th Swimmerets. Protopodite stout. Endopodite a broad plate; the exopodite similar and hinged. These swimmerets form, with the telson, the swimming paddle.

Give a short Description of the Gills of Astacus, indicating their Position on the Body. What is the precise Function of the Scaphognathite?

The gills are situated on both sides of the thorax, in the branchial chamber (i.e., the space between the body-wall and the branchiostegite); they are soft, plume-like vascular outgrowths. Each gill consists of a hollow stem and numerous hollow filaments with thin walls, through which the blood takes up oxygen from the water. The stem is divided into two longitudinal vessels (afferent and efferent) with which the filaments communicate.

There are three sets of gills:—

1. The pleurobranchs resemble bottle-brushes. Arising from the body-wall, above the last walking-leg, there is a well-developed pleurobranch; and there are rudiments of two above the 3rd and 2nd legs.

2. The arthrobranchs are like the pleurobranchs; and they arise *in pairs* from the membranes beside the bases of the 2nd (*one gill only*) and 3rd maxillipedes, the chelae, and the 2nd, 3rd, and 4th legs.

3. The podobranchs have flattened and folded stems (epipodites) bearing the filaments; and they arise *singly* from the bases (coxopodites) of the 2nd and 3rd maxillipedes, the chelae, and the 2nd, 3rd and 4th legs. The 1st maxillipede has an epipodite only.

The scaphognathite (of 2nd maxilla) occupies the front end of the branchial chamber, and, by its continuous action, keeps a current of water flowing from behind forwards.

NOTE.—*Nephrops* has five podobranchs and a rudiment (on 2nd maxillipede), eleven arthrobranchs, and four pleurobranchs.

Write a general Account of the Internal Organs of Astacus.

A short gullet leads upward from the mouth into the large stomach or gizzard; and these parts constitute the fore-gut or stomodaeum. The mid-gut or mesenteron is a very small area with a dorsal pouch or caecum; and the

long straight intestine is the hind-gut or proctodaeum. The greater part of the gut is lined with cuticle, the only part lined with endoderm being the mesenteron.

The front or "cardiac" chamber of the stomach is a gastric mill with ossicles and teeth; and there the food is ground fine and passed through a sieve of setae into the "pyloric" chamber. Two large and branched digestive glands open by two ducts into the mesenteron where the food is digested.

Above the intestine is the pericardium, a large space in which the dorsal heart is suspended. The heart has three pairs of openings (ostia) through which it receives blood (purified in the gills) from the pericardium.

Behind the bases of the antennules are the cerebral or pre-oesophageal ganglia, connected by a wide nerve-ring with the first ganglia of the ventral nerve cord. In the thorax the cord is double and lies in the tunnel of the endophragmal skeleton. There are six pairs of thoracic ganglia and six abdominal ganglia.

There is a "green gland" or kidney behind the base of each antenna. The gonads are situated beneath the pericardium, and are three-lobed (Y-shaped) organs in both sexes. The vasa deferentia (of the male) are long coiled ducts which issue, one at each side, from the junction of the three lobes, and which open on the coxopodites of the last walking legs. The oviducts (of the female) are short, and the external openings are on the second pair of legs.

The greater part of the abdomen is occupied by thick ventral flexor and thinner dorsal extensor muscles.

What is the general Course of the Blood Circulation in the Crayfish?

The impure blood is collected in irregular spaces (haemocoelae) and passes to the gills. The purified blood returns from the gills, *via* the pericardium, to the heart which drives it to the body through muscular-walled arteries. From the heart a median dorsal ophthalmic artery and two antennary arteries pass forward; and, outside these, two short hepatic arteries. Posteriorly the heart gives off a vessel which at once divides into a dorsal abdominal artery

going backwards over the intestine, and a sternal artery which goes straight down to supply the ventral nerve cord.

Contrast a typical Crab (Carcinus or Cancer) with a Crayfish, and point out the principal Structural Differences.

The Crab has a broad cephalothorax, broadened by the expansion of the branchiostegites at the sides. The abdomen is greatly reduced and is permanently bent in under the thorax and applied to its slightly-hollowed undersurface. The abdominal appendages have also been reduced; those which are locomotor being absent, namely the last pair (the paddle swimmerets) in both sexes and also the three preceding pairs in the male. The male retains the first two pairs of (copulatory) appendages only; the female has the first five pairs, and uses them for carrying the eggs.

Mention the chief developmental Features of the Crustacea.

The eggs or ova generally have much yolk, massed in the centre, and consequently segmentation is partial and superficial (meroblastic and peripheral).

In most Crustaceans development involves one or more pelagic larval forms (i.e., the life-history exhibits metamorphosis). Entomostraca have usually only one larval form, a free-swimming Nauplius; but in Cirripedes the Nauplius is succeeded by a Cypris larva (see life-history of *Sacculina*, page 127). The Malacostraca have higher differentiated larval forms. The shrimp, *Penaeus*, has three successive stages, a Nauplius, a Zoea, and a Mysis. Crabs have two, a Zoea (with well-developed appendages, a segmented abdomen, and a carapace with long spines) and a Megalopa (crab-like but with the abdomen not yet tucked under). The Lobster (*Homarus*) is hatched out as a Mysis with biramous thoracic limbs (used for swimming).

The life-histories of the Decapod Crustacea show a tendency to shorten metamorphosis in the higher forms (e.g., the lobster begins at an advanced stage, the Mysis).

In some Crustacea development is direct (e.g., most water-fleas, Isopods, Amphipods, *Astacus*). Water-fleas

and *Astacus* pass through the Nauplius stage before they are hatched out. The "winter eggs" of *Daphnia* (water-flea) develop into parthenogenetic females which produce the "summer eggs" that are never fertilised. See *Parthenogenesis*, page 13, Part I., "Catechism," Zoology.

CLASS PROTOTRACHEATA.

Describe the External Appearance of Peripatus. What is its Zoological Interest, and where is it found?

Small and caterpillar-like, the body soft and rounded and bearing numerous pairs of soft and cylindrical limbs with claws. One pair of antennae, at the bases of which are the eyes; a pair of jaws and a pair of oral papillae, which secrete slime for securing prey.

Peripatus is a connecting-link between Annelid worms and tracheate Arthropods. Its Annelid features are:—Thin cuticle, hollow appendages, simple eyes, a muscular pharynx, stomodaeum and proctodaeum short, a series of paired nephridia, and cilia (in the genital ducts). Its Arthropod features are:—Antennae, appendages modified as jaws (gnathites), heart with ostia communicating with pericardium, reduced coelome and extensive haemocoel, and respiration by tracheae or air-tubes.

It is terrestrial, and like certain other primitive creatures, it has a discontinuous distribution, i.e., it is found in regions of the world far apart (e.g., one type of *Peripatus* occurs only in Chili and in South Africa).

CLASS INSECTA. ✓

State the General Features of Insects.

The cuticle is chitinous, parts of it are thickened (sclerites), and it forms the exoskeleton. The body of the adult shows three distinct regions: head, thorax, and abdomen. The head (with or without a neck) has simple or compound eyes (or both) and bears one pair of antennae and three

pairs of mouth appendages, variously modified ; the thorax, which consists of three segments (often united) has three pairs of limbs for locomotion and usually one or two pairs of wings (on second and third segments); and the abdomen, which as a rule is without appendages, generally has ten segments, but two or more of the hinder ones are frequently telescoped.

There is a ramifying system of respiratory air-tubes (tracheae). Fat-cells in the haemocoel form a diffuse fatty body. The central nervous system consists of a nerve ring with cerebral ganglia, and a double ventral nerve cord with, typically, one pair of ganglia to a segment. The excretory organs are tubular outgrowths of the hind-gut (Malpighian tubules). The sexes are separate; but parthenogenesis occurs. The life history generally exhibits metamorphosis (larva, pupa, and imago), the larval forms (maggots, grubs, or caterpillars) being markedly different from the adults or imagines.

‡ Insects are terrestrial, aerial, and aquatic; their instincts and their adaptive features are remarkable, they present many of the most striking examples of Resemblance and Mimicry. Some insects are social, living in communities and showing specialisation of individuals, and some are parasites; many are of great economic importance, e.g., honey bees and other "beneficials," insects injurious to agriculture and forestry, and those blood-sucking species and germ-carriers which spread disease in Man and animals.

Structure of a Typical Insect.

The Cockroach (*Periplaneta* or *Blatta*).

Describe the External Features of the Cockroach.

The chitinous cuticle is leathery, except about the joints. The head, vertically long, is connected by a slim neck to the thorax. The abdomen is flattened.

The head bears two large compound eyes, two long and jointed antennae, a pair of mandibles without palps (between which is the mouth), and two pairs of maxillae. The largest of the three thoracic segments is the prothorax; its tergum (the pronotum) overlaps the neck. The meso-

thorax bears, at the front corners of its tergum, a pair of horny elytra or wing-covers (rudimentary in the female of *B. orientalis*); the metathorax has a pair of wings (absent in the female of *B. orientalis*). Each thoracic segment bears a pair of walking legs.

The abdomen has ten segments; the first one has a reduced sternum; and the tenth, which bears a pair of tactile cerci, has the sternum modified into two podical plates between which is the anus. In the male the sternum of the ninth segment has a pair of styles. In the female the eighth and ninth segments are telescoped within the seventh, the sternum of which is produced backwards as a boat-shaped prolongation, and forms the floor of the genital chamber in which the egg-capsule is made and carried.

The male genital aperture is below the anus, and is surrounded by a set of chitinous processes (gonapophyses). The female aperture is within the genital chamber; and above it there are gonapophyses. On the sides of the body, between the thoracic segments and upon the first eight abdominal segments, are the paired respiratory openings or stigmata.

Give a Description of the Head and Mouth-parts of the Cockroach.

The head represents seven fused segments. The upper epicranium and the lower clypeus form the broad front of the head. The sides, between the epicranium and the genae or cheeks, are occupied by the large compound eyes. The antennae are inserted on the front below the eyes. At the inner side of each antenna there is a small white oval patch, the fenestra.

Hinged on to the lower edge of the clypeus is the plate-like upper lip or labrum; and behind it, at the sides of the mouth, are the two stout mandibles or jaws with toothed inner edges. Behind these are the two 1st maxillae; and the two 2nd maxillae, which are fused together, form the lower lip or labium.

Each 1st maxilla consists of a basal piece bearing inner and outer branches. The basal piece has two joints, proxi-

mal cardo and distal stipes; the inner branch has two gnathobases, a blade-like lacinia and a softer galea; the outer branch is a sensory, five-jointed maxillary palp.

The 2nd maxillae have the basal pieces united to form the lower lip or labium, which consists of an upper submentum and a lower mentum bearing the two inner and

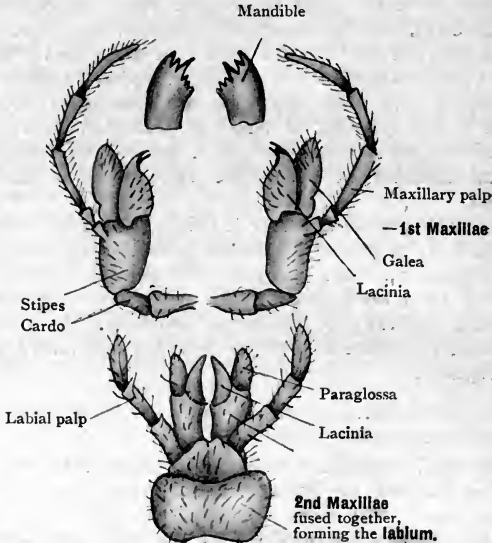


FIG. 27.—Mouth-parts of Cockroach.

the two outer branches. The inner branches are similar to those of the 1st maxillae, and together constitute the ligula. The outer branches are sensory, three-jointed labial palps.

Name the Parts of the Cockroach Leg.

A thick flat **coxa** which articulates with the sternum, a very small **trochanter**, a stout **femur**, a slender **tibia** set with spines, and a six-jointed **tarsus** or foot. The

last tarsal joint, the pulvillus, bears two claws. Under each tarsal joint there is a soft pad.

Write an Account of the Alimentary Canal of the Cockroach.

On the floor of the mouth or buccal cavity, and above the labium, there is a fold, the lingua or tongue or hypopharynx. A narrow gullet or oesophagus passes, through the neck, into the expansive crop which is separated by a constriction from the pear-shaped proventriculus or gizzard. The muscular gizzard has six internal teeth and six pads with setae. All these parts are lined with cuticle and represent the stomodaeum or fore-gut. The next portion is a short tube, the mid-gut or mesenteron, with seven or eight hepatic caeca at its anterior end; and where it joins the hind-gut or proctodaeum, a number of excretory malpighian tubules are given off. The hind-gut has three parts: a short and narrow ileum, a longer and wider colon, and a short rectum ending at the anus.

A pair of branched salivary glands and a salivary reservoir lie along each side of the crop; their ducts unite to form a common duct which opens into the mouth at the base of the tongue or hypopharynx. Digestion takes place in the crop; the secretion from the hepatic caeca passes forward into it. The mid-gut is the absorptive area.

Briefly describe the Respiratory and Circulatory Systems of the Cockroach.

There is a ramifying system of branching air-tubes or tracheae throughout the body and wings. These tubes have a silvery appearance, and their cuticular lining has a spiral thickening which renders them elastic and keeps the lumen of the tube open. The air is taken in through the ten pairs of lateral openings or stigmata, and it is expelled when the body muscles contract and compress the tracheae.

The heart is a chambered tube situated beneath the skin along the middle line of the body. Each chamber has a pair of ostia, through which the blood passes from the surrounding pericardium. The heart drives the blood

forwards into the ill-defined hæmocoele spaces amidst the organs. The main function of the circulation is the distribution of soluble food and the removal of wastes and fat; the respiratory function is discharged chiefly by the tracheae.

THE ORDERS OF INSECTS.

Blood-sucking insects, and Orders to which blood-sucking species belong, are marked *.

The **insect parasites of Man** belong to the Orders marked †.

Order **APTERA**. Wingless. No metamorphosis.

Order **ORTHOPTERA**. Metamorphosis incomplete.

Examples, Earwig, Cockroach (*Periplaneta*, *Blatta*),
Leaf-insect, Stick-insect, Locust, Cricket.

Order **NEUROPTERA**. Metamorphosis variable.

Examples, Termites. Social, living in communities,
and showing polymorphism.

Order **MALLOPHAGA** (Biting Lice). Wingless. Metamorphosis slight.

Example, *Trichodectes*. A biting louse of dogs and
other quadrupeds.

Order **HYMENOPTERA**. Metamorphosis complete. Many are social,
living in communities and showing polymorphism.

Examples, Bees, Wasps, Ants.

Order **COLEOPTERA** (Beetles). Metamorphosis complete.

Order **LEPIDOPTERA**. Mouth-parts of perfect insect or imago for
sucking only. Metamorphosis complete.

Examples, Butterflies and Moths. The social "**pro-
cessionary caterpillars**" of the moth,
Cnethocampa, cause "**urticaria epi-
demica**" in certain parts of Europe.

*†Order **DIPTERA** (Two-winged Flies). One pair of wings, the hind
pair having been reduced to knob-like balancers (halteres). Mouth-
parts for piercing and sucking, or for sucking only. Metamorphosis
complete. The larvae are footless maggots, often without a head,
but with a mouth. The pupa in many instances is within a pup-
arium (the moulted skin of the larva). Many are important (blood-
sucking species, germ carriers, parasitic larvae) in relation to disease.

*Family *Simuliidae*. **Simulium*. The females of various species
attack domestic animals and Man.

Family *Chironomidae* (Midges). **Ceratopogon* or *Culicoides*.

Family *Psychodidae* (Owl-midges). **Phlebotomus papatasi*.
Attacks Man and transmits germ of **papatasi** or **phlebotomus
fever** in Southern Europe (Malta), Africa and India.

*Family Culicidae (Gnats or Mosquitoes). Small and slender. A long piercing and sucking proboscis projecting in front of the head. Scales on the body and the wing veins. Towards apex of wing two bifurcated veins separated by one simple vein. Antennae with plumes in whorls, dense in the male. In repose the hindmost legs are raised (a diagnostic habit). Eggs laid on surface of the water; and floating singly, or in small groups and on their sides (*Anopheles*) or upright and in adherent "egg-rafts" of 200 or 300 (*Culex*). Larvae aquatic. Pupa "comma-shaped" and with two trumpet-like stigmata behind the large head. Blood-sucking habit confined to female.

*Sub-family Anophelinæ.

Example, **Anopheles maculipennis* (The Spotted Gnat). A natural carrier of **malaria** in Italy. (See "Catechism," Zoology, Part I., page 61.) A locally common British mosquito.

*Sub-family Culicinae.

Examples, **Stegomyia fasciata* (The Tiger Mosquito). The carrier of **yellow fever**.

**Theobaldia annulata* (The Wood Gnat). A large and common British domestic mosquito. Wings five-spotted, and legs with white ring-markings.

**Culex pipiens* (The common European House-gnat or Mosquito). The commonest British domestic mosquito. Brown, without distinctive markings.

Culex fatigans* (A common Tropical Gnat). Similar in appearance to *C. pipiens*. The chief carrier of the larvae of *Filaria bancrofti* which cause **filariasis in Man. It probably also conveys the virus of **dengue fever**.

*Family Tabanidae (Horse-flies, Clegs, etc.). A stout piercing and sucking proboscis, usually projecting downwards. Blood-sucking habit confined to female.

Examples, **Haematopota* (Cleg or Stout).

Tabanus*. Various species attack domestic animals and Man. *Tabanus lineola* is suspected as carrier of *Trypanosoma evansi* which causes "surra**" in horses in Indo-Burma. (See page 45, Part I., "Catechism," Zoology.)

**Chrysops dimidiata*. Is the intermediate host of *Microfilaria diurna*, the larva of *Filaria loa* of Man. See page 110.

† Family Oestridae (Bot-flies or Warble-flies). The larvae or "bots" are important internal parasites of animals and Man.

Examples, *Hypoderma bovis* (The Ox Warble-fly) and *H. linearis* attack Man, in Europe (Sweden) and America, causing "**creeping disease**" (peculiar eruptions of the skin due to the migratory activities of the "bots" beneath it).

Oestrus ovis (The Sheep Nasal-fly). In Algeria it attacks Man, causing "**thim, ni,**" a form of **myiasis**. The term *myiasis* signifies the various symptoms and lesions produced by parasitic larvae or maggots.

Family Muscidae. Flies of the house-fly type.

*Group I. The "biting" and blood-sucking Muscidae.

Examples, **Stomoxys calcitrans* (The Stable-fly). Resembles the common house-fly, but has a stiff awl-like proboscis projecting horizontally in front of the head. Is suspected as a carrier of pathogenic organisms, e.g., **anthrax**.

Glossina palpalis* (The Dusky Tsetse-fly). West and Central Africa. A stiff awl-like horizontally-projecting proboscis. During repose the wings are folded flat over the back, like a closed pair of scissors. The principal carrier of *Trypanosoma gambiense* which causes "sleeping sickness**" in Man. (See page 43, Part I., "Catechism," Zoology).

Glossina morsitans*. The carrier of *Trypanosoma brucei*, which causes "nagana**" in domesticated animals, and *T. rhodesiense* which produces a form of "**sleeping sickness**" in Nyassaland and N.E. Rhodesia. (See page 43, Part I., "Catechism," Zoology.)

**Philaematomyia*. Central Africa, India, Cyprus. Proboscis retractile and consisting of a hard proximal portion with cutting teeth and a soft distal portion for sucking. Attacks Man and animals.

*Group II. The non-biting, blood-sucking Muscidae. Feed on serum from sores, and suck blood oozing from wounds made by "biting" flies. Potential germ-carriers.

Examples, **Musca gibsoni*. Feeds in association with *Stomoxys*.

**Musca corvina* (The Raven-fly).

Group III. The non-blood-sucking Muscidae. To this group belong house-flies and others which have a soft vertical sucking proboscis, and which swarm on food and filth of every kind, and which by reason of their gross feeding habits and their ubiquity are **active agents in the spread of zymotic disease.**

Examples, *Musca domestica* (The Common House-fly) carries the *bacillus typhosus* of **enteric or typhoid fever**; is also a disseminator of **cholera, dysentery, and infantile diarrhoea.**

Calliphora (Blow-fly or "blue-bottle"). The larvae (normally useful scavengers) sometimes cause **cutaneous myiasis** in Man and animals.

Chrysomyia, syn. *Comptosyia macellaria* (The Screw-worm Fly). Brazil and other parts of Tropical America. Lays its eggs in wounds and sores and in the nasal cavities, and the †larvae cause serious **myiasis** in Man and animals.

Auchmeromyia luteola. Nigeria to Natal, especially Belgian Congo. Lives in the darkest parts of the natives' huts. The *larva, the "*Congo Floor-maggot*," is blood-sucking; it shelters under the sleeping mats during the day, and attacks the resting inmates at night.

Cordylobia anthropophaga (The African Thumbu or Cayor Fly). The †larva, the "*cayor maggot*," is a subcutaneous parasite in Man and animals; it causes painful boils or warbles.

Family Anthomyiidae. *Homalomyia*, syn. *Fannia scalaris* (The Latrine-fly). "**A dangerous disseminator of intestinal disease in villages and camps.**"

*†Family Hippoboscidae. Flies of crawling habit. Proboscis protrusible. Larviparous. Blood-sucking ectoparasites of birds and mammals, sometimes attacking Man.

Examples, *†*Hippobosca rufipes*. (See page 45, Part I., "*Catechism*," *Zoology*.)

*†*Melophagus ovinus* (The Sheep-tick, louse or Ked). Wingless. Sometimes attacks Man (sheep-shearers).

Where would you expect to find the Larvae of Mosquitoes?

Along the margins of streams, swift or sluggish; in almost every pond, pool and ditch; in puddles clean or foul, and in standing water (e.g., about houses, in holes of trees), no matter how slight the quantity may be. Woodland ditches full of fallen leaves, ponds, and rainwater barrels are the favourite breeding places of *Culex pipiens*.

The larvae of the species of *Stegomyia* are generally found in pots, tins, or barrels containing water.

Swampy pools, irrigation channels, and the weedy margins of slow-flowing streams are the principal resorts of many *Anopheline* species.

Pyrethophorus costalis, the commonest West African *Anopheline*, breeds in roadside puddles, and in barrels and pots about the native dwellings. In tropical countries during the rainy season the numbers of mosquitoes are greatly increased, and the subsequent result is epidemics of malaria.

Describe the External Features of a Mosquito, e.g., Anopheles maculipennis (the Spotted Gnat).

The slender body is about a quarter of an inch long. The head has two prominent compound eyes, two long plumose antennae composed of fifteen joints, and a long piercing proboscis. The thorax, grayish brown and hairy, consists of three fused segments and bears three pairs of long and slender legs, a pair of wings, and two minute halteres or balancers. When expanded, the membranous wings measure nearly half an inch; each has four characteristic spots, and towards the apex there are two bifurcated veins separated by a simple vein. The abdomen has eight segments; there are fine hairs and scales on the body, and scales on the wing veins. In repose the hindmost legs are held raised, a habit diagnostic of mosquitoes.

Write an Account of the Mouth-parts, Mode of Feeding, and Alimentary Organs of a Mosquito.

The mouth-parts are lengthened and together form a piercing proboscis which has the following parts: The

upper lip or labrum is fused with the epipharynx and forms the labrum-epipharynx which is grooved; the lower lip or labium, which represents the fused pair of 2nd maxillae,

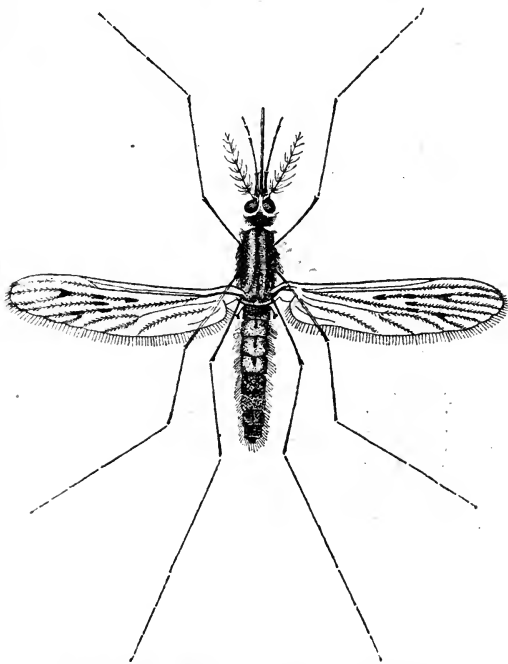
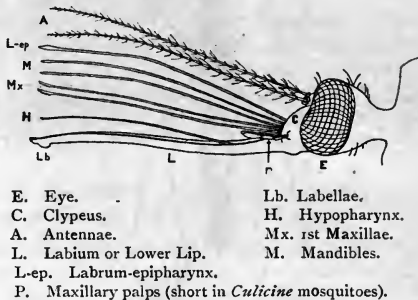


FIG. 28.—**The Spotted Gnat** (*Anopheles maculipennis*). Female. Magnified 4 diameters. **A carrier of malaria. A locally common British mosquito.** With permission, from "British Museum (Natural History) Special Guide, No. 7."

is also grooved (labial gutter). The labrum-epipharynx and the labium together form a tube within which are the five stylets, namely, the two mandibles and the two first maxillae with blade-like and finely-toothed cutting

ends, and the needle-like hypopharynx. The long five-jointed palps of the 1st maxillae are carried at the sides of the proboscis tube.

When the female mosquito is about to feed, she places the sensory bilobed tip (labellae) of the flexible labium upon the skin; and, holding the palps out of the way, she then proceeds to make the wound, directing the piercing and cutting stylets between the two lobes "in much the same way as a billiard cue is guided between the fingers of the player." The puncture is (probably) made by the labrum-epipharynx and hypopharynx, and is widened by



E. Eye.	Lb. Labellae.
C. Clypeus.	H. Hypopharynx.
A. Antennae.	Mx. 1st Maxillae.
L. Labium or Lower Lip.	M. Mandibles.
L-ep. Labrum-epipharynx.	
P. Maxillary palps (short in <i>Culicine</i> mosquitoes).	

FIG. 29.—Side View of Head and Mouth-parts of a Female Mosquito (*Culex pipiens*).

the maxillae and mandibles which act like saws. The stylets cut deep, and the labium bends like a bow. Saliva then passes (through the hollow hypopharynx) into the wound; and the blood is sucked up in the labial gutter, by the action of the suctorial pharynx. The blood passes from the pharynx into the oesophagus which has two small dorsal pouches and a long ventral reservoir where the blood is stored. These three diverticula represent the crop. The end of the oesophagus is swollen (oesophageal valve); and succeeding this is the mid-gut which has a long tubular portion and a dilated "stomach" in which the food (blood) is digested. The gametocyte stages of the malaria parasite are found in the "stomach." Five

Malpighian tubules are given off at the junction of the "stomach" and the hind-gut; the hind-gut consists of an ileum, a colon, and a dilated rectum opening at the anus.

Embedded in the fatty body (in the haemocoel), above the first pair of legs, there are two trilobed salivary glands; the ducts unite to form a common salivary duct which opens into the base of the hypopharynx. The malaria germs (sporozoites) are found in the salivary glands.

The *male* mosquitoes have no mandibles, their maxillae are very short, and the hypopharynx is fused with the labium; they cannot therefore pierce or "bite."

How could you distinguish an Anopheline from a Culicine Mosquito?

Their resting attitudes are different; the Anopheline rests with the body held out at an angle, and the proboscis straight in front of the head; the Culicine holds its body parallel with the surface on which it rests, and the proboscis is bent downwards.

As a rule Anophelines have spotted wings, and the maxillary palps and proboscis are about equal in length. Culicines have palps shorter than the proboscis, in the female; and longer than the proboscis, in the male.

Briefly describe Stegomyia fasciata, and state what you know about its Habits and Life-History.

Stegomyia fasciata, the Tiger Mosquito, is the carrier of yellow fever. It is a small domestic species, always found about houses. It is widely distributed throughout Southern Europe, Africa, Asia, and North and South America, and is very common in the West Indies. It is black with conspicuous white line markings on the body and legs. The lyre-shaped white mark on the thorax is at once its distinguishing feature. It bites chiefly during the daytime. The black and oval eggs are laid singly or in chains in clean or foul standing water, in puddles, water-barrels, broken bottles, old tin cans, etc. The eggs can resist dry conditions for weeks, for even so long as six months.

Normally the larvae hatch out in from six to twenty hours, and the whole life-cycle can be completed in about twelve days. These mosquitoes can live for six or eight weeks; and readily entering ships, they may spread the disease from port to port.

Name four Examples of Malaria-carrying Mosquitoes.

ANOPHELINES	{	Anopheles maculipennis (The Spotted Gnat). The chief carrier of malaria in Europe and North America.
		Pyrethophorus costalis. The commonest West African Anopheline. It is also a carrier of the larvae of <i>Filaria bancrofti</i> .
		Nyssorhynchus fuliginosus. India.
		Cellia argyrotarsis. South America. It is also a carrier of the larvae of <i>Filaria bancrofti</i> .

Give a short Description of the Mouth-parts of Stomoxyx and of Glossina (Tsetse-fly).

In the biting Muscidae the mandibles and 1st maxillae (excepting the maxillary palps) are absent; and the labium (or 2nd maxillae) is greatly modified to form a hard piercing



- | | |
|-------------------------|--------------------------|
| E. Eye. | B. Bulb. |
| A. Antennae. | H. Hypopharynx. |
| L. Labium or Lower Lip. | L-sp. Labrum-epipharynx. |
| Lb. Labellae. | P. Maxillary palps. |

FIG. 30.—Side View of Head and Mouth-parts of a Tsetse-fly (*Glossina*).

proboscis, which makes the wound and which consists of the rostrum (a protrusible part of the head containing the buccal cavity and pharynx), the haustellum or food channel and the labella.

The hard and slender proboscis of *Stomoxys* projects straight out from the under part of the head and has a swollen base, the bulb; and the labellae at the tip bear teeth with which the wound is made. In the deep labial

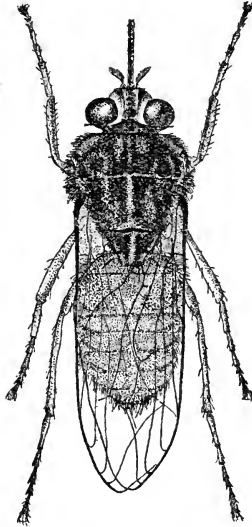


FIG. 31.—The Dusky Tsetse-fly (*Glossina palpalis*). Female. Magnified 5 diameters. The chief carrier of "sleeping sickness." Showing the characteristic resting position, the wings folded flat over the back.

gutter the slender and needle-like labrum-epipharynx and hypopharynx lie concealed. The palps are short.

The proboscis of *Glossina* is similar to that of *Stomoxys*; but the rostrum is larger, the hypopharynx is more delicate, and the whole proboscis is ensheathed and hidden by the palps which are hollowed-out and long.

Write an Account of the Distribution, Habits, and Life-History of Glossina palpalis.

The Dusky Tsetse-fly, *Glossina palpalis*, the chief carrier of the deadly trypanosome of "sleeping sickness," is common throughout West and Central Africa, in the forest country of the Senegal, Congo and Niger Rivers. "Usually it infests certain areas; but its prevalence in these tracts or "fly-belts" varies according to rainfall and the migratory habits of the big game. It is most numerous about fords where the human inhabitants frequently congregate." It "bites" in the daytime, and is active only in sunny weather. It has, like other tsetse flies, a characteristic habit of resting with the wings folded flat over the back, like a closed pair of scissors. As in all the blood-sucking Muscidae, the blood-sucking habit is common to both sexes. Unlike other Muscids, it is (as all tsetse-flies are) larviparous; and the larvae (8 to 10) are born (at intervals of nine or ten days) ready to pupate. Before birth the larva is nourished by specialised milk-glands which open into a "teat" on the inner wall of the uterus. The larva remains within the uterus about ten days; then it crawls to some suitable spot, e.g., under soil or debris (an inch under or thereabout) at the base of a tree near the edge of a stream, and at once pupates within a puparium which is barrel-shaped and has two small protuberances at the posterior end. The duration of the pupal state is from thirty-two to thirty-five days.

State what you know about the Life-History and Habits of Lice, and their connection with Disease.

The whitish oval eggs or "nits," truncated at the end where the young louse emerges, are laid one at a time. "A female louse lays four or five eggs a day for about a month, and then dies." The eggs are "glued" to hairs or fibres of underclothing, and hatch out in from eight days to five weeks. There are three growth-stages with accompanying moults. The young resemble the adults; and the adult stage is attained in about twelve days.

Lice are permanent ectoparasites and, unlike fleas and

bugs, cannot live away from the body of the host. The louse, when feeding, holds on firmly by its powerful recurved and ridged claws to hairs or underclothing; the head is bent down, and the proboscis is thrust obliquely forwards into the skin. *Pediculus capitis* is the species usually found on the head, *P. vestimenti* is the clothes or body-louse, and *Phthirus pubis*, the crab-louse, is a short squat form infesting the pubic parts of the human body. Lice are a result of personal uncleanliness; but these noxious parasites are often accidentally acquired by clean persons through contact with verminous individuals, and in other ways. Crowded conditions and body neglect (e.g., troops on campaign) favour the spread of pediculosis. The Clothes Louse is a carrier of the typhus virus; and the spirochaetes (*Spiroschaudinniae*) of European and North African relapsing fever are also conveyed by it and by the Head Louse. (See "Catechism" Zoology, Part I., page 47). *Phthirus pubis* often causes dermatitis. Lice are also suspect in relation to tubercle, plague, leprosy, and other diseases.

Mention some Insects of Economic Importance.

Injurious Insects.—Locusts, saw-flies, many beetles, and their larvae, e.g., *Anobium*, *Scolytus*, "wireworm" larvae. The larvae of certain butterflies and of many moths destroy crops, produce, etc. The Hessian-fly is a serious pest of cereal crops. Some species of Hemiptera (Bugs) are very injurious, e.g., *Oxycarenus* (the Egyptian Cotton-stainer) which damages cotton, *Phylloxera* which is destructive to vines, and *Cryptococcus*, a dreaded pest of arboriculture. Also blood-sucking, germ-carrying, and parasitic insects. (See pages 142-147.)

Beneficial Insects.—Honey-bees, Ichneumon flies, certain beetles, e.g., *Scarabaeus*, Burying beetles, Ladybirds, Blister-beetle or "Spanish-fly" (*Cantharis*, syn. *Lytta*). The larvae of Silkworm Moths, the maggots of Hover-flies, the Cochineal insect (*Coccus cacti*), and *Carteria* which produces lac, these are also useful species.

CLASS ARACHNIDA.

State briefly the General Features of the Arachnida.

The head and thorax are united and constitute the **prosoma** which is covered by the **carapace**. The abdomen, with or without segments, is sometimes divided into a **mesosoma** and a **metasoma**. The head, thorax, and abdomen may be fused together.

The prosoma generally bears six pairs of appendages; the first two pairs are the **chelicerae** and **pedipalpi**, the other four pairs are usually **walking-legs**. There are no antennae and no true gnathites or jaws; but the bases of the limbs are modified as **gnathobases**, for crushing the food. The abdomen has (on the mesosoma) six pairs of appendages, specially adapted for respiration. In the prosoma there is (in King-crabs, Scorpions, and Spiders) a skeletal structure, the **endosternite**.

Arachnids breathe by **gill-books** (i.e., plates with numerous branchial lamellae between which the water circulates), or by **lung-books** (i.e., insunk gills adapted for air-breathing, with numerous laminae between which the air circulates) or by **tracheae**; certain spiders have tracheae as well as lung-books. The sexes are separate (Spiders show sexual dimorphism). Scorpions are viviparous.

Name the Principal Orders of the Class Arachnida.

Order XIPHOSURA. Carapace of prosoma wide and horseshoe-shaped, segments of abdomen fused; a long tail-spine. Prosoma bears seven pairs of appendages; the last pair of legs have spatulate processes for digging. First pair of abdominal appendages form a double genital "operculum;" it covers in the remaining appendages which are modified for breathing as gill-books.

Example, *Limulus* (King-crab).

Order SCORPIONIDA (Scorpions). Form elongate. Prosoma (six segments) short; mesosoma (seven segments) long; metasoma long and narrow with five segments and a terminal curved poison-sting. The pedipalps large and chelate, for seizing prey. The 3rd, 4th, 5th and 6th segments of the mesosoma have each a ventral pair of slit-like stigmata, openings of the lung-books.

Example, *Scorpio*.

Order ARANEIDA (Spiders).

*†Order ACARINA (Mites and Ticks). See pages 158 and 161-162.

‡Order PENTASTOMIDA (Tongue-worms). Parasites. The body worm-like and ringed. Two pairs of retractile hooks at sides of the mouth. Respiration cutaneous. Metamorphosis: the larva unlike the adult.

Example, † *Pentastoma taenioides* (syn., *Linguatula rhinaria*). The larvae occur in the liver and the adults in the nasal passages of dogs and other quadrupeds and Man. Europe (Central France).

*This Order contains blood-sucking species.

†Parasites.

ORDER ACARINA (MITES AND TICKS).

Mention the Special Features of the Acarina.

The body is generally either oval or round, and compressed dorso-ventrally; it may be covered by a chitinous shield or scutum. The integument is either soft or leathery. The three regions of the body are usually fused together. The front portion of the prosoma may form a distinct "false-head," the capitulum, bearing the mouth-parts (collectively termed the rostrum or beak) which may be concealed within or may project from a depression, the camerostoma.

The first two pairs of appendages, the chelicerae or mandibles and the pedipalps, are adapted either for biting or for piercing and sucking. The chelicerae may be chelate, or, as in Ticks, long piercing styles. The pedipalps are generally united together at their bases; and their inner margins are often hollowed out, so that the two, when applied together, form a sheath enclosing the chelicerae and the hypostome. The adults usually have four pairs of jointed legs which end in one or more claws with suckers at their bases.

Respiration is by tracheae; but some aquatic mites breathe through the skin. The sexes are separate. Most lay eggs. The metamorphosis is incomplete; the larva has three pairs of legs. Many of the Acarina are free-living

(aquatic or terrestrial); some are parasites of plants, certain Mites (of the Family Gamasidae) are blood-suckers, and the Family Ixodidae or Ticks are blood-sucking parasites of reptiles, birds, and mammals including Man. Many of the blood-sucking species convey pathogenic organisms (e.g., *Spirochaetes* and *Piroplasmata*) to Man and domesticated animals. The Order includes numerous forms important in relation to disease.

Name some Mites which are Important in relation to Man and Domesticated Animals.

- †Eriophyes (syn. Phytopus) ribis. The Currant Gall-mite. A degenerate worm-like form with very short legs (two pairs only) and the posterior portion of the body tail-like and ringed. Causes "**big-bud**" disease of fruit bushes.
- †Demodex folliculorum. Degenerate and worm-like. A common parasite in the hair follicles and sebaceous glands of Man.
- †*D. caninus* causes "**follicular mange**" in dogs.
- †Sarcoptes scabiei. Itch-mite of Man and animals. Forms galleries in the skin and causes "**scabies**."
- †Sarcoptes mutans. Produces "**scaly-leg**" in poultry.
- †Psoroptes. Produces "**sheep-scab**."
- *Dermanyssus gallinae. The Red-mite of poultry. Occasionally attacks Man, causing skin irritation.
- *†Pediculoides ventricosus. The Grain-itch Mite. Attacks dock-labourers unloading grain, etc. Causes **dermatitis**.
- *Trombidium holocericeum. The Harvest-mite. Its larva, *Leptus* or *Microtrombidium autumnalis*, is the so-called "harvest-bug" which attacks Man.
- *Microtrombidium akamushi. The Japanese Harvest-bug. Transmits the very fatal disease, **kedani, or river fever of Japan**.
- *Blood-sucking.
- †Parasites.

Family Ixodidae (Ticks).

Write a short Description of the External Features of the Ixodidae or Ticks.

The body is roughly oval in shape and flattened dorso-ventrally. The abdomen is fused with the prosoma. The integument is leathery; and there is generally a dorsal shield or scutum. This shield, in the male, covers the

back entirely; but in the female it is merely a small anterior plate (see Fig. 33). The capitulum or "false-head" bears the mouth and the mouth-parts which together form a projecting rostrum or beak.

The Soft Ticks (sub-family Argantinae), e.g., *Argas* and *Ornithodoros*, have no shields; and the capitulum and mouth-parts (of the adult) are ventral, not projecting in front.

There are four pairs of six-jointed legs, each of which has two curved claws with a sole or pulvillus. The two front legs have each a small pit with sensory hairs (Haller's

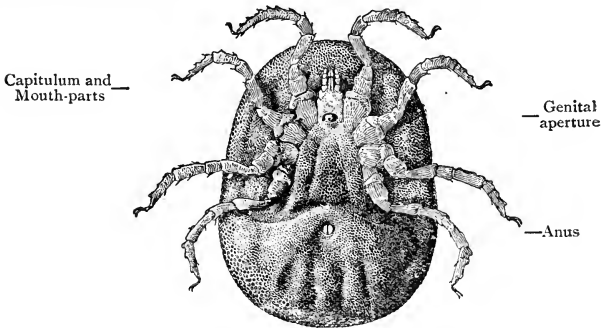


FIG. 32.—*Ornithodoros moubata*. Ventral aspect. After Castellani and Chalmers. **Note the ventral position of the capitulum and mouth-parts.** With permission, from Castellani and Chalmers' "Manual of Tropical Medicine."

Organ) on the terminal joint. There is a pair of stigmata near the bases of the hindmost pair of legs. Eyes may be present or absent. The anus is situated ventrally near the end of the body. The genital opening is ventral, between the anus and the capitulum, in both sexes.

Describe the Mouth-parts of a Tick.

The four-jointed sensory palps (pedipalpi) are used as feelers. The median ventral hypostome (or labio-maxillary dart) has numerous recurved teeth; it is thrust into the

skin of the host, and a firm hold is thus secured. The wound is deepened by the simultaneous action of the chelicerae or mandibles, which are cutting stylets with serrated ends.

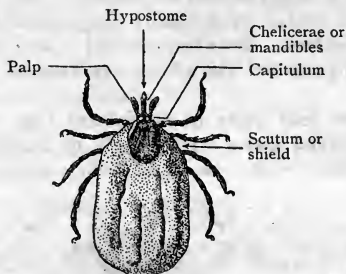


FIG. 33.—The Grass or Sheep and Dog-tick of Europe (*Ixodes ricinus*). Dorsal aspect of Female, enlarged. Note the anterior position of the capitulum and mouth-parts. With permission, from "British Museum (Natural History) Economic Pamphlet, No. 6."

The mandibles have sheaths; applied together, they form the dorsal wall of the front portion of the buccal cavity; the ventral wall is formed by the hypostome. The back part of the buccal cavity, into which the salivary

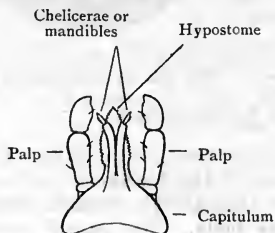


FIG. 34.—Capitulum and Mouth-parts of a Tick (Dorsal view).

ducts open, is a sac-like extension behind the entrance to the pharynx.

The blood is drawn up the sucking-tube, which is formed by the two mandibles and the hypostome closely applied together.

State what you know about the Reproduction of Ticks.

The male employs his mouth-parts to push the **spermatophore** (packet of spermatozoa) into the genital orifice of the female. After fertilisation, the female leaves the host, drops to the ground. She bends the capitulum so as to bring it close to the genital aperture, and the bilobed cephalic gland (**Gene's Organ**) is then protruded from under the front edge of the shield; it receives the eggs, one at a time, and, rolling them round, covers them with a sticky secretion. The eggs are then transferred to the rostrum, and are laid in long masses in front of the tick. **Parthenogenesis** occurs in Ticks.

Write a General Account of the Life-History of Ticks.

The female shrivels and dies after laying a batch of eggs (except species of sub-family Argantinae). As many as 15,000 eggs may be deposited by one female (e.g., the Bont Tick). The active **six-legged larva** ("seed-tick" or "grass-lice") ascends a blade of grass and waits for a passing host, to which (first host) it fastens itself and on which it remains two days or longer. When full of blood the larva drops to the ground, moults, and changes into a **nymph** with four pairs of legs. The nymph, acting like the larva, attaches itself to the second host; when replete with blood, it drops off, and, remaining on the ground for about three months, slowly develops into the adult state. The adult lives on the third host.

The **three hosts** may be different species of animals, or different individuals of a species. Some ticks (e.g., *Rhipicephalus evertsi*) require only two hosts; others (e.g., *Rhipicephalus annulatus* var. *decoloratus*) require only one, the larva and nymphs not dropping off to the ground, but remaining on the host.

Name some Ticks which cause Disease in Man and Domesticated Animals.

Sub-family Argantinae (Soft Ticks).

*†*Ornithodoros moubata* (Fig. 32). Transmits *Spirochaeta duttoni*, which is the cause of **human tick-fever, or relapsing fever** of Tropical Africa. (See "Catechism," Zoology, Part I., pages 46 and 47.)

Sub-family Ixodinae (Hard Ticks).

- *†*Amblyomma hebraeum*. The South African Bont Tick. Transmits the blood-parasite of "**heartwater**," a deadly disease of sheep, goats, and cattle.
- *†*Ixodes pilosus* in South Africa and *Ixodes holocyclus* in Australia cause "**tick-paralysis**," an obscure malady, often fatal in children.
- *†*Ixodes ricinus*, syn. *reduvius* (Fig. 33). The Grass or Sheep and Dog-tick of Europe. It occurs also in other parts of the world, and attacks various animals and Man. Is a carrier (in Europe) of *Piroplasma*, syn. *Babesia bigeminum*, the blood-parasite of **redwater, or Texas cattle-fever**.
- *†*Haemaphysalis punctata* is the carrier in England of the piroplasm of **redwater, or Texas cattle-fever**.
- *†*Rhipicephalus capensis*. Cape Colony and other parts of Africa. Is the carrier in Africa of the piroplasm of **redwater, or Texas cattle-fever**.
- *†*Rhipicephalus* or *Margaropus annulatus* (syn. *Boöphilus bovis*). This cattle-tick is widely distributed in Central and South America, and it is the carrier of the piroplasm of **redwater or Texas cattle-fever**. (See "*Catechism*," *Zoology, Part I.*, page 66.)
- *†*Rhipicephalus appendiculatus*. The common cattle-tick of South Africa. Is the carrier of *Theileria parva*, the blood-piroplasm which causes **Rhodesian cattle-fever**.
- *†*Rhipicephalus evertsi* transmits *Theileria parva*, the piroplasm of **East Coast, or Rhodesian cattle-fever**; and it is the carrier, in Africa, of *Piroplasma equi*, the blood-parasite of **biliary fever** in horses.
- *†*Dermacentor reticulatus*. Europe and Northern Asia. Transmits *Piroplasma equi*, the blood-parasite of **biliary fever** in horses.
- *†*Dermacentor venustus*, syn. *andersoni*. The tick which causes in Man the typhus-like disease, **Rocky Mountain Spotted Fever**, in the Bitter Root Valley of Montana, and in Idaho and other States of the Rocky Mountain region. In Montana the death-rate of this disease is about 70 per cent.

*Blood-sucking.

†Parasites.

*Briefly describe the Habits and Life-History of the Bont Tick (*Amblyomma hebraeum*).*

The adult attaches itself, thrusts its mouth-parts deep into the skin of the bare parts of its host (e.g., the genitals and udders of cattle). The female seeks the spot where

the male is attached; and after mating, she attaches herself, feeds until gorged, and then drops off to the ground and there produces a great number of eggs.

The larvae and the nymphs feed on different individual hosts, and therefore three hosts are necessary for the completion of the life-cycle.

The organisms of "heartwater" disease are sucked up with the blood of an infected ox by the larva, and are transmitted to the second host by the nymph. If the nymph feeds on an infected animal, the disease organisms may be conveyed, when the nymph becomes adult, to the third host. The organisms are not transmitted through the egg.

(For modes of infection by Ticks see "*Catechism*" *Zoology*, Part I., pages 47 and 66.)

PHYLUM ECHINODERMATA.

What are Echinoderms? State their General Characters.

They are prickly-skinned marine animals of sluggish habit, which outwardly exhibit radial symmetry; they have a limy body integument, with a more or less developed dermic exoskeleton of limy plates or spicules, and the extensive coelome or body-cavity is divided into two distinct portions, namely, the perivisceral cavity (the body-cavity proper) and the characteristic water-vascular system or hydrocoel. Additional parts of the coelome are the axial sinus and the periaermal spaces, which form an ill-defined system of "blood sinuses." In the coelomic fluid there are numerous wandering amoebocytes. There are no special excretory organs. The sexes are separate. The gonads or generative glands open directly to the exterior; and the reproductive elements are discharged into the sea, where the eggs are fertilised. There is generally a free-swimming larva, which outwardly exhibits bilateral symmetry.

Mention the Chief Classes of Echinoderms and give Examples.

Class ASTEROIDEA (Starfishes). The body, flattened dorso-ventrally, is stellate or pentagonal, and has five or more distinct rays or "arms." Each "arm" contains diverticula of the gut and gonads, and has a ventral ambulacral groove bearing two or four rows of locomotor tube-feet.

Examples, *Asterias* (The Common Starfish).

Solaster (Sun-star), with nine or more rays.

Goniaster (Cushion-star). A pentagonal form.

Class OPHIUROIDEA (Brittle-Stars).

Class ECHINOIDEA (Sea-urchins). Spherical or heart-shaped. The rays fused together. The exoskeleton a complete test or shell composed of limy plates and set with movable spines. Ambulacral grooves closed. Five double rows of slender locomotor tube-feet.

Example, *Echinus* (Sea-urchin).

Class HOLOTHUROIDEA (Sea-cucumbers). Body elongated and cylindrical. An exoskeleton of loose spicules. The body-wall muscular. Mouth with contractile tentacles (modified buccal tube-feet) for feeding. Locomotor tube-feet present or absent. Breathing by "gill-trees," branched outgrowths of terminal portion of gut.

Examples, *Cucumaria*. With non-retractile tube-feet.

Synapta. Without tube-feet, and with an exoskeleton of anchor-like spicules.

Class CRINOIDEA (Feather-stars).

Give a General Account of the Water-Vascular System of Echinoderms.

On the outside of the body there is a small porous plate, the madreporite, through which water is drawn into the stone canal, which is lined with cilia and which leads vertically into the circumoral or ring canal. The ring canal often has, interradially, accessory reservoirs, the polian vesicles, and small glandular pouches, Tiedemann's bodies, in which the amoebocytes are formed. The polian vesicles, having muscular walls, serve also to vary the pressure of the fluid in the whole system. Radial canals, one in each radius or ray, are given off from the ring canal; and the radial canals give off small lateral branches, one to each tube-foot. There is an ampulla or bladder-like reservoir at the base of the tube-foot where the lateral canal enters it; and the lateral canal has a pair of valves which, under

pressure, open and admit fluid into the tube-foot, but prevent fluid from passing back into the radial canal. By this means, and by the contraction of the ampullae, the **protrusible tube-feet** are rendered tense. The tube-feet have terminal discs which act as adhesive suckers.

The primary function of the whole system is **locomotor**; but in those Echinoderms (e.g., Ophiuroids and Crinoids) in which the tube-feet are without ampullae and sucker-discs, the function is **respiratory and tactile**. In certain Holothurians the tube-feet are few and modified (**buccal tentacles**) for feeding purposes.

PHYLUM MOLLUSCA.

State the Distinctive Characters of the Mollusca.

The body is **not segmented**. Typically, the dorsal portion of the integument forms a projecting flap, the **mantle**, which covers in the space (**mantle cavity**) occupied by the respiratory organs and which secretes the exoskeleton, a limy univalve or bivalve **shell** of very variable form. The shell is not closely attached to the body-wall; and in some instances (e.g., Cuttlefish) it is internal. Part of the ventral body-wall is usually formed into the characteristic muscular "**foot**," which may be a sole for creeping on (e.g., Snail), or wedge-shaped for ploughing through sand or mud (e.g., Freshwater Mussel), or it may be greatly modified, one part being divided into "**arms**" with suckers and the other portion forming a tube or funnel through which water is squirted out from the mantle cavity (e.g., Cuttlefish). Most Molluscs (except Pelecypoda) have an **odontophore**, with a chitinous **radula** or toothed rasping ribbon, on the floor of the mouth cavity.

The true body-cavity or coelome is represented by the **pericardium**, which communicates with the outside through the nephridium or kidneys. There is an **extensive haemocoel**. The **blood system** is well developed; the circulation is partly lacunar, i.e., through irregular spaces or sinuses of the haemocoel. Typically, the dorsal heart consists

of a ventricle and two auricles. Respiration is by gills or ctenidia. (See page 174.) Terrestrial forms breathe through an air chamber formed by the mantle cavity.

The central nervous system consists of cerebral ganglia on a circum-oesophageal ring which may be drawn out into ventral cords or commissures connecting the inferior ganglia (pedal and pleura!); there is also a visceral system of two commissures with ganglia. Eyes (simple or complex) are generally present.

Molluscs are dioecious (sexes separate), or hermaphrodite. Some are viviparous (e.g., *Paludina*). The development is direct (e.g., *Helix*), or indirect and involving two larval stages, the trochosphere and the characteristic veliger. Most Molluscs are aquatic, and the majority are marine (littoral, pelagic, abyssal).

THE PRINCIPAL CLASSES OF THE PHYLUM MOLLUSCA.

With Examples and Notes.

Class GASTEROPODA. Most are asymmetrical. The head is distinct and usually bears tentacles. There is an odontophore with a radula. Typically, the "foot" is adapted as a sole on which the animal creeps; and it is generally has, at the posterior end, a hard operculum for closing the opening of the shell when the creature withdraws inside. The mantle is a continuous fold completely encircling the body behind head and "foot." The shell, when present, is composed of one piece (univalve), or of more than two pieces.

Examples, Chiton. *Bilaterally* symmetrical. Shell consists of eight overlapping plates. "Foot" occupies the whole ventral aspect of body. Gills paired, a row along each side between mantle and "foot." Marine (littoral).

Neomenia. Worm-like; without a shell and a "foot," but with a ventral ciliated groove. The body completely invested by the mantle which has numerous limy spicules. Radula absent. Marine.

Patella (Limpet). A univalve conical shell. Head with one pair of tentacles. Ctenidia replaced by secondary gills around the "foot," between it and the fringed mantle. Marine (littoral).

Paludina, syn. Vivipara (a river snail).
Viviparous.

Buccinum (Whelk). Thick spirally-coiled shell. The "foot" large and with a horny operculum. A single pair of tentacles at the bases of which are the eyes. The mantle edge of the left side forms a spout-like siphon for conducting water into the mantle-cavity. One ctenidium (of left side) attached to mantle. Sexes separate. Marine.

Clione (a shell-less Pteropod, or "Sea-butterfly"). The sides of the "foot" developed as swimming fins ("wings"). Marine (pelagic).

Doris (a sea-slug). One of the Nudi-branchia or naked-gilled Molluscs. Shell absent in adult. The exposed gills form a retractile crown on the back. Marine (littoral).

Order PULMONATA. Land and freshwater air-breathing Gasteropods. Ctenidium absent. The mantle-cavity is an air-chamber or "lung" formed by the union of the front edge of the mantle with the head.

Examples, *Limnaea truncatula*. Shell spirally coiled. A single pair of non-retractile tentacles at the bases of which are the eyes. Freshwater. The intermediate host of the Liver-fluke (*Fasciola*, syn. *Distoma hepatica*).

Limax (Slug). The thin plate-like shell is internal, hidden under the skin. Two pairs of retractile tentacles; the eyes at the tips of the upper pair. Terrestrial.

Helix (Snail). The shell has a short spire. Two pairs of retractile tentacles; the eyes at the tips of the upper pair. Hermaphrodite. Terrestrial.

Class PELECYPODA or LAMELLIBRANCHIATA (Bivalves). Bilaterally symmetrical. Without a distinct head and odontophore. The mantle has two flaps, and is usually more or less prolonged to form two siphons (inhalent and exhalent). The shell has two valves (bivalve). The "foot" is more or less wedge-shaped. The paired ctenidia or gills are lamellate (numerous filaments in plate-like rows).

Examples, *Mytilus* (Mussel). The "foot" small. Lives (in colonies) attached by a byssus of threads. Marine. See page 175.

Meleagrina, syn. *Margaritifera* (Pearl Oyster). Marine.

Pecten (Scallop, or Clam). The "foot" not locomotor, but used for spinning the byssus. Marine.

Lima. Edges of mantle have very long filaments. Swims freely by flapping its valves, or attaches itself by the byssus and forms a large nest of fragments of shell, stone, coral, etc. Marine.

Ostrea (Edible Oyster). Without a "foot" and a byssus. Hermaphrodite.

Anodonta (Freshwater Mussel). The "foot" large and wedge-shaped. Without a byssus. Sexes separate. A *Glochidium* larva.

Cardium (Cockle). Siphons short. The long and bent "foot" is used for leaping.

Mya (Gaper). Siphons long. Marine.

Pholas (Piddock). A boring Mollusc; bores in rock, shale, etc. Marine (littoral).

Teredo (Ship-worm). Body long and worm-like, and more or less enclosed in a thin shelly tube continuous with the small shell. A destructive wood-borer.

Class SIPHONOPODA or CEPHALOPODA. Bilaterally symmetrical. The head distinct and surrounded by prehensile "arms" with suckers. An odontophore with a radula, and two jaws. The front portion of the "foot" forms the sucker-bearing "arms," and the hind portion forms the siphon or funnel through which water is expelled from the mantle-cavity. The ganglia are massed together and protected by an internal cartilaginous "skull." Eyes, coelome, and vascular system are well developed. Sexes separate. Development direct. Free-swimming and marine.

Examples, *Octopus*. Body bag-like. Head large. Eight long and webbed "arms" each with two rows of suckers. Two gills. Shell absent.

Sepia (Cuttlefish). Body oval, with narrow lateral fins. Eight short and two long "arms," each with four rows of suckers. Two gills. The shell internal ("cuttle-bone"). An ink-sac.

Nautilus. The front part of the "foot" formed into lobes with tentacles instead of suckers. Four gills. An external plano-spiral and chambered shell; the last or outer chamber containing the body.

Helix pomatia (The Edible Snail).

A Type of the Gasteropoda.

Describe the External Features of the Snail.

The body consists of head, "foot" and visceral hump. The elongated muscular "foot" is the flattened ventral portion of the body-wall. Overlying the "foot" is the head region which bears anteriorly two pairs of retractile "horns" or tentacles; on the tips of the upper and longer pair are the eyes. The mouth is between the front of the "foot" and the under surface of the head. The genital aperture is situated below the right large tentacle and at the end of the groove along the right side of the body.

The head and "foot" may be withdrawn within the shell, a right-handed conical spiral, which is carried somewhat obliquely on the back, and within which is lodged the twisted dorsal visceral hump containing the principal internal organs. The integument of the hump is thin; a free fold of it, the mantle, extends over the back and ends in a thickened edge, the collar, around the mouth of the shell. This collar is fused with the body-wall, except at an opening on the right side, the pulmonary aperture. Beside the pulmonary aperture there is a smaller opening, the anus.

How does the Snail Move?

In the "foot" there is a tubular pedal gland, which opens below the mouth and which secretes slime. By means of this slime, and by wave-like contractions of the

longitudinal muscles of the "foot," the snail glides along or creeps.

Write an Account of the Alimentary and Nervous Systems of Helix.

The mouth opens into the buccal cavity, which has, on the roof, a horny bar or jaw, and on the floor, a radula, a chitinous ribbon set with transverse rows of minute teeth. The front portion of the radula rests on a cartilaginous pad, and its hind portion lies in the tubular radula-sac, where it was formed and where it is added to when worn. It is worked, by muscles, against the jaw, and in this way the snail rasps pieces out of leaves on which it feeds. The whole mechanism is termed the odontophore. From the buccal cavity a short gullet leads into the large storing crop. Attached to the outside of the crop are the two diffuse white salivary glands; their ducts pass forward along each side of the gullet and open into the buccal mass. The large brown bilobed digestive gland occupies the greater part of the coiled visceral hump, and it surrounds the next portion of the gut, the "stomach," a dilated loop into which its ducts open. This is followed by the long intestine, the first portion of which is embedded in the digestive gland or "liver" and is coiled; the terminal portion (rectum) has a straighter course, passing forward to the anus.

The central nervous system consists of a ring round the gullet with two supra-oesophageal or cerebral ganglia and a sub-oesophageal ganglionic mass, which is composed of pedal and pleuro-visceral ganglia. From these ganglia, nerves are given off to the head, "foot," mantle, and viscera.

How does the Snail breathe? Describe the Heart and the Course of the Circulation.

Air passes through the pulmonary aperture into the mantle-cavity or pulmonary chamber, the space between the mantle and the body-wall. On the inner surface of

the mantle there is a network of thin-walled blood-vessels ; in these the blood is aerated.

The venous blood from the body is collected into the **pulmonary sinus** which passes round the mantle-cavity where the mantle joins the body-wall. **Afferent veins** from this sinus are connected (by the network of thin-walled vessels in which the blood is purified) to **effluent vessels** ; and these pass into the **pulmonary vein** which receives a vessel from the kidney and enters the auricle of the heart. The pure or arterial blood is pumped by the ventricle into **two main arteries** which give off branches to the various organs and tissues.

The **two-chambered heart** (auricle and ventricle) is enclosed in a sac, the **pericardium**, situated at the back of the mantle on the left side.

Describe the Excretory System of Helix.

Beside the pericardium there is a greyish and somewhat triangular **kidney** ; its duct, the **ureter**, passes along the dorsal side of the rectum and opens to the outside above the anus. There is a narrow ciliated passage, the **reno-pericardial canal** (**nephrostome**), between the kidney and the pericardium.

Write an Account of the Reproductive Organs of the Snail.

Near the top of the spire and embedded in the "liver," there is a small yellowish **hermaphrodite gland** or **ovotestis** in which ova and sperms are formed, but at different times. The white and sinuous **hermaphrodite duct** leads to the base of the tongue-shaped **albumen gland**, from which a nourishing fluid is received. Where the duct enters the gland, a **common duct** arises ; it passes forward to near the head ; it is wide and consists of two parallel but distinct passages, the one, along which the ova pass, being more convoluted than the other, along which the sperms travel. The two passages diverge as separate male and female ducts. The female duct or **oviduct** is short and thick, and it leads into a muscular tube, the **vagina**, into which the following

accessory organs open: the spermatheca or receptaculum seminis (a globular sac with a long tube), a tuft of tubular mucous glands, and a dart sac. The male duct or vas deferens is long and thin, and it leads into the muscular protrusible penis, which has at its base a long tubular flagellum and a retractor muscle. The vagina and the penis open together at the genital pore.

In the ovotestis sperms are produced first and ova later: this form of hermaphroditism is known as protandry. The sperms pass into the flagellum, and are there massed together (spermatophores). Limy darts, formed in the dart-sac, are forcibly shot out, through the genital aperture, by the pairing snails; copulation then takes place, and the spermatophores received by each snail are passed into the spermatheca. The ova, produced later, are fertilised at the upper end of the female portion of the common duct, by the sperms received from another snail (cross-fertilisation). The eggs are coated with limy mucus secreted by the mucous glands. The development is direct; the young are hatched as miniature adults.

Anodonta (The Freshwater Mussel). ✓

A Type of the Pelecypoda or Lamellibranchiata.

Give a short Description of the Shell of Anodonta.

The bivalve shell is rounded in front and bluntly pointed behind. The two equal valves are connected together by a dorsal and elastic hinge-ligament. The umbo, the oldest part of the shell, is in front of the hinge. A succession of curved lines on the outside of the shell indicates the growth, the extent between any two lines being that of one year. The shell has three layers: the inner pearly or nacreous layer is made by the surface of the mantle which lines the shell; the median prismatic limy layer and the outer horny periostracum are formed by the thickened edges of the mantle which are attached along the lower inner borders of the valves.

Describe the General Structure of Anodonta.

The main portion of the body is between the upper parts of the shell; a keel-like extension is the visceral mass, which contains the middle portion of the gut, the "liver," and the reproductive organ. This mass is continued downwards and forwards as the muscular and median wedge-shaped protrusible "foot."

Two large gill-plates, attached along each side of the body, hang down at each side of the "foot." The gills and "foot" are within the mantle-cavity, the large space enclosed by the two mantle lobes or flaps (downgrowths of the body wall) which line the shell. At the posterior end of the shell, the mantle lobes form two siphon-like openings of the two chambers into which the mantle-cavity is divided by a partition at the bases of the gills. Water enters by the large ventral inhalent opening into the large infra-branchial chamber, and passes through the gill-plates (between the filaments) into the small upper or supra-branchial chamber, and along that chamber it flows backwards to the small dorsal exhalent opening. The current is kept going by the cilia on the mantle and gills.

Two large muscles, anterior and posterior adductor, which stretch across from valve to valve, close the shell; and beside these are the smaller retractor and protractor muscles of the "foot."

In front of the gills are the labial palps, two pairs of small triangular flaps forming the lips of the mouth which is below the anterior adductor muscle. The heart, which consists of two auricles and a median ventricle, lies within a pericardium situated beneath the dorsal hinge-ligament. The ventricle surrounds the rectum, the terminal portion of the gut, which, passing upwards from the visceral mass traverses the pericardium and opens (anus) into the supra-branchial chamber near the dorsal exhalent opening. The paired kidney (Organ of Bojanus) lies below the pericardium, and communicates with it through two crescentic reno-pericardial openings (nephrostomes) at the anterior end of the pericardium. The ureter opening is where the inner gill-plate is attached to the visceral mass; and just below it is the genital aperture.

The nervous system consists of three pairs of ganglia: **cerebro-pleural ganglia**, one at each side of the mouth, under the skin, **pedal ganglia** in the middle of the "foot," just within the visceral mass, and **visceral ganglia** on the ventral surface of the posterior adductor muscle. The pedal and visceral ganglia are connected by **commissures** to the cerebral ganglia. There are two **otocysts** beside the pedal ganglia. Eyes are absent.

Explain the Structure of the Gills of Anodonta. How do the Gills of Mytilus differ from those of Anodonta?

The gills (**ctenidia** or **branchia**), two at each side of the body, are long and plate-like, and their surfaces have slight vertical ridges indicating the numerous **gill filaments** of which they are composed. Each filament somewhat resembles the letter V, and so each gill is a double plate consisting of an **inner and outer lamella**. The outer gill has the outer lamella attached dorsally to the mantle along its whole length; the inner lamella and the outer lamella of the inner gill are united dorsally and together attached along the visceral mass. The inner lamella of the inner gill is also attached dorsally (its front portion only) to the visceral mass; its middle portion is free, and its hind portion, extending beyond the visceral mass, is united with the corresponding lamella of the inner gill of the other side of the body. All the gills extend beyond the visceral mass and below the posterior adductor to a point behind that muscle; and in that region their lamellae being all united dorsally, a partition is thus formed dividing the mantle-cavity into an upper **supra-branchial** and a lower **infra-branchial** chamber. The upper chamber is continuous with the passages above and between the gill lamellae throughout the body. The slender **gill filaments** are **ciliated** and have supporting **chitinous rods**, and they are joined together by horizontal strands of tissue (**inter-filamentar junctions**); their V-portions are similarly connected, and thus the space between the lamellae of a gill is traversed by **interlamellar junctions** and divided up into numerous **water-tubes**.

In the marine edible mussel (*Mytilus*) the filaments are loosely connected by interlocking groups of cilia, ciliary (interfilamentar) junctions, and the edges of their bent-up portions are not fused to the mantle.

What is the General Course of the Blood Circulation in Anodonta?

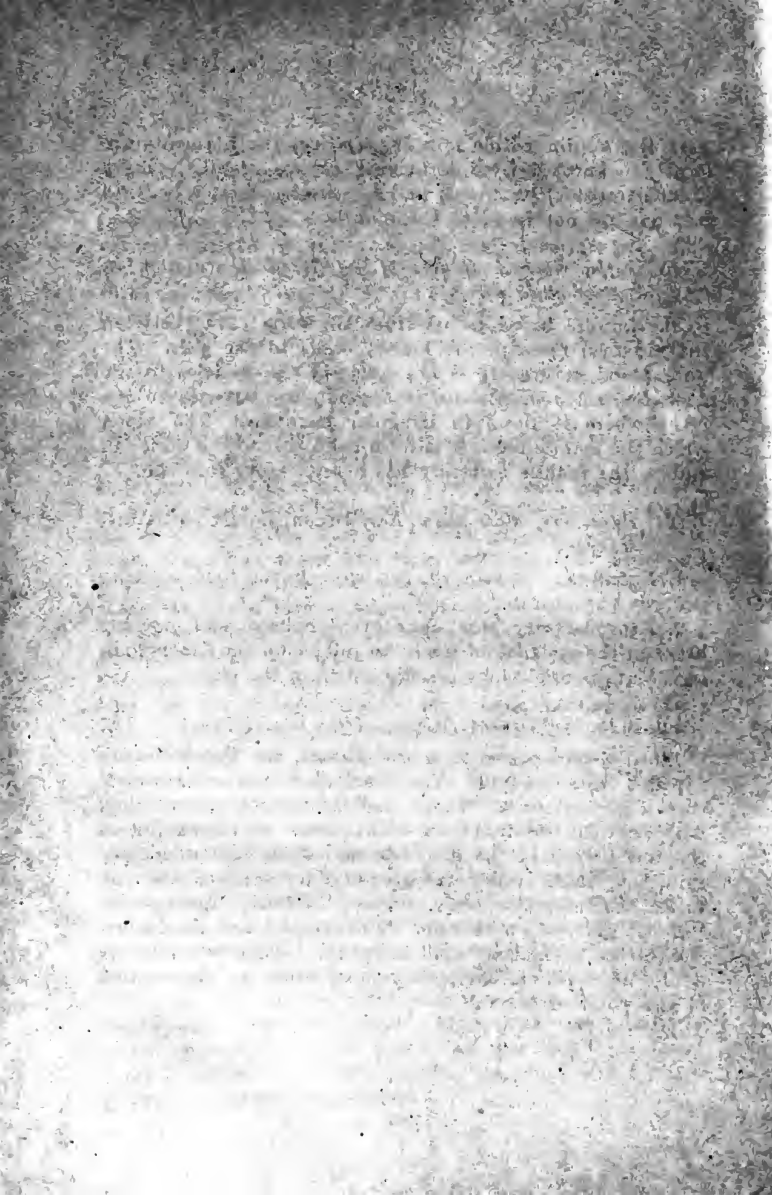
The impure blood passes from the **vena cava** (between the kidneys) through the kidney walls to the gills. The pure blood returns from the gills *via* the **auricles** to the **ventricle** which distributes it through **two arteries** to the body where it flows in **irregular channels**. The blood which the mantle receives is returned direct to the auricles; and so the mantle evidently has a respiratory function.

What Functions, other than Respiration, do the Gills discharge?

1. **Nutritive**; certain of the cilia impel food-particles towards the mouth.
2. **Reproductive**; the eggs are fertilised and develop between the lamellae of the outer gill; and the **Glochidium** larvae are nourished by a secretion from the gills.

What is the Subsequent History of the Glochidium?

When a fish passes near the Mussel, the Glochidia are expelled from the gills. The Glochidium has a "byssus" thread instead of a "foot," and a delicate porous shell with an incurved tooth on each valve. It fastens on to the fins or tail of the fish, becomes embedded under the skin, and there it remains parasitic for some weeks and undergoes metamorphosis. The "byssus" disappears; "foot," gills, and adductors are developed, and the formation of the permanent shell is begun. Then, a miniature adult, it leaves its temporary host, drops to the bottom of the pond or stream.



ZOOLOGY.

THE VERTEBRATA.

PHYLUM VERTEBRATA OR CHORDATA.

State the Chief Features of the Vertebrata or Chordata.

The body is supported by an *internal* skeleton (endo-skeleton), the main axis of which is the **dorsal notochord**, an elastic rod developed from the dorsal wall of the enteron. In the higher Vertebrates, the notochord is replaced (in the adult) by a more rigid **vertebral column** or **segmented backbone**.

Gill-slits or **visceral clefts**, with cilia or with gills, for aquatic respiration, are formed in the wall of the pharynx (the first part of the alimentary canal), and open indirectly or directly to the outside. In Reptiles, Birds, and Mammals the gill-clefts are present during embryonic life, but are not functional as breathing organs.

The **central nervous system** (brain and spinal cord) is tubular and dorsal. The eye is mainly an outgrowth from the brain. The heart is ventral.

A Classification of the Vertebrata overleaf.

SUB-PHYLUM ENTEROPNEUSTA OR HEMICHORDA.

Balanoglossus or Dolichoglossus.

Give a general Description of Balanoglossus.

The Balanoglossida (*Balanoglossus* and others) are worm-like and marine, mostly littoral forms which burrow in sand or mud. The soft skin (epidermis) is ciliated, and secretes much mucus. The body (from 1 to 6 inches, or more, in length) consists of a conical expandible proboscis (the preoral lobe) connected by a small constriction or neck to a short thickened "collar," which is followed by a long trunk. The mouth is ventral, between the proboscis and collar. On each side of the front part of the trunk there is a row of **branchial pores**; these are the external openings

A CLASSIFICATION OF *THE VERTEBRATA*.

METAZOA AND COELOMATA.

Phylum Vertebrata or Chordata.

ACRANIA (*i.e.*,
without skulls).

{ Sub-phylum Enteropneusta or Hemichorda (Balanoglossus,
Cephalodiscus, Rhabdopleura).

{ Sub-phylum Tunicata or Urochorda (Tunicates or Ascidians).

{ Sub-phylum Cephalochorda (Branchiostoma or Amphioxus).

{ Sub-phylum Craniata.

Division Cyclostomata or Round Mouths. Without
true jaws. (Lampreys and Hagfish.)

Division Gnathostomata. With true jaws.

Sub-division Anamnia (Embryo without an amnion
or a functional allantois).

Ichthyopsida { Class Pisces (Fishes).
(Fishes and
Amphibians). { Class Amphibia (Newts, Frogs).

Sub-division Amniota (Embryo with an amnion
and an allantois).

Sauropsida { Class Reptilia (Lizards, Snakes, Tor-
(Birds and
Reptiles). { toises, Crocodiles).
Class Aves (Birds).

Class Mammalia (Mammals).

CRANIATA (*i.e.*, with skulls).

of the gill-pouches, which also have internal openings (gill-slits) in the side walls of the pharynx. The anus is terminal, at the attenuated end of the trunk. The body wall is muscular and contractile. The creature moves by wriggling, and by means of its proboscis; and it swallows the mud, its food being the organic matter which the mud contains.

The ectoderm has a feltwork of nerve-fibrils; a mid-dorsal thickening of this, in the trunk, is the dorsal nerve-cord, which is closely connected with a central nerve mass, or neural tube, in the "collar." There is also a similarly formed ventral nerve-cord. A nerve-ring (between the "collar" and the trunk) connects the two nerve-cords.

The gut or alimentary canal is a straight tube. The first portion of the gut (within the "collar") is the buccal cavity, which has a dorsal tubular outgrowth with a tough fibrous sheath; this is the notochord, very short and restricted to the proboscis into which it extends and which it supports. The second portion of the gut is the pharynx; it has two distinct regions, an upper one with the internal gill-slits in its walls, and a lower one along which the food (mud) passes. Between the gill-slits there are skeletal supports called primary bars, and each slit is divided by a tongue-bar. The body cavity or coelome is developed as five pouches from the embryonic enteron. The largest of these are two (blind) spaces situated in the trunk throughout its length; the others are the two "collar" sacs, which open into the first pair of gill-pouches, and the proboscis sac, which opens to the exterior by one or by two dorsal pores. On the inner wall of the proboscis sac is the glomerulus, an excretory gland; it is situated at the front end of the notochord, above which is the pericardium (a closed sac).

Above the notochord, between it and the pericardium, is the dorsal heart; it is the anterior contractile portion of the dorsal blood channel, along which the blood flows forward from the body into the glomerulus. Thence the blood passes indirectly into a ventral blood channel (below the gut) in which the flow is backwards.

The gonads or reproductive organs are derived, like the muscles and connective tissue, from the coelomic walls, and form a series of simple sac-like outgrowths in the trunk coelome of each side, in and behind the gill-slit region. The gonads open to the exterior by minute genital pores. The sexes are separate. Development is either direct (e.g., *Dolichoglossus*) or indirect (e.g., *Balanoglossus*) involving a free-swimming *Tornaria* larva.

Briefly describe Cephalodiscus and Rhabdopleura.

(The chief differences between these forms and the Balanoglossida are printed in *italics*).

They belong to the Enteropneusta. Their general structure is similar to that of the Balanoglossida; but they present several features of difference here indicated.

Cephalodiscus forms colonies. The individuals or zooids are of *minute size* (about 2 mm. in length), and each one *lives in a tube* of flexible brown substance like chitin, which is secreted by the proboscis. The zooids are not attached inside these tubes, nor are they connected one with another; but the tubes are closely massed together. The size of a colony may be about 9 by 6 inches.

The *body is greatly reduced lengthways, but broadened dorso-ventrally.* The stout trunk has, on the ventral surface, a stalk-like projection, the pedicle, at the end of which new zooids are formed by budding (asexual reproduction). The "collar" has projections, 4 to 6 *pairs of arms bearing numerous tentacles.* The proboscis is broad and disc-shaped (*buccal disc*). The *gut is bent like the letter U*, so that the *anus is dorsal* and almost level with and near the ventral mouth. There is only *one pair of gill-slits* and *one pair of gonads.* The sexes are usually separate (sexual reproduction), and development is direct. *Budding (asexual reproduction)* is frequent.

Cephalodiscus is marine, and has been found at various depths (Straits of Magellan, Antarctic, Malay Archipelago, and in other seas).

Rhabdopleura forms colonies. The zooids are of *minute size*, and each one *lives in a tube* of clear chitin-like substance made (in ring-like sections) by the proboscis. The basis of the colony is a branching and creeping stolon, containing a chain of living matter from each link of which a zooid arises more or less erect. The zooids are therefore connected by a common organic axis; but they are not closely massed together.

The body is borne on a narrow stalk, which is the ventral pedicle of the short stout trunk. The "collar" has *one pair of arms with tentacles.* In the stalk, arms and tentacles there is a supporting skeletal tissue. By contracting the muscular stalk, the zooid withdraws down the tube; it moves up again by means of the proboscis. The proboscis is a *buccal disc.* *The gut has the same conformation as that of Cephalodiscus.* There are *no gill-slits*; but there are two branchial grooves. *Rhabdopleura* is marine; it is found at moderate depths, and is widely distributed.

SUB-PHYLUM TUNICATA OR UROCHORDA.

What are Tunicates ?

Tunicates or Ascidians have the body enclosed in a tunic or test of cellulose ; they also have a large pharynx, usually with numerous gill-slits, and more or less completely surrounded by the atrium, a large space between the pharynx and the body wall.

Metamorphosis (retrogressive) is usually a feature of their development. The tadpole-like larva has a tubular and dorsal central nervous system, a brain-derived eye, and a notochord in the tail region ; but these characteristic Vertebrate structures generally disappear during transition, and are not commonly present in the adult.

Some Tunicates are solitary, others form colonies ; and they are either sedentary, fixed to one spot, or free and palagic. Propagation by budding is a frequent mode of multiplication.

Give a general Account of (1) the Reproduction, and (2) the Development of the Tunicata.

1. Tunicates are, with few exceptions, hermaphrodite ; the gonads mature at different times (i.e., dichogamy. See page 12, Part I.), and usually the ova ripen before the sperms (i.e., protogyny, a rare phenomenon among animals). Asexual reproduction by budding is also frequent, and results in clusters (e.g., *Clavellina*) or in close colonies (e.g., *Botryllus*). The buds arise from a common stolon (except *Botryllus*). In several instances (e.g., *Salpa*, *Doliolum*) both modes of reproduction occur in the course of the life-history, which shows alternation of generations or metagenesis (See page 13, Part I.) ; the embryo, or the larva, becomes an asexual form, which by budding produces sexual forms, and these beget a new asexual generation. The asexual form of *Doliolum* produces buds of three different kinds (polymorphism), namely, sexual zooids and their "foster-mothers," and nutritive zooids.

2. The fertilised egg is developed either outside the body (i.e., in the sea) or within the atrium, or in special brood pouches of the atrium (e.g., Compound Ascidians) ; and generally a free-swimming tailed larva is formed. The larva has a large pharynx, with few gill-slits and an endostyle ; and the short intestine, bent upwards, ends in a dorsal anus in front of the tail. The atrium is developed from two invaginations of ectoderm which gradually extend around the pharynx. The tubular nervous system consists of

a large anterior cerebral vesicle (in the wall of which an eye and an otocyst (statocyst) are formed), a thickened median part which becomes the trunk ganglion, and a thin posterior portion in the tail. The notochord is restricted to the tail region (*Urochorda*). The body is completely invested by a thin cuticle, an excretion of the ectoderm; this is the tunic or test, and an outgrowth of it is the delicate fin which fringes the muscular tail.

When hatched out, the tadpole-like larva leads a free-swimming life, but only for a few hours; and it does not feed, because the mouth and anus are covered in by the cuticle. Then it settles down head foremost, fixing itself by three papillae on the front of the head, and retrogressive metamorphosis begins. The tail atrophies, is absorbed, and with it the notochord and caudal nerve-cord disappear. The eye and the otocyst are also lost (except *Salpa*, *Doliolum*, and the *Appendiculariae*); only a part of the nervous system remains, that from which the trunk ganglion is developed. The atrium enlarges, the two portions coalesce dorsally, and it opens to the outside by a single atrial aperture. Numerous gill-slits are formed. The mouth, which was near the fixed end, becomes shunted round to the opposite end, and the hind end is brought near the fixed end; there is a marked change from the horizontal to the vertical in the formation of the inert and degenerate adult.

In the life-history of certain Tunicates (e.g., *Molgula*, *Pyrosoma*, *Salpa*) the tadpole larva is absent.

Describe the general Appearance and Structure of an adult simple Ascidian (e.g., Ascidia).

Ascidia mentula is sac-like and roughly oval; it is greenish-grey, and its average height is about 3 inches. The lower and broader end is fixed to rock or other surface; the upper or anterior end has two siphon-like openings, the inhalent aperture or mouth, and near it (on the dorsal side) the exhalent or atrial aperture. When the sphincter muscles of these siphons suddenly contract, water is squirted out; hence the popular name, "sea-squirts." The thick opaque cuticle covering the body forms a cellulose tunic or test. It is a loose tunic; about the openings and where blood-vessels enter it, there only it is attached to the underlying body-wall or mantle. The mantle consists of ectoderm upon a matrix of connective tissue, muscle fibres, and blood spaces.

The mouth leads into a short stomodaeum (lined with cuticle) at the end of which is a sphincter muscle with a

ring of tentacles around its posterior border ; these tentacles form the sieve-like entrance to the large **pharynx**, which extends to the posterior end of the body. The rest of the gut is on the left side of the pharynx, and is largely embedded in the mantle ; and it consists of a short **oesophagus**, a **pyriform stomach**, and a **looped intestine** ending in a **dorsal anus** which opens into the **atrial outlet**.

The pharynx has walls with **numerous transverse rows of ciliated gill-slits** ; and along its inner ventral surface there is a ciliated groove with glandular cells, the **endostyle**, opposite which is a ciliated fold along the inner dorsal surface, the **dorsal lamina**, extending to the oesophagus. Both are connected with a ciliated circular **peripharyngeal groove** below the tentacles round the entrance to the pharynx. The cilia of the endostyle force the slime (secreted by its gland cells) forward into the peripharyngeal groove ; and the slime is moved on round that groove and thence down the dorsal lamina. The water-borne food particles and organisms are caught in the moving slime, and are in that way conveyed into the oesophagus. Water is drawn in at the mouth into the pharynx or branchial sac, which, having highly vascular walls for the aëration of the blood, also acts as a respiratory organ. The current is kept going by the action of the cilia on the gill-slits, through which the water passes into the atrium, the large space between the pharynx and the body wall. The water passes out through the atrial aperture.

The only remaining part of the nervous system is the **trunk ganglion**, situated between the mouth and the atrial opening. The **ventral heart** is a simple sac situated below the ventral end of the stomach ; it has a reversing action, which causes a periodic change in the direction of the blood-flow ; it is placed within the **pericardium**, which, along with a small associated space, represents the **coelome** or body cavity.

The **hermaphrodite** reproductive organs (an **ovary** surrounded by a **testis**) are situated in the loop of the intestine ; and the ducts (**oviduct** and **vas deferens**) together lead into the atrium, and open near the anus. The gonads mature at different times (i.e., **dichogamy**. See page 12, Part I.).

A Classification of the Sub-Phylum Tunicata.

Order ASCIDIACEA. Fixed or free-swimming; solitary or colonial. Adults without tail and notochord. Muscles irregular. Pharynx large. Numerous gill-slits opening into atrium, which has one atrial aperture. Anus opens into atrium.

Tribe 1. Ascidiæ Simplicæ. Simple solitary Ascidians (the typical "sea-squirts"). Usually fixed. Tunic thick and opaque. Reproduction sexual (hermaphrodite). Generally there is a tailed larva.

Examples, Ascidia. See description, page 182. Lives in mud at depths from 5 to 20 fathoms.

Ciona. Elongated form, Muscles form bands.

Digestive portion of gut is behind the pharynx.

A common littoral tunicate.

Boltenia. Body on a long stalk.

Styelopsis (syn. Cynthia). A common small and red littoral tunicate.

Molgula. Without a tailed larva.

Tribe 2. Ascidiæ Compositæ. Compound Ascidians. Colonies usually fixed. Individuals of colony generally within one common test. Reproduction asexual (budding or gemmation) and sexual (the embryos, developed in atrium or in special atrial pouches, become tailed larvae).

Examples, Botryllus. Forms bright-coloured gelatinous incrustations on rocks and seaweed. Zooids grouped in small star-like colonies, within a common test; their mouths open directly to the outside, but their atrial apertures open into a common chamber (the cloaca) with a central outlet.

Clavellina. Zooids grouped together on a creeping stolon; but not within a common test. A common littoral tunicate; one of the "social" forms.

Tribe 3. Ascidiæ Luciac. Free-swimming pelagic colonies, shaped like hollow cylinders with an open truncate end and a closed rounded end; the hollow being the common cloaca into which open the atrial apertures of the numerous zooids forming the cylinder wall. Tests gelatinous and transparent. Phosphorescent. Reproduction asexual (budding) and sexual. Without a tailed larva.

Example, Pyrosoma. Colonies vary in length from a few inches to about four feet.

Order THALIACEA. Free-swimming (effected in jerks by forcing water out at atrial opening). Pelagic. Solitary or "social." Adults without tail and notochord. Muscles

form bands. Sexual and asexual reproduction. Life-history shows alternation of generations (metagenesis).

Examples, *Salpa*. Body barrel-shaped, with mouth at one end and atrial opening at or near opposite end. Test thin and transparent. Muscles like incomplete hoops. Pharynx simple, with two large holes instead of gill-slits. Without a tailed larva. Embryo (nourished by a "placenta") becomes a solitary asexual form, which, by budding, produces a chain of sexual zooids, which produce the asexual forms (metagenesis).

Doliolum. Body barrel-shaped, with mouth at one end and atrial opening at opposite end. Test thin and transparent. Muscles form complete hoops. Pharynx simple, with few gill-slits. The tailed larva develops into an asexual ("nurse") form, which, by budding, produces three different kinds of buds (polymorphism), namely, nutritive buds (which feed the "nurse") and "foster-mothers," to which are attached for a time those buds which become sexual forms.

Order LARVACEA or APPENDICULARIAE. Solitary and pelagic Ascidians of minute size, with long tails and notochord present throughout life. Form very large tests (temporary "house") within which they move about freely and which they often vacate. After remaining "houseless" for a time, the Appendicularian forms a new test within a few hours. Mouth anterior. Anus ventral, at root of tail. Gill-slits (two) and anus open directly to outside (without an atrium). Dorsal nerve cord, extending into tail, with cerebral ganglion and otocyst and from 8 to 40 caudal ganglia. Hermaphrodite (protandrous), except *Oikopleura*.

Examples, Appendicularia.

Oikopleura. Tail very long. Not hermaphrodite.

SUB-PHYLUM CEPHALOCHORDA.

Amphioxus or Branchiostoma (The Lancelet).

Describe the External Features of Amphioxus. Where is it found?

Amphioxus is small (about 2 inches in length) and fish-like; its body, almost colourless and translucent, is elongate, compressed at the sides, and pointed at the ends. Each side is marked by a close succession of < shaped lines, which indicate the connective tissue septa between the << shaped myotomes or segments (62) of the lateral

muscles; these, and the row of sac-like gonads, partly visible below segments 10 to 35, show the segmentation of the body. Along the back there is a slight median fold of skin, the dorsal fin; this is extended round the tail as a wider caudal fin, and is continued ventrally, a short distance, as the narrow anal fin. The dorsal and anal fins are stiffened by numerous small fin rays.

Under the anterior end of the body is the oral hood, which encloses the buccal cavity; its external opening, fringed with ciliated processes (buccal cirri), is the buccal opening, often called the ventral mouth. The true mouth is the aperture of the velum, which is "a muscular diaphragm between the buccal cavity and the pharynx" fringed with twelve tentacles. The flattened ventral surface of the anterior two-thirds of the body is bordered by two lateral metapleural folds, which extend from the oral hood and meet together behind the atrial pore in front of the anal fin. The ventral anus opens midway between the atriopore and the tip of the tail, slightly to the left of the middle line.

Amphioxus lanceolatus is found in the shallow coastal waters around Britain (English Channel), North Sea, Mediterranean, and other seas. It burrows in the sand, habitually lying buried with only the mouth protruding. It also swims actively (by wriggling).

How does Amphioxus feed? Explain the Structure of the Alimentary Canal of Amphioxus. Which part of the Alimentary Canal is respiratory, and how is Respiration effected?

The buccal cavity (stomodaeum) has a ciliated lining, certain parts of which have specially long cilia and form the "wheel-organ"; by that means the indrawn water is driven into the pharynx. The small organisms and particles in the water become entangled in the mucus which is secreted in the endostyle (the mid-ventral groove along inner wall of pharynx) and moved on up the sides of the gill-slits and the anterior peripharyngeal bands (behind the velum) into the mid-dorsal epipharyngeal groove which opens into the stomach. In this way *Amphioxus* feeds.

The large pharynx forms about half the length of the alimentary canal; the other half is the intestine, a straight tube ending in the anus. A pouch-like outgrowth, from the swollen anterior (stomach) portion of the intestine, is the "liver," which is directed forwards on the right side. Dorsally the pharynx is attached to the sheath of the

notochord; laterally and ventrally it (and also a portion of the intestine) is surrounded by the atrium, an extensive space between gut and body wall. The side walls of the pharynx have numerous gill-slits directed downwards and slightly backwards. The narrow portions between the slits are supported by *double* chitinous rods with forked or split lower ends (*primary bars*); and each slit is double, being divided, during later development, by a secondary downgrowth, which is stiffened by a *single* unsplit rod (*secondary or tongue-bar*) containing a coelomic cavity. There are also short horizontal bars (*synapticulae*) connecting the primary and tongue-bars.

This gill-slit or branchial region of the pharynx is respiratory; it is richly ciliated and has numerous blood-vessels. There the blood is aerated by the water. Passing through the gill-slits into the atrium, the water then passes out at the *atriopore*.

Describe the Skeletal Structure of Amphioxus.

Between the dorsal spinal cord and the alimentary canal there is a median flexible supporting rod, the *notochord*, which extends throughout the body from end to end; it is composed of large vacuolated turgid cells, and it has a double sheath of connective tissue, the outer one being part of the connective-tissue framework of the body.

The margin of the oral hood has an oval *buccal ring*; it consists of a number of pieces, and each bears an offshoot which supports a *buccal cirrus*.

The *chitinous primary and tongue-bars and synapticulae* of the gill-slit region of the pharynx, and the *fin-rays*, are also structures of a skeletal nature.

Write an Account of (1) the Nervous System, and (2) the Circulatory System of Amphioxus.

1. The central nervous system is a *dorsal spinal cord*, nearly as long as the notochord and situated above it. The spinal cord is enclosed in a sheath of connective tissue; and it has a narrow canal which expands into a *cerebral vesicle* (ventricle of "brain") at the front end. From the anterior wall of the vesicle there is a small hollow outgrowth, which is connected with an *ectodermal olfactory pit*. There is also a *pigment spot* ("eye") in the vesicle wall at the extreme front end of the cord; and along the canal, at regular intervals, there are other *pigment spots*, probably sensitive to light.

Two sets of nerves are given off from the spinal cord, namely, dorsal sensory nerves to the skin, and ventral motor nerves to the myotomes; the former have single roots, the latter are multiple-rooted. The nerves of the first two dorsal pairs ("cranial nerves") arise opposite each other; and there are no ventral nerves corresponding with these. All the other dorsal and ventral pairs of nerves show a segmental arrangement corresponding with the myomeres or myotomes; consequently the nerves of each pair are not opposite on each side, but arise alternately.

2. There is no heart, but the principal vessels are contractile. Blood from the alimentary canal is collected in an intestinal plexus (i.e., a network of connected vessels), which forms the sub-intestinal vein; it passes forward to the "liver" where it is spread out as a plexus, and reformed (as the hepatic vein). It is continued forward, below the pharynx, as the ventral aorta, which is contractile and gives off vertical branchial vessels which ascend the septa between the gill-slits on each side (where the blood is purified). The branchial vessels are connected, by short cross vessels (in the synapticalae), with parallel vessels (of the tongue-bars). These double branchial vessels pass upward to the dorsal surface of the pharynx, and there form at each side a longitudinal aorta. The two aortae are continued forwards (the right one supplying the anterior region with blood); and behind they unite (near the end of the pharynx) to form a single dorsal aorta, which passes backwards along the dorsal surface of the intestine.

Give a General Account of the Body Cavity (Coelome) of Amphioxus.

The body cavity or coelome is well developed in the posterior third of the body, around the sides and ventral surface of the hind portion of the intestine. In front of this, owing to the extension of the atrium, it is displaced and greatly reduced. A forward portion of it surrounds the "liver"; and it further extends along each side of the dorsal region of the pharynx, above the atrium, as two dorsal coelomic canals (dorsal coelome), and along the ventral region of the pharynx as a ventral coelomic canal (endostylar coelome). The dorsal canals and the ventral canal are connected by portions of coelome in the septa between the gill-slits, which portions collectively form the branchial coelomic canals of the two sides of the pharynx. The gonad sacs are also coelomic.

Where are the Excretory Organs of *Amphioxus* situated? Describe them.

The paired nephridia, restricted to the region of the pharynx, are situated in the dorsal wall of the atrium and project into the dorsal coelomic canals (dorsal coelome). Each nephridium is a ciliated tubule; one end opens into the atrium, and the other end (in the coelome) is expanded into several short blind funnels. On the funnels there are groups of cells like knobbed stalks, the flame-cells or solenocytes (cf., flame-cell, page 91, Part II.). The stalk is a fine tubule, which opens through the funnel wall into the excretory canal, and within the tubule there is a long vibratile flagellum, which arises from the protoplasm surrounding the nucleus in the knob end. The flagella project into the excretory canal. On the wall of each nephridium there is a network or anastomosis of capillary blood-vessels, which is connected with the dorsal ends of the branchial vessels and the aorta. This vascular network is the glomerulus.

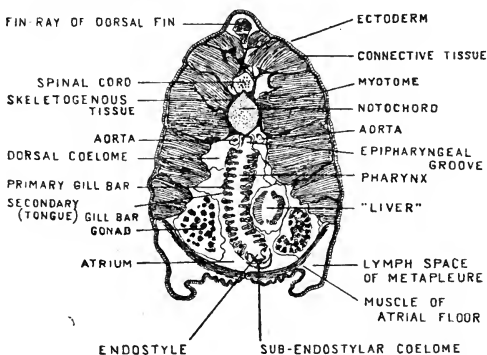


Fig. 35.—*Amphioxus*. Transverse section through pharyngeal region of body.

Write a short Description of the Reproductive System of *Amphioxus*.

The sexes are separate. The gonads (testes and ovaries, are outwardly similar, cube-shaped, structurally simple) and without ducts; there is a row of 26 along each side on the wall of the atrium at the lower ends of myotomes 10 to 35. Each gonad is enclosed in a coelomic sac, a

constricted-off portion of the myocoel. The sperms and ova are discharged into the gonad sac; and, through pores in its wall, they pass into the atrium, thence out by the atriopore.

The spawning period is from April to July; and evening is the spawning time. The eggs are generally fertilised in the sea.

Development of Amphioxus.

Briefly describe the Segmentation of the fertilised Egg.

The egg contains very little food-yolk; consequently the segmentation or cleavage is nearly equal and complete (holoblastic). The egg is divided vertically into two halves (right and left halves of future embryo). These halves are divided vertically into four blastomeres. The next division, nearly equatorial, results in eight blastomeres; the four lower ones being larger (macromeres) than the four upper ones (micromeres). Further bisection results in sixteen. Subsequent division is less regular, the segmentation cavity (blastocoel) increases in size, and a spherical blastula is formed. (See description of Blastula, page 14, Part I.).

What is the next Stage of Development?

The forming of a cup-like two-layered embryo, the gastrula (see Gastrula, page 14, Part I.), by (1) infolding (invagination) of the vegetal hemisphere, and by (2) inturning (involution) of animal pole cells developed at the dorsal part of the blastopore lip, and accompanied by (3) continuous overgrowth (epiboly) of the lip, whereby the gastrula is elongated and its opening reduced. The embryo is now elongate, flattened dorsally and convex ventrally, with a small posterior opening (the blastopore) dorsalwards.

Explain the further Development of the Embryo to the time when it is hatched.

Along the dorsal line, the ectoderm (epiblast) thickens to form the medullary plate, which sinks in and is detached; and the lateral ectoderm grows over it. The plate widens, becomes grooved; and ultimately, by the union of its sides (medullary folds), it is formed into a tube, the central (medullary) canal of the nervous system. The overgrowth of ectoderm extends backwards from the hind end; and so the blastopore becomes the short neurenteric canal or communication between the archenteron and the medullary canal, which ends anteriorly in the neuropore. The neuro-

pore is closed when the adult state is attained. Dorsally at each side the hypoblast or endoderm (wall of the archenteron) is pushed out, thus forming two longitudinal folds (mesoblast pouches); these become constricted into a succession of segments, and in that way, on each side, a series of mesoblastic somites is formed (two pairs at this stage, the others later), and the mesoderm is thus established. (See Mesoderm, page 15, Part I.)

Each cell of the ectoderm has a flagellum; by means of the flagella, the newly-hatched embryo swims.

Give an Account of the later Development of the Embryo.

The dorso-median endoderm (roof of archenteron) develops a longitudinal ridge, which separates off and forms a solid rod of cells between the archenteron and the medullary tube; this is the notochord.

The mesoblastic somites extend down the sides of the archenteron, between it and the ectoderm. The cells of the somite walls next the notochord become elongated muscle cells, and form the first \llcorner shaped myotomes (14 or 15). Anteriorly the mouth, a large oval opening on the left side, is developed; and also the first gill-slit, a small opening on the ventral surface which is soon extended on the right side. Later the anus is formed, near the hind end and to the left of the middle line.

The anterior part of the body is extended; and there is a corresponding extension forwards of the notochord. The embryo lengthens out, becomes thin, and is tapered at both ends. The tail is fringed by a large vertical fin. The gut shows an anterior enlargement (pharynx) and a long intestine. The mouth, anus, and first gill-slit having been formed, the thirty-six-hours' embryo is now a larva.

Mention the chief Developmental Features of the Larval Stage of Amphioxus.

The mesoderm segments (mesoblastic somites) are detached from the archenteron, which has now a wall of definite endoderm and becomes the enteron or gut. Additional segments are successively developed (from the original ones). The portions of the segment walls which adjoin the ectoderm consist of somatic mesoderm; those adjacent to the spinal cord, notochord, and gut, consist of splanchnic mesoderm. Each segment is divided into two portions, a dorsal myotome (protovertebra) and a ventral lateral plate. The cavity of the myotome is the myocoel; from its

inner or splanchnic wall, the muscles of the body wall are formed, and from its outer or somatic wall arises the cutis or basis of the skin.

The inner wall at its lower end shows that proliferation (characteristic of mesoderm) which results in a mass of discrete cells or mesenchyme. (See page 16, Part I.) This outgrowth (the sclerotome) extends inwards then upwards between the myotome and the notochord, and forms the connective tissue which sheathes the notochord, spinal cord, and other parts. The myotomes remain separate; but the ventral portions of the somites lose (by absorption) their septal walls, and form a continuous lateral plate, the cavity of which is the splanchnocoel, the future coelome or body cavity of the adult (and enterocoelic, therefore, in origin). The two lateral plates meet together ventrally, their cavities become continuous and thus form the main body cavity or peritoneal cavity.

Additional primary gill-slits are formed ventrally and shifted on to the right side; and above them eight secondary gill-slits develop. Later, the first and the last five primary slits disappear and the remaining eight are shunted on to the left side; there is then an equal number of eight gill-slits on each side. The number increases, and the slits become vertically elongated.

On the under surface of the body two longitudinal folds of skin (metapleural folds) appear behind the gill-slits and grow forward above them. From each fold an inner shelf grows out; the two coalesce, and thus a canal, the atrium, is formed. It enlarges, pushes in the ventral body-wall, compresses the coelome and extends right round each side of the gut, as far back as the middle of the intestine; there it opens externally by the atriopore. Therefore the gill-slits no longer open directly to the outside, but into the atrial chamber.

The neurenteric canal is closed. The endostyle is formed. The mouth is shifted to a median position; it is reduced to a small opening, its margin becomes the velum, and two folds grow out in front and form a vestibule, the oral hood. The gonads appear as thickenings on the myocoel wall, at the lower ends of the myotomes. The portion of myocoel containing the gonad is constricted off later.

The larval period extends to about three months. Change of habitat marks the transition to the adult state; pelagic life is abandoned, and the young *Amphioxus* takes to the sand. A feature of the development is the asymmetry of the larva, as seen, for example, in the original position of the mouth and the primary gill-slits.

State the Chief Features of Resemblance and of Difference between Tunicates, Amphioxus, and the Craniata.

TUNICATES.

Notochord temporary—present only in embryo or larva, and restricted to tail.

Without a definite head.

Slight segmentation of body.

Coelome imperfectly developed.

Epidermis has a thick cuticle (a cellulose tunic or test).

Dorsal nervous system with cerebral vesicle and rudimentary unpaired sense organs in larva degenerates in adult, and is represented by a trunk ganglion only.

Numerous ciliated branchial clefts (gill-slits), opening into an atrial chamber.

Pharynx has a ventral endostyle and a dorsal lamina, which are connected by a peripharyngeal groove.
A simple ventral heart.

No special excretory organs.

Gonads with ducts.

Sexes not separate (hermaphrodite).
Asexual reproduction (budding) frequent.

AMPHIOXUS.

Notochord permanent, and extending through whole length of body.

Without a definite head.

Pharynx (gill-slit region) supported by primary bars, secondary bars (tongue-bars), and synapiculae.

Definite metameric segmentation, as seen in muscle segments (myotomes), gonads, nephridia, etc. Externally visible.

Coelome well developed. Formed from mesoblast pouches of archenteron, which become completely segmented; the ventral portions of the mesoderm segments becoming continuous later as the coelome (enterocoelic).

Epidermis is a single layer.

Spinal cord (shorter than notochord) with dorsal single-root and ventral multiple-root spinal nerves, which do not join, and with an anterior cerebral vesicle (brain rudiment) and rudimentary unpaired sense organs.
The first two pairs of spinal nerves are termed "cranial" nerves.

Numerous ciliated branchial clefts (gill-slits), opening into an atrial chamber.

Pharynx has a ventral endostyle and a dorsal epipharyngeal groove, which are connected by a peripharyngeal groove.

No definite heart; but chief blood-vessels are contractile.

Excretory organs are separate nephridia (segmentally arranged), which open directly to the outside (i.e., into the atrium).

Gonads (segmental) arise from wall of myocoel, and are without ducts.

Sexes separate.

CRANIATA.

Notochord does not extend in front beyond the infundibulum (of brain); and it is usually replaced (in adult) by a vertebral column or segmented backbone.

Head well developed, and with a cranium or skull.

Mouth and pharynx walls supported by a separate visceral skeleton consisting of visceral arches (usually seven), which are united ventrally and free dorsally. Five of these are the branchial arches (between the gill-clefts) of Fishes and Amphibians.

Paired limbs (except Cyclostomata).

Metameric segmentation strongly marked in embryo, less so in adult. Not externally visible.

Coelome well developed. Formed from solid mesoderm outgrowths of archenteron, which are hollowed out later by apparent splitting, and become incompletely segmented; the ventral portions of the segments being continuous and forming the coelome (schizocoelic and secondary).

Epidermis has several layers, and develops scales, feathers, hairs, etc.

Spinal cord (longer than notochord) with spinal nerves, each having a single dorsal root and a ventral root usually multiple; and with a complex brain and well-developed paired sense organs (eyes, nose, ears).

There are ten or twelve pairs of cranial nerves.

Generally there is a visceral or sympathetic nervous system. Never more than eight visceral or gill-clefts; functional and with associated gills in Fishes and Amphibians, but not functional in Reptiles, Birds and Mammals, though present during embryonic life.

Endostyle becomes the thyroid gland.

A well-developed (chambered) ventral heart. Blood has red corpuscles.

Renal organs are composed of nephridia, which open into a longitudinal duct (archinephros and archinephric duct).

Gonads (not segmental) arise from lining of splanchnocoel or coelome, and have ducts.

Sexes usually separate.

SUB-PHYLUM CRANIATA.

Structure and Development of the Craniata.

Describe the External Features of the Body.

The body is elongated, more or less rounded and bulky, and bilaterally symmetrical; and it has distinct regions, namely, head, neck (frequently), trunk (thorax and abdomen), and tail (an appendage in higher Craniates). The mouth is transverse and anterior; and near it are the paired nostrils (single in Cyclostomata). At the sides of the head are the paired eyes; and behind them are the ears, and the gill-slits or branchial clefts (in the neck region). The anus is ventral, at or about the end of the trunk, and near it are the urinary and genital openings (frequently combined). Commonly there is only one opening, that of the cloacal chamber, within which are the anus and urino-genital apertures.

There is a dorsal unpaired fin which extends round the tail in certain Fishes and Amphibians, and which in most Fishes is broken up into separate fins. Fishes have also paired fins, representing limbs; and there are two chief types, namely, the primitive archipterygium (e.g., *Ceratodus*), which consists of a median segmented axis bearing on each side supporting radials obliquely directed and overlapped by a fringe of fin-rays, and the ichthyopterygium (of most fishes), in which the radials arise from basal pieces. In higher Craniates these fins are replaced by fore- and hind-limbs, each of which has, typically, five digits (pentadactyl limb or cheiropterygium).

Give a Description of the Structure of the Integument or Skin, and state its Functions.

The skin consists of an outer epidermis (modified ectoderm) and an underlying dermis or cutis (connective tissue formed from mesenchyme). The epidermis has several layers, the lowest being the actively growing stratum malpighii which forms and renews the upper layers (stratum corneum).

The epidermis of fishes has gland cells, which secrete mucus for reducing friction between the body and the water. The preen-gland of birds (for oiling the plumage), also feathers and hairs are formed by the epidermis. Pigment (to prevent penetration of light), glands for keeping the skin moist (e.g., frog), scales (of fishes and reptiles),

and bony shields (e.g., armadillo) are developed from the dermis. Skin-teeth or dermal denticles (of Elasmobranchs), and ordinary teeth are formed mainly (bone basis, and core of dentine or ivory) from the dermis, partly (enamel crown) from the ectoderm. As indicated by these structures, the skin is protective; it is also highly sensory, it receives impressions from the outside world, develops sense organs, and from it are formed the main portions of the central nervous system. Regulation of the body temperature, excretion, and respiration (e.g., frog) are also functions of the skin.

Write a short general Account of the Muscles of the Body.

There are two kinds, namely, myotome muscles, which are developed from the inner walls of the myotomes, and visceral (mesenchymatous) muscles, which arise from the wall of the coelome (splanchnocoele).

The myotome muscles, which have cross-striped fibres, form the muscular layer of the body wall, and are concerned with locomotion; the layer being composed of zig-zag segments (separated by connective tissue septa), this permits of side to side wave-like bending. The development of limbs in the higher Craniates results in varied movements and corresponding modifications of the myotome muscles, so that only traces of the original segmental arrangement remain in the adult. The visceral muscles, which generally have smooth or unstriped fibres, are those of the alimentary canal, heart, blood vessels, and other parts. The heart muscles are of the cross-striped type.

How is the Body Cavity (Coelome) developed? Describe the Body Cavity of an Adult Craniate.

Solid mesoderm (in the trunk region on each side) is derived and detached from the endoderm (wall of archenteron), and is segmented dorsally (protovertebrae or myotomes) but not ventrally (lateral plate). The mesoderm segments are therefore incomplete, and their continuous ventral portions thus form a sheet on each side. (Cf. Development of Chick, page 248.) Spreading downwards, the two sheets meet below the gut and there coalesce as one; above the gut they become closely apposed (when the dorsal myotome segments are separated off from them), and their conjoint walls form the fold of mesentery to which the gut (intestine) is attached. When the solid mesoderm is later hollowed out by splitting, the cavity thus formed

(schizocoele) in the sheet around the gut is the splanchnocoele, which becomes the coelome or body cavity (schizocoelic and secondary in origin). Between the cavities of the dorsal myotome segments and the splanchnocoele, there remain for some time narrow connections, the nephrotomes, from which the nephridia or kidney tubules are formed. The nephrotomes correspond with the gonad sacs of *Amphioxus* (see page 189).

In the adult the coelome or body cavity forms the peritoneal cavity of the body; it contains the chief viscera, and its lining (peritoneum) consists of inner coelomic epithelium and outer connective tissue. Portions of this cavity become separated off; one of these is the anterior pericardium which surrounds the heart. In lower Craniates (e.g., Dogfish) communication between the pericardium and the main peritoneal cavity is perpetuated through a backward extension of the pericardium, the pericardio-peritoneal canal, which opens into the main peritoneal cavity on the ventral surface of the oesophagus.

In Amniota portions of the cavity are shut off to form the pleural cavities around the lungs.

*What is the Nature and Origin of the Skeleton of Vertebrates?
Mention its principal Parts.*

It is mainly internal, an endoskeleton. Certain parts (e.g., scales, feathers, hairs, teeth) are external and constitute an exoskeleton, which is, however, not a cuticle formation as in Invertebrates. (For origin of scales, etc., see Integument or Skin, page 194.) In the vertebrate embryo, and in adult lower vertebrates (e.g., Cyclostomata and certain Fishes) the endoskeleton is cartilaginous; in adult higher vertebrates the elastic cartilage is supplemented or is largely replaced by rigid bone.

The foundation of the skeleton, the notochord, a rod-like series of turgid cells with a double membranous sheath, is developed from the endoderm. The notochord extends from the tip of the tail forwards as far as the infundibulum of the brain. The vertebral column (replacing the notochord) and additional skeletal parts, which together form the supporting framework of the body, are of later origin, being produced by secondary development from connective tissue or mesenchyme (see *Amphioxus*, page 192,) which is cartilage-forming (i.e., the cells secrete an intercellular matrix of a firm elastic substance, chondrin). But the matrix may become rigid through infiltration with lime, or the tissue may be invaded or extensively replaced by

another kind of connective tissue, namely, cells which form true bone.

The principal parts of the skeleton are :—

- | | | |
|---|---|--|
| 1. Axial portion | } | <p>(a) Notochord of embryo. The notochord sheath becomes cartilaginous in adult Cyclostomata, Elasmobranchii, Holocephali and Dipnoi; and in Elasmobranchii is further transformed into a segmented vertebral column.</p> <p>(b) Vertebral Column (backbone), with associated Ribs, becomes ossified in certain fishes (e.g., Teleosteans), in Amphibians, Reptiles, Birds, and Mammals.</p> <p>(c) Skull, with associated Visceral Arches.</p> |
| 2. Appendicular portion
(absent or rudimentary in certain Craniata.) | } | <p>(d) Fore Limbs, and Pectoral Girdle.</p> <p>(e) Hind Limbs, and Pelvic Girdle.</p> |

Name the Chief Parts of a typical Vertebra or Segment of the Vertebral Column.

A vertebra consists of a **body or centrum**, a dorsal **neural arch** (around the spinal cord) culminating in a **neural spine**, and **transverse processes** which project at the sides of the centrum, and which are either without or with connected ribs. In the tail region, instead of transverse processes there is a ventral **haemal arch** (around the blood-vessels). There are **articular processes and facets** on the centrum. The centra may be concave at both ends, i.e., **amphicoelous** (e.g., Skate, Teleostean Fishes), or concave in front and convex behind, i.e., **procoelous** (e.g., Frog), or convex in front and concave behind, i.e., **opisthocoelous** (e.g., certain Fishes and Amphibians, Horse, Ox). The cervical vertebrae of Birds are **heterocoelous**, i.e., the front end of the centrum is convex from above downwards and concave from side to side, and the hind end has the curvatures reversed.

How are the Vertebrae formed?

The cartilage-forming (mesenchyme) tissue around the notochord constitutes the “**skeletogenous layer.**” Cells

from that layer invade the notochord sheath; it becomes cartilaginous, and (excepting the anterior portion) it is divided into segments which thicken centrally (centra of the vertebrae), and the notochord is thus constricted and reduced. The neural and haemal arch rudiments arise as outgrowths from the "skeletogenous layer"; and from their bases the tissue spreads over the centra, which are therefore formed by segmentation of the chondrified notochord sheath followed by overgrowth of skeletogenous (arch-rudiment) tissue.

In the tail region the ventral arch rudiments form a haemal arch; but in the trunk region, they form projecting transverse processes from which a portion (the rib) becomes jointed off.

Give a General Description of the Skull and its Development.

The skull or cranium supports the parts of the head, and forms a protective case for the brain and sense organs. Its primitive form is that of a cartilaginous trough, the chondrocranium, and the mode of development (from mesenchyme) is mainly as follows:—

Beneath the brain, cartilages are developed, namely, two, the trabeculae, which become or are already continuous with other two, the parachordals. The parachordals arise one along each side of the front part of the notochord, and in part represent the unsegmented portion of its sheath. By growth and fusion these cartilages form a floor, which has a hollow for the infundibulum of the brain; the part in front of the hollow (formed by the trabeculae) is the ethmoid region, and the part behind (formed by the parachordals) is the basilar plate.

Continued chondrification, from the floor upward, forms the side walls and roof (incomplete). The cartilaginous capsules around the nose and ear, which have a more or less independent origin, become completely united with the chondrocranium; the nasal capsules are fused with the ethmoid region, and the auditory capsules are fused with the occipital (notochordal) portion of the basilar plate to form the back part of the brain-case.

The principal regions, now established, are:—

1. The wide anterior or nasal region, with the mesethmoid between the olfactory capsules.
2. The narrow interorbital or sphenoidal region between the orbits (i.e., incurvings of the side walls to form sockets for the eyes).

3. The wide auditory region.
4. The posterior or occipital region surrounding the foramen magnum, through which the spinal cord is continuous with the brain. This region is either united to or articulated with the vertebral column. Besides the foramen magnum, there are smaller openings in the walls for the passage of the cranial nerves.

Such is the primary formation of the skull; in this cartilaginous state it remains throughout life in the lowest Craniates (e.g., Cyclostomata and Elasmobranch fishes), but in higher Craniates that condition is temporary, the cartilage being strengthened or replaced (to a varying extent, never entirely) by a secondary development of bone. In the salmon the chondrocranium is largely supplemented and replaced by bone; and in the cod only remnants of the original cartilages remain.

The open parts (fontanelles) of the skull roof are in Elasmobranchs covered only by the tough integument, which often bears placoid scales or skin teeth of dermal bone. The sturgeon has on the top of the head, above the chondrocranium, large bony plates.

Several of the skull bones are of dermal origin; some of these retain their dental character, and cover the cartilage superficially (e.g., vomer and palatine of roof of mouth, and premaxilla, maxilla, and dentary of the jaws); others become investment bones, and are in close contact with the cartilage (e.g., nasal, frontal and parietal of the skull roof). The substitution or replacement bones (e.g., the occipital and sphenoid) replace the cartilage which is destroyed; and these are often termed cartilage bones, the other two kinds being the so-called membrane bones. The skull of the higher Craniate is therefore of mixed origin.

Write an Account of the Visceral Arches.

The visceral arches, a series of (from 4 to 9) hoop-like cartilages, are closely connected with the skull, and form the supporting framework of the slit walls of the branchial portion (pharynx) of the alimentary canal. In that region, on each side, cartilaginous rods are developed (from mesenchyme) between the gill-clefts and around the mouth. In gill-breathing fishes, each of these rods is typically, composed of four segments; the rods are united in pairs by ventral pieces, and the successive arches, thus formed,

may be joined together mid-ventrally. The arches bear gill-rays (of independent origin).

The foremost of the arches is the mandibular, the second is the hyoid, and the others are called branchial arches (1st, 2nd, etc.) because they support the gills. In all Craniates, except Cyclostomata, the jaws which support the mouth are formed from the mandibular arch, each half of which consists of an upper portion, the palato-quadrate, with a forward palato-pterygoid process, and a lower portion known as Meckel's cartilage. In Dipnoi and Amphibians, the palato-pterygoid is greatly reduced, and the palato-quadrate becomes the upper jaw and is fused with the cranium. Meckel's cartilage is segmented off to form the lower jaw, which is connected with the cranium by the dorsal portion of its own (mandibular) arch; and therefore the skull is described as autostylic or protostylic. In Elasmobranch fishes the palato-quadrate is greatly reduced and the palato-pterygoid becomes the upper jaw, but it is suspended by ligaments to the cranium, and, along with Meckel's cartilage (the lower jaw), is connected with the cranium by the hyomandibular, the upper portion of the hyoid arch; therefore the Elasmobranch skull is hyostylic. When the connection is partly autostylic and partly hyostylic, the skull is described as amphistylic (e.g., Teleosteans).

As already noted, the upper portion of the hyoid arch is the hyomandibular; the lower portion being the hyoid proper. In Fishes the hyoid and branchial arches are concerned with respiration and are well-developed; in the air-breathing Craniates these arches are by atrophy reduced to remnants which are fused together to form a supporting skeleton in connection with the tongue (e.g., hyoid plate of frog, and hyoid of mammals).

State the Origin of the Central Nervous System.

The central nervous system arises as a thickening of the ectoderm called the medullary plate, which later becomes a medullary groove. The sides of the groove, the medullary folds, coalesce dorsally, and thus the neural tube is formed; it is separated off from the ectoderm, and is surrounded by mesenchyme. The greater part of the tube becomes the spinal cord; the brain is developed from the anterior dilated portion or primary vesicle. A detached portion of the central nervous system is formed as a neural crest above the neural tube; it is divided into two longitudinal halves which develop outgrowths, the ganglia, and from

these arise the dorsal roots of the spinal nerves, and the 5th, 7th, 8th, 9th and 10th cranial nerves (which are peripheral nerves, having been formed from the neural crest).

During later development the nerves become attached to spinal cord and brain.

Describe (1) the Brain and Spinal Cord, and (2) the Sympathetic Nervous System.

1. By constriction of the primary vesicle, the primitive fore-brain or cerebrum (prosencephalon), the mid-brain or mesencephalon, and the hind-brain (rhombencephalon or metencephalon) are established. Bulgings of the side walls of the fore-brain project forwards and form the two cerebral hemispheres, from which anteriorly the olfactory lobes arise. The cavities of the cerebral hemispheres are the lateral ventricles. The fore-brain becomes the thalamencephalon; its cavity is the third ventricle (communicating with the lateral ventricles by the foramen of Monro), from its thin roof arises the small pineal body or epiphysis (a primitive sense organ), its thickened side walls form the optic thalami, and an outgrowth from its floor is the infundibulum (without or with *lobi inferiores* and a glandular *saccus vasculosus*).

The infundibulum is associated with the hypophysis (derived from the stomodaeum), the two forming the glandular pituitary body, which influences or regulates the growth of bone; its superfunction causes that hypertrophy of the bones (skull and limbs) known as *acromegaly*.

On the floor of the thalamencephalon transverse ridges arise; one of these becomes the optic chiasma, the others form the anterior and posterior commissures connecting the optic thalami.

The thick roof of the mid-brain is bulged out (in most Craniata) to form the two optic lobes; and the side walls and floor constitute the thick *crura cerebri*. The contracted cavity of the mid-brain is the *iter* or aqueduct of Sylvius, which is continuous with the cavities of the optic lobes. The thickened front portion of the roof of the hind-brain becomes the cerebellum, which is a special centre for that co-ordination of muscular movement known as *equilibration*. The hind-brain, beneath and behind the cerebellum, forms the medulla oblongata or bulb; it projects forwards (*restiform bodies*) along each side of the mid-brain, it is continuous behind with the spinal cord, and its cavity is the fourth ventricle; across its ventral surface, and connected

with the sides of the cerebellum, there is (in higher Craniates) a transverse band, the pons Varolii. The bulb contains centres which control the respiratory movements, the action of the heart, deglutition, and other functions.

The higher types of brain show marked flexure and overlapping. The brain and spinal cord are closely invested by a delicate vascular membrane, the pia mater, which is thickened here and there as a very vascular choroid plexus (e.g., of lateral ventricles). Outside the pia there is (in higher Craniates) an arachnoid membrane. Outermost is the tough dura mater, which lines the cranium and ensheathes the spinal cord. The tissues of the brain and spinal cord consist of nerve cells (the white and grey matter) and supporting neuroglia cells. In the brain the grey matter is mostly superficial, and it forms the cortex; but in the spinal cord it is the interior tissue around the slight central canal.

Ten or twelve pairs of cranial or brain nerves are distributed throughout the head and body; and paired spinal nerves of the cord, which usually pass out between adjacent vertebrae, supply the muscles and skin. The 1st cranial nerve (so-called), the olfactory, is a drawn-out connection between brain and olfactory organ, the 2nd or optic is formed as explained on page 203-4, the 3rd, 4th and 6th probably arise as outgrowths from the neural tube; for the origin of the others see page 201. Each spinal nerve has two roots, a dorsal (single) and a ventral (often multiple). Cf. *Amphioxus*, page 188. The dorsal roots have each a ganglion, and are as a rule wholly afferent or sensory (i.e., receiving and transmitting impressions); the ventral roots are efferent or motor (i.e., transmitting impulses to muscles). For origin of dorsal roots see preceding answer; the ventral roots are outgrowths from the spinal cord; and the dorsal and ventral strands, bound together within a common sheath of connective tissue, form the trunk of the spinal nerve.

2. The sympathetic nervous system is closely associated with the spinal nerves, and consists of two longitudinal ganglionated cords, one at each side of the vertebral column and connected anteriorly with the cranial nerves. The sympathetic ganglia are derived from the spinal and from certain cranial nerves, and remain connected with them by short rami communicantes, and give off nerves to the alimentary canal, heart, and blood-vessels.

Name the principal Sense-Organs of the Craniata.

The chief organs of special sense are:—

- | | | |
|----------------------------------|---|---|
| Origin from sense-cells of skin. | } | <ol style="list-style-type: none"> 1. The organ of vision or eye. Paired and brain-derived. 2. The olfactory organ or nose. Single or paired. 3. The auditory organ, otocyst or ear. Paired. The functions are balancing and hearing. 4. The lateral line canal (of Fishes and some Amphibians) in skin along the body and branching upon the head; represents a series of sense-buds for "detecting slow vibrations in the water, a function closely allied to hearing." The sensory jelly-tubes (of Elasmobranchs) in the snout and skin of ventral surface of body; these have ampullae (containing sensory cells) at the inner ends, and the outer ends are porous. 5. Tactile corpuscles of skin, vibrissae or tactile hairs of face, and taste-buds of the tongue papillae of Mammals. |
|----------------------------------|---|---|

How is the Eye developed? Describe its Structure.

The side wall of the thalamencephalon develops a rounded optic outgrowth, which is or becomes hollow and which narrows about the base to form the short optic stalk (optic nerve, ultimately); and it comes into contact with the inner surface of the ectoderm, which there thickens (lens rudiment) and pushes it in, causing it to become invaginated, a two-layered optic cup. A fissure (closed later) occurs in the cup-wall ventrally, and is continued as a groove along the optic stalk. The outer part of the cup-wall becomes the thin pigment layer of the retina; the inner part becomes the retina, and it secretes the clear jelly (vitreous body) which fills the cavity of the cup.

The hollow lens is detached from the ectoderm; later it is solid and crystalline. An ingrowth of mesenchyme into the vitreous body, *via* the fissure, forms either a vascular tissue, the pecten (in Birds and Reptiles), or a muscular

falciform process for accommodation (in Fishes). A growth of mesenchyme, outside the pigment layer, forms the vascular choroid coat; and outside this the mesenchyme develops the tough protective capsule of connective tissue, the sclerotic, which, continuous with the cornea in front, completely encloses the eye. The transparent cornea (covered externally by delicate ectodermal epithelium, the conjunctiva) is jelly mesenchyme formed into layered tissue (corneal endothelium) by immigrant amoebocytes; and it contains a space filled with fluid (aqueous humor) which becomes the anterior chamber between cornea and lens.

The edge of the optic cup is inturned and overlaps the lens in front, thus forming a circular rim (of choroid), the iris, surrounding a central open space, the pupil. The iris, muscular in front, acts as a diaphragm; by this means the pupil is dilated or contracted, and the amount of light entering the eye thus regulated. Being pigmented behind, the iris gives the characteristic colour to the eye. Behind the iris are projections of the choroid, the ciliary processes (ciliary muscles); here the lens is held in position by the suspensory ligament around its circumference (the forward portion of the hyaloid membrane which invests the vitreous body). By the action of the ciliary muscles on the ligament, alteration of the lens shape is effected (in accommodation).

The retina apparently ends, near the ciliary processes, in a notched *ora serrata*; actually, however, it is continued (non-percipient) to the edge of the pupil. In the centre of the retina, near the optic nerve area or blind spot, there is an elevated yellow spot (*macula lutea*) with a central depression (*fovea centralis*); this is the area of most acute vision. The retina is complex, and has several layers; the innermost one is next the vitreous humor, and consists of nerve fibres from which the optic nerve is formed; the outermost one is next the pigment layer, and is composed of sensory cells carrying rods and (in the higher Craniata) cones. Before the light can reach these cells, it has to penetrate the intervening layers, and it passes through the basal end to the rod or cone; this is a peculiarity of the Vertebrate eye. Further, these sensory cells, though not derived directly from the ectoderm, as in Invertebrates, are of that origin indirectly, since they are formed from a portion of the inner layer of the brain which was originally continuous with the ectoderm, before the closing of the medullary groove.

The optic stalk becomes the optic nerve; its fibres are derived from the retina. The cornea, aqueous humor, lens,

and vitreous humor are the dioptric parts of the eye. The lens produces the image, the retina (percipient rods and cones) receives it, and the nerve impulses formed through conversion of the light waves are transmitted *via* the optic nerve to the brain.

The eye is lodged in the orbit (of skull); the vessels and nerves supplying it are there, also the six muscles which move it, namely, four rectus muscles inserted round its equator, and two oblique muscles inserted respectively on its dorsal and ventral surface. Other associated parts are the eyelids, with sensitive lining (conjunctiva) kept moist by the secretion of lachrymal glands. There are also (in Mammals) meibomian glands; and a third eyelid or nictitating membrane, for cleaning the cornea, is frequently present in the higher Craniates, e.g., Pigeon, Rabbit.

Give an Account of the Origin and Structure of the Olfactory Organ.

The olfactory organ, paired in all Craniata (except Cyclostomata), arises near the front end of the head as two local thickenings of the ectoderm, which sink in and become sac-like. The sacs are lined by ridged mucous membrane (Schneiderian folds), covered with an epithelium of elongated supporting and sensory cells. From the latter, which have hair-like processes, the olfactory nerves are formed. In Reptiles, Birds and Mammals the folds are fewer, the mucous membrane being spread over the turbinal bones.

The external openings (nostrils) are narrowed, and each may be double (anterior and posterior naris), e.g., Dipnoi and Teleosteans; or the anterior nares may be the external nares, and the posterior nares may be internal nares opening into the buccal cavity, e.g., Amphibians and Amniota. Certain Reptiles have accessory olfactory sacs (Jacobson's organ).

Write a General Description of the Ear, its Principal Parts and Development.

The otocyst or ear of Vertebrates is paired, one at each side of the hind-brain. Compared with the otocyst of Invertebrates, it shows structural complexity and marked advance in function; originally a balancing organ, it has been further specialised for hearing.

From an insunk thickening of ectoderm, the otocyst arises as a closed pear-shaped sac which develops into two

distinct regions, an upper utricle and a lower saccule. An upgrowth from the saccule forms the endolymphatic duct; it opens to the exterior in some Elasmobranchs, and in *Chimaera*, but in higher Craniates it is a blind diverticulum. In Amphibians (e.g., Frog) this duct becomes spread out and forms a long extension above the spinal cord with outgrowths along the spinal nerves; the ends of these outgrowths expand round the spinal ganglia and contain the conspicuous calcareous bodies.

Three bulgings (not synchronous) of the utricle become the semicircular canals. Each bulging flattens, and by ingrowth of the wall at each side a hollow arched tube (the canal) is formed, opening into the utricle at both ends; one of the ends is a dilated ampulla, inside which are cells with long sense-hairs. "These canals, arranged in planes at right angles, have for their function the analysis of any rotatory movement into its components in these three planes." Two of the canals (the anterior and the posterior) are vertical, the third is horizontal.

From the saccule or vestibule a long curved pouch grows out; this is the auditory organ, the lagena in Reptiles and Birds, greatly enlarged and spirally coiled in Mammals and known as the cochlea. The auditory sense-cells in the cochlea form the complex organ of Corti.

The entire otocyst or membranous labyrinth is filled with fluid, endolymph, which (except in Mammals) often contains limy otoliths or "ear-stones" associated with the sensory cells, which are connected with branches of the 8th or auditory nerve. Between the labyrinth and the auditory capsule, which are similar in conformation, there is a buffer fluid, the perilymph.

The foregoing description is strictly that of the internal ear. There is also (in Amphibians and higher Craniates) a middle ear, tympanum or drum; its cavity opens through the Eustachian tube into the back of the mouth, and is closed externally by the tympanic membrane, which may be at the exterior (e.g., Frog), or at the inner end of a passage (external auditory meatus) the external opening of which is within a pinna or ear-flap projecting from the head.

Within the tympanic cavity are the ossicles (malleus, incus, and stapes). The handle of the malleus or hammer is attached to the tympanic membrane, and the stapes is fixed to the fenestra ovalis (a membranous window of the vestibule); and thus vibrations are transmitted to the labyrinthine fluid. In Amphibians, Reptiles and Birds there is only one ossicle, the columella.

*Describe the Alimentary Canal and associated Organs.
State how developed.*

The enteron (alimentary canal or gut) of the higher Craniata is developed mainly from secondary endoderm. The greater portion, the mesenteron or mid-gut, is lined with endoderm; the front and terminal portions, stomodaeum and proctodaeum, are lined with ingrowths of ectoderm. Around this lining (the mucous membrane) the enteric wall is formed from splanchnic mesoderm, and it consists of muscles, connective tissue, blood-vessels, nerves, and an outer covering of coelomic (peritoneal) epithelium.

The gut is supported by folds of peritoneum (mesentery); and its principal differentiated parts are the mouth or buccal cavity (stomodaeum), pharynx (the first portion of the mesenteron), gullet or oesophagus, stomach, intestine, anus. In certain Fishes, in Amphibians, Reptiles, Birds, and in Prototherian Mammals, the intestine ends in a cloaca, into which the urinary and genital ducts also open.

Associated with the buccal cavity are the teeth, the tongue (an outgrowth from the buccal floor), and the salivary glands, which secrete saliva for converting starch into sugar. In higher Craniates the nasal sac opens into the mouth, and usually (e.g., Birds and Mammals) there is a palate between the upper nasal and the lower buccal cavity. The hypophysis arises as an outgrowth from the buccal roof and is subsequently constricted off.

The walls of the pharynx have gill-clefts (8 or fewer). The first pair of clefts are the spiracles of Elasmobranch fishes, and become the Eustachian tubes in higher forms; the other clefts bear gills in Fishes and Amphibians, but are vestigial in Reptiles, Birds, and Mammals. Outgrowths from the pharynx are the thyroid gland (subsequently constricted off), the lungs and the air-bladder (swim-bladder or float), which in some fishes is shut off from the pharynx. Buds from the epithelium of the visceral clefts combine to form the thymus "gland."

On the wall of the proximal or cardiac region of the stomach there are gastric glands, which secrete the gastric juice (pepsin and hydrochloric acid) for changing proteids into soluble peptones. The food is moved onwards by peristalsis (i.e., wave-like contractions of the muscles of the wall). Until digestion is completed, the stomach is kept closed at the distal end or pylorus by a sphincter muscle.

The bulky liver is a ventral outgrowth from the gut, behind the stomach; its functions are:—(1) the storing of

starchy substance, which is derived from the food and transformed into glycogen and supplied (in the form of sugar) to the blood as required; (2) the conversion of nitrogenous wastes into urea or uric acid for excretion through the kidneys; and (3) the secretion of bile for emulsifying fats. There is generally a bile reservoir, the gall-bladder, associated with the bile-duct. The pancreas (sweetbread) arises from the region of the bile-duct; it secretes pancreatic juice which contains the ferments for completing the process of digestion.

The intestine (digestive and absorptive) is usually long, and more or less looped and convoluted; its principal portions are the small intestine (duodenum, jejunum and ileum) and the large intestine (caecum with vermiform appendix, colon, and faecal rectum). In some Fishes (e.g., Elasmobranchs and Dipnoi) the large intestine (colon) has an internal corkscrew-like fold, the spiral valve, and thereby the absorptive surface is greatly increased. This fold is the result of the twisting growth of the intestine *within* its outer peritoneal coat. In Amphibians (e.g., Frog) the rectum has a ventral outgrowth, which functions as a urinary bladder; in the embryos of higher Craniates this becomes the allantois (*see pages 213, 249, 260*).

Name the Ductless Glands, and state what you know about their Functions and Development.

1. The lymphatic "glands." (*See page 211*.)
2. The spleen, chiefly a blood-making organ, in which blood corpuscles are formed. It is situated near the pyloric end of the stomach, frequently beside the pancreas, and is developed from "a condensation of mesenchyme of the gut-wall."
3. The thymus. (*See previous answer*.)
4. The thyroid, the secretion of which has an important influence on the general metabolism, especially in relation to the nervous system and the growth of sub-cutaneous tissue. Atrophy or disease of the thyroid in children produces that form of idiocy called *cretinism*, and in adults is the cause of *myxoedema*. Hypertrophy of the thyroid results in *goitre*. (*See previous answer*.)
5. The supra-renal or adrenal bodies, which are situated on or beside the kidneys, secrete a substance essential for muscle tone.

6. The pituitary body. (*See page 201*.)

NOTE.—1, 2 and 3 are not "glands" in the strict sense.

Describe the General Plan of the Circulatory or Vascular System.

There are two main longitudinal vessels, one (the dorsal aorta) above the alimentary canal, and one (ventral vessel) below it, connected by a series of half-loop-like vessels (aortic arches) round each side of the pharynx. The blood system of an Annelid worm is fundamentally similar. That portion of the ventral vessel "within the limits of the pericardiac coelome" is the cardiac tube, and it becomes the heart within the pericardium; the portion in front of the heart is the ventral aorta, and the portion behind is the subintestinal vein.

State what you know about the Development of the Heart and Blood-vessels, and indicate the General Structure of the Heart.

The muscular walls of the heart and principal vessels (veins and arteries) are developed from splanchnic mesoderm, and are lined internally with endothelium (i.e., mesenchyme cells which have become flattened and united to form a delicate membrane). The walls of the capillaries consist of endothelium only.

The cardiac tube (see previous answer) becomes kinked, and develops four successive chambers, varying in diameter and thickness of wall, namely, the posterior sinus venosus, the atrium or auricle (receiving chamber), overlying the thick-walled ventricle (pumping chamber), and the thick-walled anterior conus arteriosus, which may be absent. Such is the primitive heart in Fishes; and (except in Dipnoi) it contains impure blood only. In Amphibians the atrium is divided by a septum into two auricles, and in Crocodiles, Birds, and Mammals two ventricles are likewise formed; therefore the heart is practically double in the higher Craniata, and it contains (in its right half) impure and (in its left or systemic half) pure blood. The chambers of the heart are separated by valves, which permit flow of blood only in the direction from auricle to ventricle.

Mention the General Features of the Blood Circulation.

In Fishes the conus (or a non-contractile bulbus) leads into a ventral aorta, which gives off on each side a series of ascending branches (afferent branchials) conveying the impure blood to the gills. The blood returns direct to the

body by a series of efferent branchials or epibranchials, which join to form two longitudinal vessels, the roots of the dorsal aorta. In Amniota, in which the gill-clefts are not respiratory, the afferents and efferents are directly continuous aortic arches, which are reduced in number. Forward extensions of the dorsal aorta roots and the ventral aorta, into the head region, form respectively the internal and external carotid arteries.

The blood returns from the head region in anterior cardinal veins, and from the body in posterior cardinal veins. The anterior and posterior cardinal of each side join to form a short transverse duct of Cuvier (precaval sinus); these ducts enter the sinus venosus, one at each side. The veins from the stomach, intestine, pancreas and spleen join to form the hepatic portal vein, which enters the liver and there branches into numerous capillaries. The liver receives sugar from the blood, and stores it to form glycogen. The blood then passes into the hepatic veins which lead from the liver into the sinus venosus. This circulation of venous blood through the liver, before returning to the heart, is the hepatic portal system. The median caudal vein from the tail region branches into two renal portal veins, which enter the kidneys. After filtering through the kidneys (renal portal system), the blood passes by renal veins into the posterior cardinals. Birds and Mammals are without a renal portal system (except in embryo). The front portions of the renal portals were originally parts of the posterior cardinals; and the caudal and hepatic portal veins represent the subintestinal vein. In the higher Craniata, the ducts of Cuvier become the superior venae cavae, and the posterior cardinals are replaced by a single inferior vena cava.

The veins have thinner walls than the arteries, and are darker in colour, owing to the bluish tint of the deoxidised blood. Some of the veins may form spacious sinuses (e.g., in Elasmobranch fishes), which are, however, never ill-defined or without walls as in many Invertebrates.

How is the Blood formed? Mention its Constituents, and explain its relation to the associated Lymphatic System.

The blood (corpuscles and plasma) is formed from mesenchyme, and from cells derived from the vessel walls (i.e., from discrete mesoderm). The corpuscles are developed chiefly in the lymphatic "glands" and the spleen. The

elliptical or circular red blood corpuscles are impregnated with haemoglobin, the oxygen-carrying pigment; the amoeboid colourless leucocytes act as phagocytes, and destroy injurious micro-organisms which enter the blood stream.

In Vertebrates the blood is not in direct contact with the body tissues; the oxygen and nutritive plasma (exuded through the capillary walls) and the waste products are interchanged through the intervening lymph, which bathes the tissues and forms the lymphatic system. The larger lymphatic ducts open into the large veins; and the numerous lymphatic "glands" supply the amoebocytes of the lymph and blood.

Write an Account of the Respiratory Organs of Craniates.

Cyclostomata, Fishes, all young and certain adult Amphibians have gills for breathing in water. The portions of the pharynx wall between the gill-clefts form partitions or septa; and the mucous lining of the septa is raised into vascular folds which are the internal gills. In Teleosteans the septa are reduced, being merely narrow strips containing the supporting cartilaginous visceral arches; and the gills are double rows of filaments, each supported by a cartilaginous gill-ray and projecting from the arch. In Elasmobranchs the septa are wide, and form complete partitions between the gill-clefts (*elasmobranch*); and the gills, being attached to the septum along almost their entire length, are lamelliform, and have internal supporting rays.

The blood is spread out on the gills and there oxygenated. In the Dogfish, Skate, and other Elasmobranchs, a flap of integument extends back from the front edge of each cleft and overlaps its external opening; this flap acts like a valve, it allows outflow of the water from the pharynx, but prevents inflow. In higher fishes (e.g., Teleosteans and Dipnoi) the flap of the front cleft becomes a large operculum overlapping all the clefts.

Generally there are six visceral clefts; the first one (in front of the hyoid arch) is the modified spiracle, present only in Elasmobranchs and certain Ganoids, and it contains a vestigial gill, the pseudobranch. The last gill-cleft has only a half-gill (hemibranch) on its anterior wall. The last branchial arch bears no gills. In Teleosteans, only the first four branchial arches bear gills.

The external gills (usually temporary organs) of Cross-ptyerygian Fishes, Dipnoi, and Amphibians have a different

origin, and are exposed branching outgrowths, typically from the outer sides of the visceral arches.

Lungs are developed in many archaic Fishes, in Amphibians and in Reptiles, Birds and Mammals in which the gill-clefts are vestigial and no longer respiratory. The lung is a ventral outgrowth (*dorsal* in the highly specialised Fishes) from the pharynx; its connection with the pharynx becomes the pneumatic duct or trachea (windpipe), and its pharyngeal opening is the glottis. The highly vascular lungs are hollow and thin-walled in Amphibians, and become sponge-like organs in Birds and Mammals. In the Dipnoi the lung is double in *Lepidosiren* and *Protopterus*; in *Ceratodus* it is single, and it also functions as a hydrostatic organ. In certain Teleostean fishes the lung (a dorsal outgrowth) remains connected with the pharynx (Physostomi); in others (Physoclisti) it becomes shut off, a closed sac, and mainly functions as a hydrostatic air or swim-bladder, or float.

Accessory air-sacs are developed from the lungs in Birds; these extend between the muscles and organs, and also into the marrowless bones.

The embryos of the higher Craniates breathe by the allantois, an outgrowth from the hind-gut. (See pages 249, 260.)

The skin is an important respiratory mechanism in Amphibians (e.g., Frog).

Describe the Excretory System of the Craniata.

The nephrotome (see page 196) in the lower Craniates (e.g., Elasmobranchs and Amphibia) remains connected with the splanchnocoel by a narrow peritoneal canal. Outgrowths from the nephrotomes (Malpighian capsules) become the nephridia or kidney tubules.

The inner end of a nephridium (opening either from the nephrotome or the peritoneal canal) is the nephrostome. A series of these nephridia, closely compacted, forms a glandular renal organ or kidney (archinephros); and its primary or archinephric duct is formed from the union of the outer ends of the nephridia, and opens into the end of the gut (proctodaeum).

A plexus of capillaries, derived from the dorsal aorta, forms the glomerulus, which bulges into the nephrotome. From the circulating blood in the glomerulus, water is extracted for flushing the nephridium and carrying away the urea wastes extracted from the venous blood, which bathes the surface of the nephridium.

The kidneys are developed in three portions. The first formed portion is the anterior pronephros; it is the functional kidney of the larva, and it degenerates, being succeeded by the mid-kidney or mesonephros (Wolffian body), which is the functional organ of later embryonic life in the Amniota. The mesonephros and the hind-kidney or metanephros together constitute the opisthonephros, which is the functional organ of adult Anamnia. In Amniota the mesonephros atrophies, and the metanephros becomes the permanent kidney of the adult.

The archinephric ducts, which are at first pronephric ducts, become the segmental or mesonephric (Wolffian) ducts; and in general these function in the female as ureters only, and in the male as vasa deferentia also. In the female the oviducts are Müllerian ducts, which in Elasmobranchs are split off longitudinally from the mesonephric ducts. The coelomic funnels of the Müllerian ducts are remnants of the pronephric nephrostomes.

The metanephric ducts or ureters arise as outgrowths from the hind ends of the mesonephric ducts.

In some Craniates the archinephric ducts unite terminally, forming a vesicle. This, in Elasmobranchs, becomes the urino-genital sinus (with an extension from each side, the sperm-sacs); and in Teleosteans it forms a urinary bladder. The allantois functions as a urinary bladder in the frog; and in Mammals that portion of it which remains in the body of the embryo becomes the bladder.

More or less closely associated with the kidneys are the suprarenal or adrenal bodies (*see page 208*). Two notable features (indicated above) of the Craniate excretory system are:—

1. The nephridia do not open directly to the exterior, as in *Annelids*, but indirectly through a duct.
2. A close connection with the reproductive system. (*See also answer to next question.*)

Give a General Account of the Reproductive System of Craniates.

The germ cells, which form the gonads (testis of male, ovary of female), arise from the germinal epithelium (mesoderm) of the wall of the coelome. (*See Part I., page 8.*)

The gonads develop (within the peritoneal cavity) as

parallel genital ridges of the dorsal lining of the splanchnocoel, near where the dorsal mesentery is attached. The testis consists of numerous seminiferous tubules amidst a stroma of vascular connective tissue (derived from mesenchyme). The tubules are continuous with tubular outgrowths (vasa efferentia) of the nephrotomes of the mesonephros; and thus the spermatozoa pass into the mesonephric or Wolffian duct, which acts as a male duct or vas deferens. The ovary has a similar nutritive and supporting stroma, amidst which there are numerous follicles. One of the cells in each follicle becomes an ovum, the others form an envelope around it. When this Graafian follicle bursts, the ovum is discharged, generally into the body cavity; thence it enters the coelomic funnel of an oviduct (Müllerian duct), and is either passed out, or undergoes development within the uterine region of the oviduct. The ova may be fertilised outside the body (e.g., Teleostean fishes, tailless Amphibians), or internally (e.g., Elasmobranch fishes, Reptiles, Birds, Mammals). Hermaphroditism occurs normally in a few Craniates.

The amount of yolk in the ova or eggs of Craniates is variable, and greatly influences development. The ova of Elasmobranch and Teleostean fishes, and of Reptiles, Birds and Monotreme Mammals have a great quantity of yolk; consequently segmentation is partial (meroblastic). In these groups the young, when hatched out, resemble the parents, except Teleosteans, which are hatched in an immature state (larva). The ova of certain Fishes (e.g., Ganoids and Dipnoi) and of Amphibians have a considerable quantity of yolk, and segmentation is complete (holoblastic) but unequal. In these groups the young are hatched as larvae. The ova of most Mammals have little yolk, and segmentation is complete (holoblastic) and equal.

Around the embryos of Reptiles, Birds, and Mammals there are protective and respiratory and nutritive foetal membranes (amnion and allantois). During gestation, in Mammals, there is a close (placental) connection between the foetus and the mother; and the young, when born, closely resemble the adult.

SUB-PHYLUM CRANIATA.

DIVISION MARSIPOBRANCHII OR CYCLOSTOMATA.
(ROUND MOUTHS.)

State briefly the principal features of the Lamprey (Petromyzon) and the Hag-fish (Myxine).

(The general characters of the Cyclostomata are in bold type.)

LAMPREY (*Petromyzon*).HAG-FISH (*Myxine*).

Body eel-like.

Body, eel-like.

Skin, smooth and scaleless, secretes mucus. A pigmented skin with sensory structures.

Skin, smooth and scaleless, secretes much mucus.

Without paired fins. Two dorsal unpaired fins, and a caudal fin around the tail.

A median fin around the tail.

A round suctorial mouth, without jaws. The mouth has a prominent sucker-like buccal funnel with numerous horny teeth and with papillae on lip. Behind the mouth there is a ventral toothed "tongue"; it has horny teeth, and is worked like a piston.

The rounded lipless mouth has sensory barbules. Two rasp-like rows of horny teeth on "tongue," and a median palatal tooth.

Paired gill-pouches. Seven pairs (with gill lamellae) on walls of a sub-pharyngeal tube, which is blind posteriorly, but which opens anteriorly into the pharynx. The gill-pouches open separately to the exterior.

Six pairs of gill-pouches on walls of pharynx. A tube from each pouch, and the tubes of each side uniting to form one; the pouches therefore opening collectively to exterior by one common aperture on each side.

A velum between buccal cavity and sub-pharyngeal tube,

A velum between buccal cavity and pharynx.

Endostyle of pharynx becomes thyroid gland (in adult).

Intestine is without a spiral valve
Anus opens into a cloaca.

Intestine has a slight spiral valve.
Anus opens into a cloaca.

Liver is without gall-bladder and bile-ducts (in adult).

Liver (bilobed) with associated gall-bladder and bile-ducts.

Without a pancreas.

Notochord and other parts of skeleton cartilaginous. Skull with an incomplete roof. A complex framework ("branchial basket") supporting the gill-pouches. Skeletogenous tissue around notochord develops neural arch rudiments. Fins have supporting "rays." Buccal funnel and "tongue" have, respectively, an internal supporting ring and rod of cartilage.

Dorsal and ventral spinal nerve roots not united.

Without a sympathetic nervous system.

Olfactory organ is single. Nasal opening (nostril) is mid-dorsal, on top of head. Hypophysis (naso-palatine canal or pituitary tube) opens anteriorly into olfactory sac; but its posterior end is blind, and therefore it does not communicate with buccal cavity.

Eyes (without cornea).

Ear consists of two semicircular canals and sacculus.

Heart and blood system fundamentally similar to that of Fishes.

Pericardium is not continuous with main peritoneal cavity (in adult).

Without a spleen.

Pronephros is vestigial in adult, and opisthonephros is functional: and its ducts or **ureters are pronephric ducts**, which unite terminally to form a urinogenital sinus, opening into the cloaca.

Without a pancreas.

Skull simple and without a roof. "Branchial basket" rudimentary. Nostril tube with rings of cartilage. Barbules and "tongue" with internal supporting rods of cartilage.

Dorsal and ventral spinal nerve roots united.

Without a sympathetic nervous system.

Nostril is dorsal, at anterior end of head. Hypophysis opens anteriorly into olfactory sac, and posteriorly into buccal cavity, just in front of pharynx.

Eyes very rudimentary and hidden under skin.

Ear consists of one semicircular canal.

As in Lamprey.

Pericardium is continuous with main peritoneal cavity.

Without a spleen.

Pronephros persists (partly) in adult.

Simple unpaired gonad, without genital ducts.	As in Lamprey.
Sexes separate.	
Ova or eggs are small, and are shed into body cavity.	Ova are large (in horny cases with adhesive threads), and are shed into body cavity.
Larva (known as <i>Ammocoetes</i>) has an endostyle functional as such; and the mode of feeding is like that of <i>Amphioxus</i> . There is no sub-pharyngeal tube distinct from the pharynx.	
Freshwater and marine species.	Marine.

What is Palaeospondylus?

A small extinct creature, found as a fossil in the Old Red Sandstone. It is possibly a "lamprey"; probably "a Dipnoan, either larval or an adult form of small size and primitive structure."

DIVISION GNATHOSTOMATA.

SUB-DIVISION ANAMNIA.

CLASS PISCES (FISHES).

State the general Characters of Fishes.

Fishes are aquatic vertebrates which breathe by gills chiefly, and which have unpaired and paired fins with skeletal supports; the paired pectoral and pelvic fins being blade-like non-digitate fore- and hind-limbs.*

The skeleton consists of cartilage, supplemented or largely replaced by bone.* The notochord is generally replaced by a segmented vertebral column. The skull and visceral arches are well developed; the first or mandibular arch forms the upper and lower jaws,* which bear teeth. The skin generally bears scales,* which are either partly dermal and partly epidermal (placoid scales or skin teeth of Elasmobranchs), or wholly dermal (thin bony scales of Teleosteans and thick bony plates of Ganoids). The skin has also glandular cells and sensory structures (e.g., ampullae of head region, lateral lines along the body). The brain is

small. There are ten pairs of cranial nerves. The olfactory organ is paired,* and rarely communicates with the buccal cavity. The hypophysis is not connected with the nasal organ.*

The ear consists of an otocyst with three semicircular canals,* and both utricle and saccule contain otoliths; there is no middle ear (tympanum). The longitudinal lateral muscles of the body are divided into segments or myotomes. In certain fishes portions of the muscular system are modified as electric organs (e.g., skate, in lateral muscles of tail). An air-bladder (hydrostatic, or also functioning as a lung) is frequently developed. The heart consists of a sinus venosus, an auricle, a ventricle and conus arteriosus. In Teleosteans the conus is absent, and the dilated base of the ventral aorta forms a bulbus arteriosus. Except in Dipnoi, in which the auricle is practically double, the heart contains impure or venous blood only; the purified blood flows direct from gills to body. Besides the characteristic posterior cardinal veins, there is also, in Dipnoi, an inferior vena cava. The ventral anus is in front of the urinary and genital openings; but when these open into the rectum, the common exit is a cloaca. The functional kidney of the adult is the opisthonephros. The sexes are usually separate. Most fishes are oviparous; the ova are small (except Elasmobranchs). The "spawn" is generally fertilised in the water, and usually there is a prolonged larva state.

Mention the chief Features which distinguish Fishes from Cyclostomata.

Those features marked * in previous answer. Fishes have also a spleen, a renal portal system, and genital ducts.

Explain the following terms:—protocercal, diphycercal, heterocercal, homocercal.

These terms indicate the formation of the tail in Fishes.

Protocercal or diphycercal, i.e., end of notochord or vertebral column is straight, and the caudal fin is vertically symmetrical around it (e.g., Dipnoi, Eel).

Heterocercal, i.e., end of vertebral column is bent up dorsalwards; and the caudal fin, along with a ventral enlargement, forms a secondary bifid tail fin with unequal lobes (e.g., Dogfish, and other Elasmobranchs).

Homocercal, i.e., end of vertebral column is at first bent up; but later it atrophies, and the ventral portion of the caudal fin is enlarged to form an outwardly symmetrical bifid tail fin with equal lobes (e.g., most Teleosteans).

The Skate (*Raia*) and the Dogfish (*Scyllium*).

Types of the Order Elasmobranchii.

Mention the external Features of the Skate and the Dogfish.

A) The Skate, flattened dorso-ventrally, is rhomboidal in shape. The anterior pointed end is the snout; the posterior end is produced as a whip-like tail (heterocercal), bearing the small unpaired fins. The broad triangular sides are the expansive pectoral fins and (behind these) the smaller pelvic fins, which (in the male) have modified portions, the copulatory claspers. The dorsal surface of the body is pigmented, and, in some species, is studded with dermal denticles or skin teeth (placoid scales. *See teeth, page 195*). Two unroofed areas (fontanelles) of the skull can be felt through the integument covering the head. Behind the eyes are the first gill-clefts, the spiracles, which open internally into the buccal cavity. Each spiracle has a rudimentary gill (pseudobranch).

On the pale or white undersurface of the body, and widely apart, are the ventral nostrils, connected by nasobuccal grooves with the angles of the transverse ventral mouth. The folds of skin covering the jaws have closely-set rows of teeth (modified placoid scales). At a width apart greater than that of the mouth, and behind it, are the two rows of gill-clefts (five pairs). At the base of the tail is the cloaca, and beside it there are two abdominal pores; these are the external openings of the abdominal or peritoneal cavity, which contains the viscera, and which is roughly indicated from the outside as that large area between the conspicuous pectoral girdle in front and the pelvic girdle behind. A small area immediately in front of the pectoral girdle indicates the pericardial portion of the coelome. The skin has numerous sensory jelly tubes, and glandular cells from which slime is freely exuded.

B) The Dogfish is elongated, somewhat flattened anteriorly, laterally compressed behind and tapering. Behind the head are the pectoral fins, freely projecting from the sides of the body ventrally; at some distance behind are the smaller pelvic fins, also ventral but close together. There are two dorsal fins, a ventral anal fin, and a caudal fin (tail heterocercal). Along each side of head and body there is a groove, the lateral line. The skin is rough (shagreen), being thickly coated with small placoid scales. The other external features correspond with those of the Skate.

Give a Description of the Skeleton of Raia and Scyllium.

The skeleton is mainly cartilaginous. In *Raia* the vertebral column consists of an unsegmented anterior plate and a segmented posterior portion. The vertebrae (amphicoelous) have dorsal neural arches, and either lateral transverse processes with rib rudiments, or (in the caudal region) ventral haemal arches.

The skull (hyostylic) has (in *Raia*) a prolonged rostrum, which (in *Scyllium*) consists of three bars converging in front. Two knob-like prominences (condyles) below the foramen magnum serve for articulation with the vertebral column. There are seven visceral arches, the posterior five (primarily four-jointed) form the framework of the gill-cleft region. There are also accessory parts (e.g., nasal cartilages about the openings of the olfactory capsules). For description of skull and visceral arches see pages 198, 199.

The pectoral girdle, behind the last branchial arch, is a hoop of cartilage incomplete dorsally; its thick ventral (coracoid) portion is (in *Raia*) attached to the anterior plate, and at each side there are three articular facets for the basal pieces of the fin. The pectoral fin has three basal pieces, namely, the propterygium (large in *Raia*, very small in *Scyllium*), the small mesopterygium and the large metapterygium; these bear jointed radials, which along with horny fibres (the fin-rays) support the fin. The small pelvic girdle consists of a bar of cartilage (pubis), not attached to the vertebral column, and with two facets on each end. The pelvic fin has only one basal piece, the basi- or metapterygium, which articulates with the posterior facet, and which (in the male) is connected with the skeleton of the clasper.

Write an Account of the Alimentary System of the Skate and the Dogfish.

The buccal cavity (stomodaeum) opens into the large pharynx, in the walls of which are the gill-clefts. From the pharynx a short gullet or oesophagus leads into the large U-shaped stomach, which has a marked thickening, the pylorus, at its junction with the intestine. The intestine is short; it consists of a small proximal portion (small intestine or duodenum), a dilated and spirally-marked colon (with an internal fold, the spiral valve), and a narrow rectum ending in the cloaca. The rectum has a small diverticulum, the rectal gland. The oesophageal and rectal portions of the gut are attached to the dorsal body wall by mesentery.

The large trilobed yellowish liver is attached by the suspensory or falciform ligament to the front wall of the abdominal cavity. Partly embedded in the liver, between the right and median lobes, is the gall-bladder; its cystic duct and two hepatic ducts unite to form the common bile duct, which opens into the intestine (duodenum) just behind the pylorus on the *convex* side of the sharp bend. The whitish bilobed pancreas is closely applied to the intestine; and from its small ventral lobe within the pyloric bend, the pancreatic duct passes into the intestine almost opposite where the bile-duct enters. A dark red organ in the loop of the stomach is the spleen.

The Dogfish has a bilobed liver, and the gall-bladder is embedded in the upper part of the left lobe. The pancreatic duct enters the intestine, ventrally, about an inch from the pylorus.

Describe the Brain of Raia and of Scyllium.

See page 201. In *Raia* and *Scyllium* the cerebral hemispheres are not distinctly separated. The olfactory lobes (strongly developed) are the expanded ends of two stout stalk-like extensions of the cerebrum, and are closely connected with the olfactory sacs.

Write an Account of the Cranial Nerves, their Branches and Distribution.

The nerves marked * are *sensory or afferent*, i.e., receiving impressions and transmitting these to the brain; those marked † are *motor or efferent*, i.e., transmitting impulses from brain to body.

There are ten pairs of cranial nerves. (For origin, see pages 201, 202):—

I. The ***olfactory** nerves (so called) are the thick stalk-like extensions from the cerebrum. The true olfactory nerves are the small nerves between each olfactory lobe and the folds of each nasal sac.

II. The ***optic** nerves, arising from the optic thalami, cross and interlace (optic chiasma) on the floor of the thalamencephalon, and pass through the orbits into the eyes (retina). See eye, page 203.

III. The slender †**oculomotor** arises from the ventral surface of the mesencephalon, anteriorly. Entering the orbit it there gives off branches to four of the six muscles of the eye, namely, the rectus internus, superior, and inferior, and the obliquus inferior.

IV. The very slender †pathetic or trochlear arises dorsally "behind the optic lobes from under the cerebellum"; and, passing forwards above and beyond the optic nerve, it enters the orbit to supply the obliquus superior muscle of the eye.

V. The *†trigeminal issues (along with VII. and VIII.) from the side of the medulla, anteriorly. Its branches are,—(1) The *superficial ophthalmic, which passes dorsally into the orbit, forwards above the recti muscles, through the olfactory capsule and across the olfactory lobes to the dorsal surface of the snout (sensory ampullae). Above it and along with it (within a common sheath, except in *Scyllium*) is the superficial ophthalmic branch of VII., which has a similar distribution. On the floor of the orbit (and together forming a broad band, in *Scyllium* and *Acanthias*) are (2) the *maxillary, which is connected with the inner buccal of VII., and which supplies the ventral surface of the snout, (3) the †mandibular, which innervates the lower jaw, and (4) the ophthalmicus profundus (above the inner buccal and on its inner side), which arises from the Gasserian ganglion of the trigeminal root, and supplies a branch to the eyeball, and passes forwards to the snout. This deep ophthalmic nerve is "absent in *Scyllium*, at least as a separate trunk. In *Acanthias* it runs ventral to the rectus and obliquus superiores muscles, and in contact with the eyeball."

VI. The slender †abducens, arising from the medulla almost mid-ventrally, below the roots of V. and VII., supplies the rectus externus muscle of the eye.

VII. The *†facial. Its principal branches are,—(1) The superficial ophthalmic. See V. (2 and 3). The inner and outer buccal, which pass under the eye to buccal ampullae. (4) The large hyomandibular, which is a mixed nerve, supplying the spiracle and the ampullae and muscles of the mandibular and the hyoid arch. It passes outwards and backwards behind the spiracle. Its chief branches are,—(a) the palatine, which goes obliquely forward across the floor of the orbit, then downwards to the roof of the mouth, (b) the prespiracular to the front of the spiracle, (c) the postspiracular or hyoidean, which passes along or through the front wall of the auditory capsule, then turns back and goes downwards to the muscles and ampullae of the hyoid arch; and (d) the external mandibular, a branch from the hyoidean, which passes behind and round the

mandibular muscle, and goes forward to the lateral line canals and the ampullae of the lower jaw.

VIII. The *auditory, the short nerve of the ear, arises behind VII., and at once enters the auditory capsule.

IX. The *†glossopharyngeal arises from the medulla, posteriorly, in front of X., and passes back across the floor of the auditory capsule to the first normal gill-cleft, over which it forks.

X. The *†vagus or pneumogastric has several roots. Its branches are:—A branchial trunk from which are given off four branchials (each of which bifurcates) to the last four gill-clefts; the trunk continuing backwards as the visceral to the heart and stomach. The lateralis, which passes backwards along with and above the branchial trunk, traverses the inner body wall to the posterior end of the body, along the course of the lateral line, which it supplies.

Give a Short Description of (1) the Eye, (2) the Olfactory Organ, and (3) the Ear of the Skate.

(1) The eye has the general structure described on page 203. The lens is round, the upper part of the iris has a fringe. There are no eyelids.

(2) See page 205, also nostrils, page 219.

(3) The ear is an otocyst or internal ear with three semi-circular canals, an endolymphatic duct, and otoliths. (See description given on pages 205, 206).

Briefly Describe the Respiratory Organs of the Skate and Dogfish.

See page 211.

Give an Account of the Venous System of Scyllium (Dogfish).

There is a renal portal and a hepatic portal system, as described on page 210. The posterior cardinal veins together form a large posterior cardinal sinus, which extends forwards dorsally from between the kidneys. It is wide in front and, near its opening at each side into the duct of Cuvier, it receives a subclavian vein from the pectoral region.

The anterior cardinal sinuses, which open into the duct of Cuvier opposite the openings of the posterior cardinal sinuses, extend directly above the gill-arches and around each eye (orbital sinus). The glossopharyngeal and vagus nerves traverse the inner wall and floor of each sinus. Behind the orbit each sinus receives a hyoidean sinus which passes downwards, along the outer surface of the hyomandibular cartilage, to the floor of the mouth, where it is connected with an inferior jugular sinus, which opens into the duct of Cuvier.

The ducts of Cuvier also receive the two lateral (epigastric) veins from the pelvic region, and are continuous with each end of the transverse sinus venosus, which opens into the auricle, and which has, in its posterior wall, the two openings of the hepatic sinus of the liver.

Describe the Heart and Ventral Arterial System of Scyllium.

The heart (see page 209) within the pericardium, is ventral, between the gills and in front of the pectoral girdle. The impure blood is driven (to the gills) from the ventricle through the contractile conus arteriosus into the ventral aorta, which gives off five afferent branchial arteries on each side. The two posterior pairs of afferent branchials either arise close together, or as branches of a common trunk from each side; the third pair arise further forwards, and the two front pairs are branches of the two trunks formed by the bifurcation of the ventral aorta at its anterior end (in front of which end is the thyroid gland).

In the Skate (*Raia*) the ventral aorta generally gives off a pair of innominate trunks posteriorly and (by bifurcation) a pair anteriorly; and these divide respectively into three and two afferent branchials on each side.

Explain the Course of the Circulation of the Purified Blood from Gills to Body.

The purified blood returns *direct* from gills to body by an efferent branchial system of arteries. (To expose these, remove the mucous membrane lining the roof of the mouth.) The efferents form loops round the clefts (first four pairs); and a half-loop vessel on the front of each fifth cleft is connected to the loop of each fourth cleft. A hyoidean artery arises from near the middle of the anterior portion of each of the first loops; and from their dorsal ends the common carotid arteries are given off. Four pairs of main

efferent vessels or epibranchials (one from each loop) pass inwards and obliquely backwards to unite in a median trunk, the dorsal aorta, which passes backwards to supply the body. The principal branches of the dorsal aorta are a pair of subclavians, a coeliac to the stomach and liver and pancreas, mesenterics to the intestine ; and its posterior continuation is the caudal artery.

Describe the Urino-genital System of (1) the Male, and (2) the Female Dogfish (Scyllium).

(1) The kidneys are situated in the abdominal cavity, one along each side of the vertebral column, and above the peritoneal lining. The front portion of each is the mesonephros (well developed); the hind portion is the metanephros. The Wolffian ducts (vasa deferentia), on the ventral surface of the kidneys, are sinuous; and each dilates posteriorly into a vesicula seminalis, opening into the urinogenital sinus (i.e., the united dilated ends of two sperm sacs beneath the seminal vesicles; these sacs, blind in front, open behind into the cloaca). The ureters, each formed from the union of about five metanephric ducts, open into the urinogenital sinus.

The two elongated testes are attached to the dorsal wall of the abdominal cavity by folds of peritoneum, and are united posteriorly. Each testis is connected with the anterior end of each mesonephros by several fine ducts, the vasa efferentia. Only vestiges of the Müllerian ducts are present. Associated structures are the copulatory claspers of the pelvic fins.

In the Skate (*Raia*) the renal and reproductive organs are similar; but the testes are not united posteriorly.

(2) The mesonephros is rudimentary; the Wolffian ducts are straight, and their dilated ends, the urinary sinuses, open into the cloaca. The metanephric ducts (ureters) open separately into the urinary sinuses.

The single ovary, when mature, has a sacculated appearance. The two large oviducts (Müllerian ducts), which are not connected to the ovary, are united anteriorly in front of the liver (falciform ligament), and there open, by one common slit-like opening, into the abdominal cavity. An anterior distension of each oviduct is the oviducal gland, which secretes the horny egg-capsules ("Mermaid's purse"). The oviducts, united at their ends, have a large common opening into the cloaca, behind the anus.

In the Skate (*Raia*) there are two ovaries ; otherwise the system is similar. See pages 213, 214.

Write a general Account of the Development of Scyllium.

The egg is fertilised in the upper part of the oviduct, and is enclosed in a horny quadrangular capsule (formed in the oviducal gland), which has its corners produced like tendrils, for mooring it to seaweeds. Development is slow, and the young dogfish emerges as a miniature adult.

Segmentation is meroblastic, and restricted to a small germinal area on the greater mass (yolk) of the egg. The resulting blastoderm is a flat disc of cells, the outermost stratum of which is the ectoderm. Between the lower cells is the segmentation cavity, which is later obliterated by the growth of mesoderm. The blastoderm gradually extends over the surface of the yolk mass, and its thickened posterior rim (future hind end of embryo) becomes involuted ; the archenteron is thus established, its roof being the inturned cells (endoderm or hypoblast). The further development of the roof is largely by overgrowth (epiboly), and the floor is derived from yolk-epithelium, formed by cells which lie next the yolk. The gastrulation process is completed by delamination. (See Part I., page 15.)

Forwards, mid-dorsally, from the embryonic rim, a medullary groove appears on the ectoderm. By upgrowth and union of the medullary folds, the groove becomes the neural tube ; it remains open for a time in front, and also behind, until the folds meet and cover in the blastopore, which then becomes the neurenteric canal. (See *Amphioxus*, page 190.) The notochord is formed, between nerve tube and gut, from the lower cells ; and at each side of it solid gastral mesoderm is developed, which unites with the peripheral mesoderm (formed between the ectoderm and involuted endoderm).

Gradually the embryo becomes folded off from the yolk, which remains connected with its body by a short constriction, the yolk stalk. The yolk-sac is the extra-embryonic extension of the blastoderm ; and upon its surface are the vitelline vessels, which absorb the yolk for the nourishment of the embryo. The gill-clefts are formed by involution, and from these grow out delicate filamentous (so-called external) gills, provisional structures which atrophy towards the close of embryonic life.

For development of principal organs see *Craniata*, pages 194 to 214.

A Classification of the Class **Pisces** (Fishes).

With Examples and Notes.

Sub-class CHONDRICHTHYES. Cartilaginous fishes, without true bone.

A spiral valve in intestine. Without an air-bladder. Gut, and urinary and genital ducts open into a common cloaca. A conus. Tail generally heterocercal. Paired fins of ichthyopterygium type. (See page 194). Pelvic fins of male have claspers. Ova few and large, and fertilisation internal.

Order Elasmobranchii or Selachii. Skin has placoid scales. Vertebral column is segmented. Skull generally hyostylic. Five to seven pairs of gill-clefts (separated by complete septa); also spiracles, frequently. Without a complete operculum. Without a larval stage.

① Sub-order Selachioidei (Sharks, Dogfishes). Body elongate and rounded.

Examples, *Chlamydoselachus*. Mouth anterior. Nostrils lateral. Six pairs of gill-clefts.

Scyllium (Dogfish). (See pages 219 to 226.)

Mustelus. Viviparous. A placenta-like connection between uterus of mother and yolk-sac of embryo.

Carcharodon (Man-eating Shark).

Selache (Basking Shark).

Acanthias, syn. *Squalus* (Spiny Dogfish). Viviparous.

② Sub-order Batoidei (Skates, Rays). Body flattened. Pectoral fins confluent with head region.

Examples, *Pristis* (Saw-fish). Snout produced as a long rostrum with saw-like teeth.

Torpedo. With electric organs between pectoral fins and head.

Raia (Skate). (See pages 219 to 226.) Has electric organ in tail region.

Order Holocephali. Skin is without placoid scales. Vertebral column is not segmented. Skull protostylic (autostylic). Four pairs of gill-clefts, covered on each side by a fold, the operculum. Without spiracles.

Example, *Chimaera*.

Sub-class OSTEICHTHYES (Bony Fishes) or TELEOSTOMI. Skeleton more or less ossified (true bone). Skull hyostylic. Mouth usually antero-terminal. Without a cloaca. There is generally an air-bladder. A gill-cover or operculum on each side. The gill septa are greatly reduced. Without claspers. Ova small

and numerous, and fertilisation usually external. The young when hatched are immature; and there is generally a prolonged larval period.

GANOIDS.

Order Crossopterygii. Paired fins are lobate, and fringed with fin-rays. Tail protocercal (diphycercal). Skin covered with rhombic "ganoid" scales set with denticles. Spiracles, a bilobed air-bladder (hydrostatic and respiratory), a spiral valve in intestine, an optic chiasma, and a conus.

Examples, *Polypterus*. Dorsal fin composed of numerous finlets. Rivers of North and Equatorial Africa.

Calamichthys. Rivers of West Africa.

Order Actinopterygii. Paired fins have short basal pieces, and are chiefly supported by fin-rays. An air-bladder (hydrostatic and respiratory), a spiral valve in intestine (in the more primitive forms), an optic chiasma, and a conus.

Examples, *Acipenser* (Sturgeon). Skin bears keeled bony scutes. Tail heterocercal.

Amia (Bow-fin). Skin has thin cycloid scales.

Lepidosteus (Bony Pike). Skin covered with "ganoid" scales.

Sub-order Teleostei (Modern Bony Fishes). Skeleton extensively bony; the skull (a chondrocranium largely supplemented and replaced by bone) has a large supra-occipital, and is amphistylic. The vertebrae are usually amphicoelous. Tail, generally homocercal, is in some forms (e.g., Eels) protocercal. Skin covered with flat and thin (cycloid* or ctenoid) scales. Gills comb-like. An air- or swim-bladder usually present. Intestine without a spiral valve. Gut, and renal and genital ducts open directly to exterior, not through a cloaca. The genital ducts generally continuous with the gonads. Optic nerves decussate, but not forming a chiasma. Without a distinct conus; but base of ventral aorta forms a non-contractile *bulbus arteriosus*. See also general features of *Teleostomi* (stated above).

* If the hind border is smoothly rounded, the scale is termed cycloid; if toothed like a comb, ctenoid.

Physostomi
(Air-bladder with an open ductus pneumaticus).

{ Examples, *Clupea* (Herring).
Salmo (Salmon, Trout).
Gymnotus (Electric Eel). Electric organ situated ventrally in tail.
Anguilla (Common Eel). The transparent larva, *Leptocephalus*, is marine.

Physoclisti
(Duct of air-
bladder
closed).

Hippocampus (Sea-horse). Pelagic. The male has an external pouch in which the eggs are hatched.

Fierasfer. Lives inside medusæ and sea-cucumbers (commensalism).

Anabas (Climbing Perch). Oriental Region. Has superior pharyngeal bones hollowed out for holding water, an accessory means of respiration used by this fish when it moves about on land.

Gadus (Haddock, Cod).

Pleuronectes (Plaice). Body flattened from side to side. Without an air-bladder.

Zoarces (Viviparous Blenny).

Sub-class DIPNOI (Double breathers). With gills and a lung (single or double), which opens into the pharynx mid-ventrally. Body covered with overlapping bony scales. Paired fins of archipterygium type (*see page 194*). Tail protocecal, and the vertical caudal fin extending more or less along the body dorsally and ventrally. External nares within the upper lip; the nasal sac also opens into the buccal cavity *anteriorly* by internal nares. The internal gills covered, each side, by an operculum. Four to six branchial arches. Notochord persistent, with an unsegmented sheath, and with partly ossified neural arches, ribs and haemal arches. The protostylic skull is a chondrocranium with a few supplementary investment or membrane bones, and without maxilla and premaxilla. Teeth, composite, are three pairs (mandibular, palatal and vomerine) of peculiar dental plates with ridges or cusps. A spiral valve in intestine. Gut, and renal and genital ducts open into a cloaca. Heart has auricle divided by a septum, and contains both pure and impure blood; the twisted conus has transverse rows of pocket valves and a longitudinal valve. The blood system shows modification towards the Amphibian type, e.g., the left auricle receives blood direct from lung by two pulmonary veins, and there is an inferior vena cava. Brain resembles that of Amphibians; and there is an optic chiasma. Ova of moderate size; segmentation total (holoblastic), but unequal. Primitive fishes, survivors of an ancient race, sluggish in habit, in many ways (e.g., their clambering movements) strongly suggestive of the newt, and illustrating "discontinuous distribution." (*See Part II., page 137.*)

Examples, *Ceratodus* (the Australian Lung-fish, or "Burnett Salmon"). Blunt fish-like shape. Acutely lobate paired fins (typical archipterygia, *see page 194*).

Lung single, and divided into compartments. Five pairs of gill-clefts, four pairs of internal gills and a hyoid half-gill. Larva tadpole-like, but without external gills. Queensland, Mary and Burnett Rivers.

Protopterus (the African Lung-fish or Mud-fish). Paired fins reduced to long stump-like tapering limbs. Lung double. Gills on the last three arches only. When the dry season sets in, it sinks down into the mud, sinks slowly as the mud stiffens, and so a passage remains open; then it encapsules itself in a cocoon of secreted mucus. A small hole in the lid of the cocoon is the opening of a narrow mucus pipe leading into the creature's mouth; and thus it breathes air by its lungs while it lies dormant in the baked mud. A nest is formed for the eggs, and the male guards them. Larva tadpole-like, with four external gills. Swamps along the White Nile, Congo, and Gambia Rivers.

Lepidosiren (the South American Lung-fish or Mud-fish). Eel-shaped. Paired fins reduced to stump-like limbs. Lung double. Gills on the last three arches only. Like Protopterus, it remains dormant in the mud during the dry season; but the cocoon is simply a bed of slime in which it rests, "the body sharply bent, the tail folded over the face." The eggs are laid in an excavated burrow. During the breeding season, vascular filaments are developed on the hind limbs of the male; and this accessory means for efficient breathing enables him to remain constantly beside the nest. The larvae, which have four external gills, strikingly resemble larval newts. Chaco of Paraguay, also Brazil.

CLASS AMPHIBIA.

State the general Features of Amphibians.

The skin is generally scaleless. The unpaired fins, when present, are without fin-rays.* The limbs, when present, are pentadactyle.* (See page 194.) The skull (autostylic) has two occipital condyles. The olfactory sacs open into the front of the mouth by internal nares. There is a middle ear, with one ossicle (the columella*). There are lateral line sense organs in the larva, and in certain adult Amphibians. The gut, and the renal and genital ducts open into a cloaca. A ventral outgrowth of the rectum (the allantois) functions as a urinary cloacal bladder.* Gills, present as a rule in the larva, may remain functional throughout life; but normally the adults breathe by lungs. The heart consists of a sinus venosus, two auricles, a ventricle, and a conus. There is a renal portal and a hepatic portal system. The eggs, small and numerous, are laid usually in water; and segmentation is total (holoblastic), but unequal. Metamorphosis is generally a feature of the life-history.

Mention the Principal Features which distinguish Amphibians from Fishes.

Those marked * in preceding answer.

Classify the Amphibia, and give Examples.

Order URODELA or CAUDATA. Tailed throughout life.

Examples, Amphiuma. Limbs rudimentary. Teeth on upper and lower jaws. Adult without gills.
Siren. Hind limbs absent. Toothless. Adult with gills.

Triton (Newt). Limbs well developed. Teeth on upper and lower jaws. Gill-clefts and gills absent in adult. Generally oviparous.

Salamandra. Viviparous. *S. atra* "lives at elevations (Alps) where water-pools are rare," and the young are born without gills (adaptation to environment).

Amblystoma or Siredon. Without gills. Its gilled larva, known as the *axolotl*, frequently breeds (paedogenesis, see Part II., page 95).

Order ANURA or ECAUDATA. Tailless when adult. Fore and hind limbs always present. Adults without gills.

Examples, Bufo (Toad). Without teeth on jaws. Eggs laid in strings. Tadpole larva.

Alytes (Obstetric Frog). The *male* carries, around his thighs, the strings of developing eggs.

Rana (Frog). *See pages 232 to 238.* Eggs laid in masses. Tadpole larva.

Pipa (Surinam Toad). Tongueless. Eustachian tubes open into pharynx by a common opening. The eggs are transferred to pockets in the skin of the back, and there develop, hatching out as miniature adults.

Order APODA or GYMNOPHIONA. Worm-like, limbless, burrowing forms, with rudimentary eyes. Examples of adaptation to environment.

Examples, Hypogeophis. Embryo has gills which atrophy before hatching.

Ichthyophis. Embryo has gills which atrophy before hatching.

The Frog (Rana).

A Type of the Class Amphibia.

Give a short Account of the External Features of the Frog.

The broad and flattened head is continuous with the short and stout trunk, which has a characteristic hump-back (sacral prominence), formed by the junction of the pelvic girdle with the vertebral column; neck and tail are absent. The limbs are cheiropterygia. (*See page 194.*) The fore-limbs are short; the preaxial digit (pollex or thumb) is rudimentary. At the breeding season, the male has a swelling or cushion on the inner side of each hand. The hind-limbs are long (ankle elongated) and the toes are webbed for swimming. On the base of the hallux or "great toe" there is a horny knob, the calcar. The mouth is wide; above it are the two small external nares (nostrils). The eyes are large; each has two eyelids and a nictitating membrane or third eyelid. Behind the eye on each side is a circular area, the tympanic membrane. At the end of

the body is the cloaca. The skin, loosely attached to the underlying muscles, is smooth, moist, and pigmented.

Mention the Structures of the Roof and Floor of the Mouth (Buccal Cavity).

ON THE ROOF.—The maxillary teeth on the upper jaw (premaxilla and maxilla). The vomerine teeth, on the vomers in the front part of the roof. The internal nares, two openings in front of the vomers and towards their outer sides. The prominent eyeballs, between the sides and central part of the skull. Posteriorly, the two openings of the Eustachian tubes above the angles of the mouth.

ON THE FLOOR.—The lower jaw (without teeth) bordering the fleshy floor, which has a supporting thin cartilaginous hyoid plate. The tongue, which is attached in front (to front part of floor) and loose behind. Posteriorly, the glottis, the slit-like opening of the tubular larynx (trachea) leading from the lungs.

Which Structures are exposed when the Skin is reflected or removed from the Ventral Surface of the Trunk and Head?

Subcutaneous lymph sacs, numerous cutaneous blood-vessels, especially the musculo-cutaneous vein which joins the brachial to form the subclavian at the shoulder, also the following muscles of the ventral body wall and head:—

Two large longitudinal recti abdomini muscles (each divided transversely into bellies) extending forwards to the sternum; the dark line between them indicates the anterior abdominal vein immediately above. The pectoral muscles, arising on each side, like outspread fans, from the surface of the recti abdomini and from the sternum along its whole length. The mylohyoid, a muscle sheet extending across from side to side of the lower jaw. By dividing the mylohyoid along the middle line and reflecting the flaps, the narrow longitudinal geniohyoid muscles (between the chin and the hyoid) are exposed, and on each is seen the hypoglossal nerve (spinal nerve II.) passing forward to the tongue.

Make Drawings of the Skull of the Frog to show the various Bones.

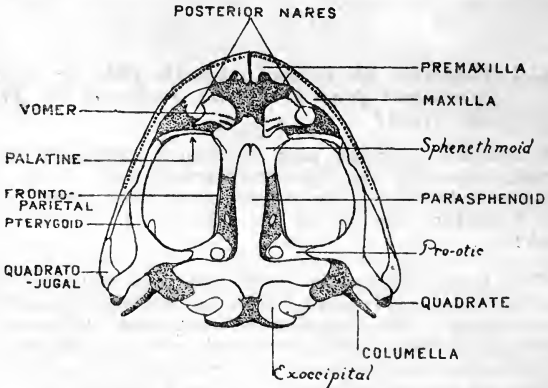
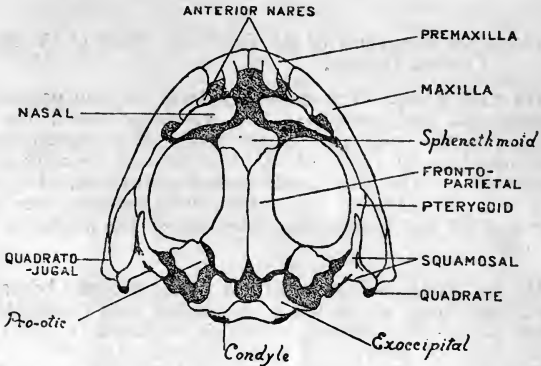


FIG. 36.—Skull of Frog (*Rana*). Dorsal view.

FIG. 37.—Skull of Frog (*Rana*). Ventral view.

NOTE.—The names of the replacement or cartilage bones are printed in *italics*. The dotted areas in the figures indicate the *persistent cartilage*.

The *replacement or cartilage bones* are the two *occipitals* (around the foramen magnum and bearing the condyles), the two *pro-otics* (ossified parts of the auditory capsule), and the *sphenethmoid*. The others (except the quadrates) are investment or membrane bones. The remainder of the skull consists of persistent portions (cartilage) of the original chondrocranium.

Each half or ramus of the lower jaw (replacing Meckel's cartilage) consists mainly of an articular angulo-splenial, in front of which is an outer dentary, and a small *mento-meckelian* at the chin; the first two are membrane bones, the third is a cartilage bone. The lower jaw articulates with the upper parts of its own (mandibular) arch, namely, the quadrate cartilages; therefore the skull is autostylic.

Give a Description of (1) the Vertebral Column, (2) the Pectoral or Shoulder-Girdle and Fore-Limbs, and (3) the Pelvic or Hip-Girdle and Hind-Limbs.

(1) Consists of nine vertebrae, and a long unsegmented portion, the urostyle. The first vertebra has two articular facets for the condyles of the skull; and it is without transverse processes. The centra of vertebrae II. to VII. are procoelous. The ilia of the pelvic girdle articulate with the large transverse processes of the ninth vertebra, or sacrum.

(2) The shoulder-girdle has (on each side) the following parts:—a dorsal supra-scapula (partly cartilaginous) and a scapula, which articulates with a ventral coracoid and a smaller precoracoid (with associated clavicle). The last two at their inner ends unite with the longitudinal cartilaginous epicoracoids, which are fused together. In front of the epicoracoids are the omosternum and cartilaginous episternum, and behind are the sternum and cartilaginous xiphisternum. At the junction of scapula and coracoid is the glenoid cavity, for articulation of the arm (humerus).

The fore-limb consists of humerus (upper arm), fused inner radius and outer ulna (fore-arm), carpus (wrist) composed of six carpals (two proximal, one central, three distal), and hand with four complete digits and a rudimentary preaxial digit (pollex or thumb). Each digit consists of a metacarpal and (except thumb) two or three phalanges.

(3) The hip-girdle consists of two long ilia, fused at their posterior ends together with the small ischia and ventral pubis; the three form and surround the socket or acetabulum (each side) for articulation of the leg (femur).

The hind-limb consists of femur (thigh bone), fused tibia and fibula (lower leg), tarsus (ankle) composed of four tarsals, and foot with five complete digits, each having a metatarsal and from two to four phalanges. The two proximal tarsals (inner astragalus and outer calcaneum or os calcis) are greatly elongated. On the inner side of the præaxial hallux or first toe, there is an extra digit, the calcar.

Describe (1) the Brain and Nerves, and (2) the Sympathetic Nervous System of the Frog.

(1) For principal parts of brain, see page 201. Only the stalk of the pineal body is present. There is an optic chiasma. The cerebellum is a narrow transverse band. The roof of the medulla has a choroid plexus. The ten cranial nerves are as in *Scyllium*, and their general distribution is similar. The ganglia of the roots of nerves V. and VII. together form the Gasserian ganglion. The first pair of spinal nerves are absent in the adult; each nerve of the second pair gives off a hypoglossal to the tongue (the twelfth cranial in higher Craniates), and also unites with the third to form the brachial plexus of the arm. The sciatic plexus of the leg is formed by the union of spinal nerves VII. to X. Round the ganglia of the dorsal roots of the spinal nerves there are sacs (see endolymphatic duct, page 206) containing calcareous otolithic particles.

(2) Along each side of the dorsal aorta there is a cord or chain of ten pigmented sympathetic ganglia, each cord is connected anteriorly with the Gasserian ganglion. See page 202.

Write a Short Account of the Alimentary System of the Frog.

The buccal cavity (see page 233) opens into a short and wide gullet or oesophagus, which leads into the stomach. At the end of the stomach is the pyloric constriction. The duodenum (first portion of small intestine) is parallel with the stomach. The small intestine is a long narrow coiled tube. The large intestine (rectum) is short and wide, and it opens into the cloaca. The liver has two main lobes, and the left one is subdivided into two; between the main lobes is the associated round gall-bladder. Short ducts from liver and gall-bladder join to form the long bile-duct; it traverses the pancreas (situated between stomach and duodenum) and, receiving the pancreatic duct, becomes the common duct of liver and pancreas, entering the duodenum about half an inch from the pylorus.

A round red organ, in the mesentery near the beginning of the rectum, is the spleen.

Describe (1) the Venous System, (2) the Arterial System, and (3) the Heart of the Frog.

(1) The impure blood is collected into three principal veins (right and left superior venae cavae and inferior vena cava), which open into the sinus venosus. Each anterior or superior vena cava is formed from the union of external jugular (formed by union of the lingual and the mandibular veins), innominate (formed by internal jugular and subscapular), and subclavian (formed by brachial and musculo-cutaneous). The posterior or inferior vena cava is formed between the kidneys from renal veins, and it receives the genital and the hepatic veins.

Each femoral vein (of the leg), divides into two branches, a femoro-abdominal or pelvic and a femoro-renal, which receives the sciatic (back of the thigh) and becomes the renal portal, which enters the kidney. The two pelvics join to form the median anterior abdominal*; it receives the hepatic portal* vein from the gut and spleen, and, dividing into two, enters the lobes of the liver. There is a renal portal and a hepatic portal system (vessels marked *).

The pulmonary veins, which return the blood (purified) from the lungs, join before entering the left auricle.

(2) From the short ventral aorta ("truncus"), and at each side, three arterial arches arise, namely, the carotid, the systemic, and the pulmo-cutaneous. The carotid gives off the lingual artery (to tongue) and the carotid artery (to buccal cavity, orbit, and brain). The two systemic arches unite in front of the kidneys to form the dorsal aorta, which gives off (at its formation) a coeliaco-mesenteric artery to liver and gut and spleen, and renals, genitals, and an inferior mesenteric to the rectum. Finally the aorta bifurcates into two iliacs, which supply the pelvic region and legs. One of the arteries given off by each systemic arch (before union) passes to the shoulder (subclavian) and thence into the arm (brachial). The pulmo-cutaneous divides into the cutaneous (to skin) and the pulmonary, which conveys the impure blood to the lungs.

(3) The heart is enclosed in a thin membrane, the pericardium, and consists of a sinus venosus opening into the right auricle, a left auricle, and a conical thick-walled ventricle with a thick-walled conus. The auriculo-ventricular opening is guarded by valves, and three pocket or semi-

lunar valves guard the opening from the ventricle into the conus. The conus contains a spiral valve, and is separated by valves from the very short ventral aorta.

The ventricle receives impure blood (from right auricle) and purified blood (from left auricle) into its right and left regions respectively, the blood mixing to some extent about the middle. The conus arises from the right side of the ventricle; consequently, when the ventricle contracts, it is the impure blood which is driven first into the conus, and it flows mainly into the pulmo-cutaneous arches. When these are filled, the conus contracts, causing the spiral valve to be so placed that the succeeding mixed blood passes into the systemics. The remaining pure blood is driven into the carotids.

How does the Frog breathe?

By lungs (see pages 212, 233); and by the skin, when hibernating in mud under water. The larva breathes at first by the skin, and later by gills.

Give a Description of (1) the Excretory, and (2) the Reproductive Organs of Rana.

(1) The two flattened oval kidneys are attached to the dorsal body wall, one at each side of the urostyle; and on the ventral surface of each there is an elongated yellowish adrenal gland. The ureters (Wolffian ducts), which arise from the outer sides of the kidneys, open separately into the cloaca, opposite the opening of the cloacal bladder.

(2) The male organs, two ovoid testes, have several short vasa efferentia leading into the kidneys. The ureters function as vasa deferentia; and each has, near the cloaca, an associated pouch-like vesicula seminalis.

The female organs are large folded ovaries. The oviducts (Müllerian ducts) are long and coiled; the wide terminal portions open into the cloaca, the narrow front portions open (coelomic funnels) beside the bases of the lungs. The ova are discharged into the body cavity, and enter the coelomic funnels. Attached anteriorly to the testes and ovaries there are yellow and lobed fatty bodies.

SUB-DIVISION AMNIOTA.

CLASS REPTILIA (REPTILES).

Mention the general Features of Reptiles. Name the Orders of Reptilia, and give Examples.

There is an exoskeleton of epidermal horny scales and (frequently) dermal bony plates. The limbs, when present, are pentadactyle. The bones are without epiphyses. The skull has one occipital condyle; and the lower jaw articulates with the quadrate. The upper and lower jaws, and (in certain forms) also the palatines and pterygoids, bear teeth. The vertebral column has distinct cervical, thoracic, sacral and caudal regions; usually only two vertebrae form the sacrum, and the caudal region (typically long) often has chevron bones (haemal arches), generally attached between the centra. Usually there is an ischial and a pubic symphysis. The ankle joint is intertarsal. There are twelve pairs of cranial nerves (except Snakes). There is one ear ossicle, the columella. The gut and the urino-genital ducts open into a cloaca. Respiration is by lungs. The heart consists of a sinus venosus, two auricles and one ventricle (two ventricles in Crocodilia); the conus is absent. The ventral aorta is completely divided. The aortic arch is paired in the adult. Most Reptiles are oviparous; and the eggs are large and have much yolk. The embryo has two foetal membranes, the amnion (protective) and the allantois (respiratory).

The Orders of Reptiles are :—

Order RHYNCHOCEPHALA.

Example, *Sphenodon*, syn. *Hatteria* (the New Zealand "lizard").

Order LACERTILIA (Lizards). Teeth fused, either to the ridges of the jaws (acrodont) or to the sides of the jaw ridges (pleurodont).

Examples, *Lacerta*.

Anguis (Slow-worm). Limbless, worm-like, burrowing, viviparous.

Amphisbaena. Limbless, worm-like, burrowing. *Chamaeleon*.

Order OPHIDIA (Snakes or Serpents). Limbless. Teeth fused to the bones bearing them.

Examples, *Typhlops*. A burrowing snake.

Python. A non-poisonous, crushing snake.

Vipera. Poisonous—Maxillae are erectile, and each bears a modified tooth, the perforated fangs.

Order CHELONIA (Turtles and Tortoises). Body within a bony case, which is covered with epidermal horny plates of "tortoise-shell," and which consists of two joined shields (dorsal arched carapace and ventral flat plastron). Generally the carapace is formed from dermal scutes combined with the thoracic vertebrae (upper parts) and the flattened ribs; the plastron consists of dermal bones. Jaws without teeth, but with horny plates.

Order CROCODILIA. Exoskeleton consists of epidermal horny scales overlying dermal bony plates. Maxillae, palatines and pterygoids are united along middle line on roof of mouth; and internal nares are placed far back on hinder portion of pterygoids and close to the glottis. External nares (nostrils) are at tip of snout. There is an os transversum between maxilla and pterygoid. Teeth in sockets (thecodont) on premaxillae, maxillae and dentaries. Cervical vertebrae have two-headed ribs. The vertebral portions of the thoracic ribs have small uncinatè processes; the sternal portions join (and form) the sternum. There are "abdominal ribs" (loose paired membrane bones). Heart has two auricles and two ventricles.

Examples, Crocodilus. The first mandibular tooth bites into a pit, the fourth into a groove of the upper jaw.

Alligator. The first and fourth mandibular teeth bite into pits of the upper jaw.

CLASS AVES (BIRDS).

State the Chief Distinctive Characters of Birds.

The epidermal exoskeleton consists of feathers and scales. Skin glands are notably absent; but there is generally an oil or preen gland above the base of the tail. The bones are light, being mostly marrowless and containing air; fusion is also characteristic. The skull is high and arched; almost all the bones are ankylosed, the sutures between them obliterated. The long premaxillae form the greater part of the beak. The orbits are large, and, as in many Reptiles, there is no intervening cranial cavity; there is a thin bony interorbital septum. A membrane bone, the basitemporal (representing the parasphenoid) covers the basisphenoid. There is one (basioccipital) condyle. The jaws, without teeth in modern birds, have horny sheaths; the lower jaw articulates with the *movable* quadrate. The neck is long; the cervical vertebrae are heterocoelous (*see page 197*) and have reduced ribs fused on their sides. The thoracic vertebrae tend to fuse. The

sacrum (*cf. Reptiles*) consists of a fusion of one or more thoracic vertebrae with the lumbar, sacral and some caudals. The last few caudals fuse to form the pygostyle or ploughshare bone of the short tail. The shoulder girdle has stout coracoids articulated with the sternum, sabre-shaped scapulae (overlying the ribs, which have uncinat processes), and a V-shaped "merrythought" (clavicles united with an interclavicle). The sternum is broad, and has (except in *Ratitae*) a ventral keel to which the big pectoral muscles are attached. Generally the fore-limb has only three digits; and the distal carpals are fused with the metacarpals, forming a carpo-metacarpus. The ilia of the pelvis are ankylosed with the sacrum; the slender ventral pubes and the broad ischia (between ilia and pubes) are directed backwards, and neither are united ventrally, except in *Struthio*, the African Ostrich (pubic symphysis), and in *Rhea*, the South American Ostrich (ischial symphysis). The proximal tarsals are fused with the tibia (tibiotarsus), and the distal tarsals with metatarsals 2, 3 and 4 (tarso-metatarsus); therefore the ankle-joint is intertarsal. The first metatarsal is free; the foot has four digits or toes (with claws).

The large cerebral hemispheres overlie the thalamencephalon and the optic lobes (displaced to the sides), and meet the cerebellum. The olfactory lobes are small, and the nasal organ is weakly developed; the nostrils are situated at the base of the beak, the internal nares are between the palatine and vomers. The eye has a large pecten, a nictitating membrane, and sclerotic ossicles. The ear has a long and curved lagena (auditory organ); there is only one ossicle, the columella. There are twelve pairs of cranial nerves.

The solid spongy lungs, fixed against the ribs, are only slightly expandible. Connected with the lungs there are large air-sacs throughout the body, and these communicate with the pneumatic cavities in the bones. Expiration is the more active breathing process. The trachea is supported by bony rings; its upper portion, the larynx, is without vocal cords; its terminal portion, where it divides into the bronchi, forms the syrinx, which is the vocal organ. The heart has four chambers, the auricle and ventricle of the right side are completely separated from those of the left; the right auriculo-ventricular valve is muscular. Only the right aortic arch is present in the adult. The renal portal system is practically absent. The kidneys (metanephros) are three-lobed; the urine is semi-solid. The ureters and genital ducts, and the gut, open into a common cloaca.

Certain birds (e.g., Ostrich, Duck) have a copulatory organ or penis. The right ovary atrophies, and the right oviduct is reduced. The eggs are large, contain much yolk and albumen, and are enclosed in limy shells; the embryo has an amnion, an allantois, and a large yolk-sac.

Birds are oviparous, feathered bipeds, which have the fore-limbs modified as wings; they are warm-blooded, and the efficiency of their respiratory mechanism is superior to that of Mammals.

The Pigeon (Columba).

A Type of Birds.

Briefly enumerate the External Features of the Pigeon.

The head is produced into a horny toothless beak, above the base of which is the sensory cere, overhanging the nostrils (external nares). Eyes with eyelids and, at the anterior angles, a third eyelid or nictitating membrane. Ear openings (external auditory meatus) behind the eyes. Neck well-developed. Trunk deep, prominent keel ventrally; tail short. Preen gland above, and cloaca below base of tail.

The feathers are attached along definite tracts or pterylae, the intervening featherless areas are the apteria. A large feather shows the following structure:—Stem or axis consisting of a lower hollow part, the calamus or quill, and an upper solid rachis or shaft, which bears the vane. The vane is composed of numerous barbs, along each side of the rachis, held together by minute barbules which have hooklets. The quill has at its proximal end an aperture, the inferior umbilicus; and at its distal end, just below the vane, is the superior umbilicus (near which, in many birds, there is a tuft called the aftershaft). The different kinds of feathers are,—(1) quills, (2) smaller contour feathers of body, (3) down or plumules (absent in pigeon), (4) filoplumes. The tail quills (rectrices) are used for steering; the wing quills (remiges) are either primaries (those attached to bones of the manus or hand) or secondaries (attached to ulna). A small tuft of feathers borne by the first digit (thumb) is the bastard wing. Some of the contour feathers are coverts, which overlie the bases of the wing and tail quills. The fine filoplumes (seen on the skin after plucking) are hair-like with a few terminal barbs. The four clawed toes, and the tarso-metatarsal part of the leg, are covered with scales.

Describe (1) the Vertebral Column, and (2) the Skull of the Pigeon.

(1) The five regions are cervical or neck, thoracic, lumbar, sacral, caudal. There are 14 heterocoelous cervical vertebrae; the first two (atlas and axis) are small and without ribs, the next ten have each a pair of vestigial two-headed ribs, the heads being fused to the centrum and transverse process (each side) and enclosing spaces (vertebra-arterial foramina) through which the vertebral arteries pass. The ribs of the last two cervicals are less rudimentary, and are not fused to the vertebrae. The first three thoracic vertebrae are fused together; the last one (the fifth) is fused along with the five lumbar, the two sacral and the first five caudals to form the sacrum. The next six caudals are free; and the last four or five, adpressed and fused, form the upturned pygostyle.

There are five well-developed thoracic ribs. The upper or vertebral portion of each rib has two heads (a capitulum articulating with the centrum of the vertebra, a tubercle articulating with a transverse process) and an uncinat process, projecting backwards. The lower or sternal portion articulates with the broad sternum, which has a deep keel.

(2) The cranium is flexibly connected with the (movable) facial portion of the skull. The large orbits, almost in front of the cranium, are separated by a thin vertical interorbital septum only.

The base of the cranium consists of the basitemporal (covering part of the basisphenoid*) and the basisphenoidal rostrum.* The back of the cranium is formed by the basioccipital* (bearing the single condyle for articulation with the atlas), the two exoccipitals* and the supraoccipital*; and these surround the foramen magnum. Paired parietals and frontals form the roof of the cranium; and at its sides are the tympanic cavities (recess with fenestra ovalis and columella*) bounded above by the squamosals, each of which has a projecting zygomatic process meeting a similar process of the frontal that is descending and post-orbital. (The jugal has no ascending process meeting the zygomatic, the orbit is therefore confluent with the temporal fossa behind.) At the front of each orbit there is a lachrymal. The interorbital septum* is mainly mesethmoid* and presphenoid.*

The facial portion of the skull consists of the small nasals, the long premaxillae (upper beak), and the bones of the upper jaw and roof of the mouth. The upper jaw

(each side) is composed of premaxilla, small maxilla, jugal, and quadrato-jugal. The palatines (with a rudimentary vomer between) are connected in front with the premaxillae and maxillae, and behind with the basisphenoidal rostrum and the two rod-like pterygoids (obliquely placed, and articulating behind with the quadrates). The stout triradiate quadrate* (the suspensorium), which forms the articular surface for the lower jaw, is articulated with the squamosal, the quadrato-jugal and the pterygoid. Each ramus of the mandible or lower jaw consists of five bones (dentary, splenial, angular, supra-angular and articular*). In the floor of the mouth is the hyoid.

(The bones marked * are substitution or replacement bones.)

Give Short Descriptions of (1) the Pectoral Girdle and Fore-limb, and (2) the Pelvic Girdle and Hind-limb of the Pigeon.

(1) See shoulder girdle, page 241. The front end of the scapula is firmly attached to the upper end of the coracoid. These ends conjointly form, on their outer sides, the glenoid cavity. Above this cavity the coracoid end is produced as a strong process curving inwards; and to it the upper end of the clavicle is attached. The end of the scapula has a corresponding process; thus the ends of the three bones form an archway, the foramen triosseum.

The parts of the fore-limb (wing) are upper arm, fore-arm, wrist and hand or manus. The upper arm has one bone, the humerus (with prominent head and deltoid ridge). The fore-arm has two parallel bones, the slender radius and the stouter ulna. The ulna is slightly curved, has a small olecranon process at its proximal end, and bears the marks of the secondaries. The wrist is represented by the two proximal carpals (radiale and ulnare). The three distal carpals are fused with the three metacarpals to form the carpo-metacarpus, which is a stout bone (2nd metacarpal) bearing a proximal knob (1st metacarpal) and united at the ends with a parallel thin bone (3rd metacarpal). The metacarpals bear three digits; the first (thumb) and third digits are small, the second has three phalanges.

(2) See pelvis, page 241. At the junction of the ischium and pubis with the ilium is the incompletely ossified socket or acetabulum, for the head of the short femur or thigh bone. The lower leg has a stout tibia with a splint-like fibula; the two proximal tarsals (ankle bones) are fused to the distal end of the tibia, the whole forming the tibio-

tarsus. The ankle-joint is intertarsal, the succeeding bone, the long tarso-metatarsus, being composed of the distal tarsals fused with metatarsals 2, 3 and 4. The first metatarsal is small and free. The foot or pes has four toes; the first has two, the second three, the third four, and the fourth five phalanges.

Name the Muscles of Flight, state their Specific Functions, and give their Origins and Insertions.

The pectoralis major, the largest, depresses the wing; it arises from the sternum (lateral portion), keel (ventral half) and clavicle, and it is inserted on the humerus (ventral surface).

The pectoralis minor (subclavian or supracoracoideus), smaller than and covered by the former, arises from the sternum (inner portion) and the keel (dorsal half). It is inserted on the humerus (dorsal surface). Its tendon passes through the foramen triosseum, which serves like a pulley. When the muscle contracts, it raises the wing.

The small coraco-brachialis arises mainly from the outer border of the coracoid, and is inserted on the head of the humerus. It assists in depressing the wing.

Describe the Alimentary System of the Pigeon.

From the buccal cavity the short pharynx leads into a long gullet or oesophagus which expands, at the base of the neck, into a large storing crop. Continuing from the crop, the gullet leads into the wider proventriculus,* which secretes the digestive juice. Succeeding this is the muscular gizzard; it contains the small stones swallowed by the bird, and its horny inner walls form a mill for crushing the food. The duodenum, which issues from the gizzard near the opening of the proventriculus, forms a U-shaped loop; it is followed by the long and convoluted small intestine. Two small rectal coeca indicate the beginning of the short rectum which opens into the cloaca.

The bilobed liver (without a gall-bladder) has two separate bile-ducts, opening into the proximal and distal parts of the duodenum. The pancreas is situated in the duodenal loop; and there are three pancreatic ducts, opening into the distal portion of the duodenum. The abdominal viscera are covered by a fat-laden fold of mesentery, the great omentum.

* Attached to its right side there is a small red organ, the spleen.

Name the Principal Air-sacs of the Pigeon, and state where situated.

Two cervical air-sacs, at base of neck in front of the lungs. One interclavicular, between the two clavicles and surrounding the lower end of the trachea; it has several diverticula, and is connected with the axillary air-sacs of the shoulder. Two anterior thoracics, two posterior thoracics, and two abdominals, situated along the sides of the body, beneath the ribs.

Describe the Heart and Principal Blood-vessels of the Pigeon, and indicate the General Course of the Circulation.

The three venae cavae, conveying the impure blood from the body, open into the right auricle; thence the blood passes through the right auriculo-ventricular aperture into the right ventricle, which is round the right side of the left ventricle. The right auriculo-ventricular valve, guarding the opening, is muscular and is connected with the ventricle wall. From the left side of the right ventricle anteriorly, the pulmonary artery arises; its opening is guarded by three crescentic semilunar valves, and it divides into two branches, conveying the impure blood to the lungs. The pure blood returns from the lungs by pulmonary veins, which open into the dorsal wall of the left auricle, and passes through the left auriculo-ventricular aperture into the left ventricle. The left auriculo-ventricular or mitral valve is a double membranous flap attached by chorda tendineae to papillary muscles of the ventricle wall. The blood is pumped to the body through the single aortic arch; it arises from the right side of the ventricle anteriorly, and its opening is guarded by three semilunar valves.

The right and left superior venae cavae, which carry impure blood from the sides of the head and neck, are each formed by the union of jugular, brachial, and pectoral veins. The caudal vein divides into two "renal portals" and a coccygeo-mesenteric, which passes forward to join the hepatic portal vein (formed by union of gastro-duodenal, anterior and posterior mesenteric veins, and going to the liver). Each "renal portal" receives an internal iliac from the pelvic wall, and, passing into the kidney, is there joined by the sciatic, the femoral* and renal; and it leaves the kidney as a common iliac. The two iliacs join to form the inferior vena cava, which passes through the right lobe of the liver and receives the hepatic veins. The epigastric vein, from the great omentum, joins one of the hepatics. The aortic or systemic arch gives off right and left innominate

arteries, and is then continued as the dorsal aorta. Each innominate divides into a common carotid and a subclavian, which divides into brachial and pectoral arteries. Arching to the right side, the dorsal aorta then passes mid-dorsally backwards; its principal branches are the coeliac (to stomach), the anterior mesenteric (to intestine), renals, femorals, sciatics, iliacs, and a posterior mesenteric (to rectum); and it ends as the caudal artery.

* *Since the femorals give off small veins to the kidneys, there is a trace of a renal portal system.*

Write a Short Account of the Renal and Reproductive Organs of the female Pigeon.

The three-lobed kidneys are embedded in the pelvis; at their front ends are the small yellow adrenal bodies. The narrow ureters, each arising from the front lobe, pass backward to the cloaca. There is only one, the left ovary; it is anterior to the left kidney. The left oviduct is a convoluted tube; its anterior opening (coelomic funnel) is close to the ovary, and posteriorly it opens into the cloaca. When a follicle bursts, the egg is discharged into the body cavity, and it enters the oviduct. The middle portion of the oviduct forms the white or albumen around the egg, the hind portion secretes the shell; the terminal part, the muscular vagina, ejects the egg.

Development of Birds.

Write a General Account of the Development of the Chick.

The spherical yellow ovum, within a vitelline membrane, consists of a large amount of yolk with a small germinal disc (containing the nucleus) at the surface; and it is surrounded by a mass of viscid albumen, which is denser close to the ovum and there twirled out into two twisted ends, the chalazae. The outer limy shell has two lining membranes; at its broad end these are separated to form an air-chamber.

Segmentation is meroblastic and restricted to the disc, which becomes the blastoderm, with an upper layer of cells (ectoderm) and larger lower layer cells, the lowest being incompletely separated from underlying yolk-nuclei. The spaces between the lower layer cells represent the segmentation cavity, soon obliterated. The lowest lower-layer cells become flattened and joined together to form the (secondary) endoderm or hypoblast. The blastoderm spreads

outwards; viewed from above, it has a central pellucid area and a marginal opaque area. The pellucid area becomes pear-shaped, and in its narrow posterior third the primitive streak appears lengthwise; it develops a longitudinal primitive groove. Ectoderm cells, which are detached at the sides of the streak, form, along with lower-layer cells, the mesoderm. In the front part of the pellucid area, a bulging arises, the head fold (its endodermic cavity is the fore gut); and between it and the streak, arise the ectodermic ridges of the medullary plate, thus forming the medullary groove. The ridges (medullary folds), continuous in front, meet gradually backwards to form the neural tube, beneath which a line of endoderm becomes the notochord.

The sheet of mesoderm at each side becomes two-layered; that next the ectoderm is the somatic layer, and that next the endoderm is the splanchnic layer, the cavity between being the coelome. Further, the mesoderm next the notochord is thicker (vertebral plate), and it becomes marked off from the outlying portion (lateral plate), and is also split up into transverse segments (protovertebrae or myotomes). The coelome of the myotomes is the myocoele, and that of the lateral plates is the splanchnocoele. The two layers (somatic mesoderm and ectoderm, i.e., somatopleure) external to the splanchnocoele form the body wall; and the two layers (splanchnic mesoderm and endoderm, i.e., splanchnopleure) internal to it form the gut wall. The main part (mesenteron) of the gut is formed by the folding-off of the embryo, when the yolk becomes a yolk-sac connected by a narrow stalk with the mid-gut.

The rudiments of blood-vessels, which appear in the mesoderm, give a mottled appearance to the inner rim of the opaque area (vascular area). Two vessels beneath the fore-gut fuse to form the tubular heart; its posterior end is formed by the union of two vitelline veins, and a Y-shaped vein (anterior and posterior cardinal forming duct of Cuvier) opens into it at each side.

Around the front of the head there is a part of the blastoderm which, before the mesoderm extends into it, is termed the pro-amnion; there the roof of the splanchnocoele bulges upwards at each side, and on each dome a whitish line appears. These lines, which curve inwards and meet in front of the pro-amnion, are the amnion folds; arching over the head they coalesce and grow backwards, uniting with similar folds which arise around the tail and (later) at the sides. The embryo is thus enveloped in a double fold of somatopleure; the inner layer of which (the true

amnion) closely invests the embryo, while the outer layer (false amnion, serous or sub-zonal membrane), which fuses with the vitelline membrane, forms a roof. The space between amnion and embryo becomes full of fluid, serving as a water-cushion.

From the hind-gut a diverticulum, the allantois, grows out between the amnion and serous membrane; ultimately it extends round the embryo and yolk-sac, and, fusing with the serous membrane, it becomes closely applied to the shell; it is the embryonic respiratory organ, it is highly vascular and, absorbing the albumen, it aids in the nutrition of the embryo.

When the remains of the yolk-sac are withdrawn within the body, and the allantois shrivels, the chick (twenty-first day) ruptures the membranes, and, by means of the knob or caruncle on its beak, breaks open the shell.

Mention the Principal Divisions of the Class Aves, and give Examples.

Sub-class ARCHAEORNITHES.

Example, Archaeopteryx. Jaws with teeth (in sockets). The three metacarpals and the three digits (with claws) are separate. Pygostyle absent. Each of the (20) tail vertebrae had a pair of feathers. Extinct (Solenhofen Lithographic Stone of Bavaria).

Sub-class NEORNITHES. Metacarpals fused.

Division Ratitae (Running Birds). Sternum without a keel. Scapula and coracoid fused. Clavicles absent or rudimentary. Without a pygostyle.

Examples, Struthio (African Ostrich). Two toes (3rd and 4th) only. A pubic symphysis.
Rhea (South American Ostrich). Three toes. An ischial symphysis.
Apteryx (the New Zealand Kiwi). Bill long and nostrils terminal. Feathers bristle-like. Without distinct tail feathers. Four toes.

Division Carinatae (Flying Birds). Sternum with a keel. Scapula and coracoid connected by ligament. Clavicles usually well developed. A pygostyle generally present.

Example, Columba (Pigeon). See pages 242 to 247,

CLASS MAMMALIA (MAMMALS).

State briefly the General Features of Mammals.

Hairs always present. A projecting external ear-flap, the *pinna*. Skin has *sebaceous* and *sweat glands*. The *mammary* (milk-producing) glands are specialised sebaceous glands. Chest and abdominal cavities separated by a complete muscular septum, the *diaphragm*. Vertebral centra and long bones generally have epiphyses (later terminal ossifications). Typically seven cervical vertebrae. Sutures between skull bones usually persistent. *Two* (exoccipital) condyles. A tympanic bone around outer ear. *Three* ear ossicles (*malleus, incus, stapes*). Otic bones (auditory capsule) fuse to form a *periotic*, which is fused with squamosal. Internasal septum produced in front of nasal bones, forming the cartilaginous support of a *flexible nose or muzzle*. Lower jaw consists (each ramus) of a single bone, and articulates on squamosal (*quadrate absent*). *Teeth* (in sockets or alveoli) on premaxillae, maxillae, and mandible; and typically heterodont (i.e., different in form and function) and diphyodont (i.e., two functional sets, a milk or deciduous set replaced later by a permanent set). *Sternum* has distinct segments. *Coracoid* rudimentary, a small hook-like process of scapula.* *Pubes*, and also *ischia*, meet ventrally; *acetabulum* completely ossified (except in *Echidna*). Large and often convoluted cerebral hemispheres connected by a broad commissure (*corpus callosum*)†, and covering the thalamencephalon and the four optic lobes (*corpora quadrigemina*; in higher forms also covering cerebellum, which has one median and two lateral lobes. *Twelve* pairs of cranial nerves. Lungs, within pleural sacs, largely free. A complex larynx with vocal cords. Heart has two auricles and two ventricles. Only one, the *left aortic arch* is continued into the dorsal aorta. Without a renal portal system. Warm-blooded. *Ureters open into bladder*,* and its outlet forms a *urinogenital sinus* (urethra of male, vestibule of female), into which the genital ducts open, and which is separated from the anus by a space, the *perinaeum*.* *Testes* descend into scrotal sacs situated (except in Marsupials) behind penis, which is traversed by urethra. *Ovaries* small. The uterine portions of the oviducts are frequently united, or partly united (*bicornuate uterus*); the vaginal portions are completely fused.†

Ovum, very small,* contains little yolk* (segmentation holoblastic), and develops within uterus (womb).* *Embryo* has two foetal membranes (*amnion* and *allantois*); these,

along with that part of the uterine wall to which they become firmly attached, constitute the true (*allantoic*) *placenta*, connecting the embryo with the mother.

Gestation (pregnancy) period long; except in Marsupials, which have a rudimentary allantoic placenta and a well-developed yolk-sac placenta. After birth the young are suckled (milk nutrition) by the mother for a variable period.

Characteristic features are printed in *italics*.

* Except Monotremes.

† Except Monotremes and Marsupials.

State the Number and Different Kinds of Teeth in a Typical Mammalian Dentition. Give the Dentition of the Rabbit.

Forty-four teeth (permanent set), eleven on each side of upper and lower jaw. The front ones (on premaxillae) are the incisors, for seizing and cutting; behind these (on the maxillae) are the canines, followed by premolars and molars, which are adapted for grinding and crushing. Incisors and canines generally have single roots, the grinders have two or more roots. Since the number of teeth on each side is the same, the formula expressing this dentition would be:—

$$i \frac{3}{3} - c \frac{1}{1} - p \frac{4}{4} - m \frac{3}{3} \times 2 = 44, \quad \text{and is usually} \quad \frac{3143}{3143} \\ \text{written thus—}$$

The form of the teeth is according to the nature of the food. When the crown has a number of cusps, the tooth is termed bunodont; when the cusps form a single (cutting) ridge, secodont; when the cusps are not conical but modified as partly longitudinal partly transverse crescents, selenodont, or forming transverse ridges, lophodont. The dentition of the Rabbit is $\frac{2033}{1023}$; it is without canines.

The Rabbit (*Lepus*).

A Type of Mammals.

Write Short Explanatory Notes on the following:—Diastema, Perineal Glands, Panniculus carnosus, Panniculus adiposus.

The diastema is a gap at each side of the mouth, between the front and back teeth; it is overlapped by the hairy lips which there extend into the mouth cavity.

The perineal glands are along the sides of the penis; their ducts open on small hairless patches, one at each side of the anus. The secretion gives the rabbit a characteristic odour.

The panniculus adiposus is a layer of fat between the skin and the underlying muscles; beneath it is the panniculus carnosus, a thin sheet of muscle, its contractions produce twitching of the skin.

Describe the Vertebral Column and Ribs of the Rabbit.

There are seven cervical vertebrae. The first, the atlas, is without a distinct centrum, has conspicuously broad transverse processes, and a large neural ring, which is divided by a ligament into an upper neural canal and a lower space for the odontoid process of the second vertebra. There is a slight neural spine; and, in front, are the two large articular concavities for the condyles of the skull. The second, the axis, has small transverse processes. The broad flattened centrum has large articular surfaces in front, and beyond these it is produced as the odontoid process (probably representing the centrum of the atlas). The neural spine forms a large crest, bifid behind. The remaining cervical vertebrae have the same parts as those of birds; the centra are short, and the spinous processes are small.

The thoracic vertebrae (12 or 13) have short thick centra, short transverse processes, long neural spines, and bear long curved movable ribs. Each of the first nine pairs of ribs has two articulating heads (capitulum and tubercle), the others have a capitulum only; and only the first seven pairs have their sternal portions (partly cartilaginous) connected with the sternum.

The lumbar vertebrae (6 or 7), the largest, have long centra, prominent articular processes, crested neural spines, and long transverse processes which are directed forwards and downwards and expanded at their ends.

The sacral vertebrae (2) are ankylosed to form the composite sacrum for supporting the pelvis.

The caudal vertebrae become reduced (size and processes) towards the tip of the tail.

Between the centra, which have thin epiphyses at their ends, there are cartilaginous intervertebral discs.

Give a Description of the Skull of the Rabbit.

The chondrocranium is almost wholly replaced by bone; and the skull consists of replacement bones with additional membrane bones (*in italics*),

Around the foramen magnum, and forming the back of the skull, is the occipital; it represents a fusion of the supra-, basi-, and two ex-occipitals, the last bear the condyles and have descending paroccipital processes (one down the side of each tympanic bulla). The roof of the skull, from the supraoccipital forwards, consists of small *interparietal*, *parietals*, *frontals*, *nasals*, and *premaxillae* (bearing the incisor teeth). At the sides of the skull are the *premaxillae* and large *maxillae* (bearing premolar and molar teeth, and together forming the upper jaw), *lacrimal*s, *orbitosphenoids* (around optic foramen), *supraorbital processes* (crests of frontals above orbits), *palatines* and *pterygoids* (between these and the alisphenoids, large *squamosals* (between alisphenoids and parietals), and *periotics* with outer *tympanics* behind.

The *squamosal* has, on its outer surface, a stout projecting *zygomatic process*, which bears ventrally the *glenoid fossa* for the condyle of the mandible. The *maxilla* has a similar process; and the two processes, united by the intervening *jugal or malar*, constitute the *zygomatic arch*, which forms a bridge between the temporal fossa and orbit, and serves for the attachment of muscles.

On the floor of the skull and roof of the mouth are the *basioccipital*, the *basisphenoid*, between the alisphenoids and with a dorsal recess (*sella turcica*) for the pituitary body, the *presphenoid* (between orbitosphenoids), *pterygoids* and *palatines*. The posterior part of the hard palate* is formed by the horizontal front portions of the palatines with the palatal processes of the maxillae united behind; and similar processes of the premaxillae form the incomplete front part.

The two nasal cavities, within which are the thin folded turbinals, are separated by the vertical *mesethmoid*; it has on its lower edge the slender *vomers*, and it is expanded behind as the sieve-like *cribriform plate*, through which the olfactory nerves pass to the nose.

The *periotic* (around the internal ear), between the occipitals and squamosal, has an inner *petrous portion* and an outer *mastoid portion*. The *tympanic*, on the outer side of the periotic, consists of an upper funnel-like part (bony wall of external auditory meatus) and a bulbous base, the *tympanic bulla*, which encloses the tympanic cavity containing the ear ossicles. The *squamosal*, *periotic*, and *tympanic* constitute the temporal bone of human anatomy.

* The **soft palate** is the muscular bridge between the pterygoids; it ends in a free border above the glottis, and it separates the posterior nasal chamber from the buccal cavity.

Each ramus of the lower jaw or mandible consists of a single bone (*dentary*). The hyoid is situated between the rami, posteriorly.

Describe the Pectoral Girdle and Fore-limb, and the Pelvic Girdle and Hind-limb of the Rabbit..

The shoulder girdle of each side is attached by muscles and ligaments to the backbone. The only well-developed part is the flattened triangular scapula; its ventral apex forms a hollow, the glenoid cavity, for the head of the humerus, and has a short curved coracoid process; its short upper border bears the cartilaginous suprascapula; and along its outer surface is a longitudinal ridge, the spine, which ends in an acromion process with a long metacromion. The thin and curved clavicle is connected with the sternum.

The fore-limb consists of the humerus (upper arm), the radius and the ulna with an olecranon process behind the elbow-joint (fore arm), the carpus (wrist) composed of nine small bones, and the manus (hand) which consists of five metacarpals bearing five digits with claws. Each digit has three phalanges, except the preaxial pollex, which has only two. The proximal row of carpals consists of the radiale (scaphoid), median semilunar, and ulnare (cuneiform); the distal row consists of the trapezium, trapezoid, os magnum, unciform, pisiform. Between the two rows is the os centrale.

The pelvic girdle consists (each os inominatum or half) of the anterior ilium and the posterior ischium with the pubis below it. The large oval space between ischium and pubis is the obturator foramen. Between ilium and ischium is the outer acetabulum or socket for the femur. The ilia are firmly attached to the sacrum, the pubes are united ventrally.

The hind-limb consists of the femur or thigh bone, the tibia and slender fibula of the lower leg, the tarsus or ankle (six bones), and the pes (foot) which consists of four long metatarsals with four toes or digits. Each digit has three phalanges, the terminal one bearing a claw. In front of the knee-joint is the knee-pan or patella, a sesamoid bone. The proximal row of tarsals consists of the astragalus (tibiale) and the calcaneum or os calcis (fibulare), which forms the heel, and on which the *tendo Achillis* is inserted; the distal row consists of the meso- and ecto-cuneiform and cuboid. Between the two rows is the navicular or centrale.

What is a Sesamoid Bone?

One which is formed within a muscle tendon, and usually near a joint, e.g., patella and fabellae of knee-joint, pisiform of wrist, small bone nodules behind the metacarpo-phalangeal joints, and epipubic bones of Marsupials.

Write a Short Account of the Alimentary System of the Rabbit.

There are four pairs of salivary glands, namely, parotid (between external ear and mandible), infra-orbital (below the eye), submaxillary (between the mandibles), and sublingual (along inner side of lower jaw); the ducts open into the mouth. The continuation of the buccal cavity beyond the end of the soft palate is the pharynx; it leads into the gullet or oesophagus, which passes through the diaphragm and opens into the stomach. The first portion of the small intestine, the duodenum, forms a long U-shaped loop; the succeeding portion, the coiled ileum (about seven feet long), ends in the sacculus rotundus which opens into the caecum (first portion of large intestine) near its junction with the colon. The large caecum (marked by a winding spiral construction) ends blindly in the vermiform appendix, and (proximally) is continuous with the sacculated colon, which is followed by the long and narrow rectum, ending at the anus. In herbivorous animals digestion is slower and the amount of indigestible matter is greater than in carnivorous types; hence the greater length of bowel.

The large five-lobed liver is attached to the diaphragm by the suspensory ligament; and partly embedded in it (right central lobe) is the gall-bladder, from which the bile duct passes (beside portal vein) to the duodenum (entering it about a quarter of an inch from the pylorus). The diffuse pancreas is spread out in the mesentery of the duodenal loop; the pancreatic duct opens into the distal limb of the duodenum (inner side).

The alimentary canal is supported by mesentery, i.e., a double fold of the glistening peritoneum which lines the abdominal cavity. The great omentum, a peritoneal fold laden with fat, is connected with the stomach.

A long-shaped crimson body attached behind the stomach is the spleen.

Describe the Brain of the Rabbit.

See page 201; also "general features of Mammals," page 250.

Mention the Chief Nerves of the Neck, and indicate their Distribution.

The tenth cranial nerve, the vagus or pneumogastric, which passes along the outer side of the carotid artery, gives off anterior laryngeal, depressor (to heart), posterior or recurrent laryngeal, and branches to heart, lungs, and oesophagus.

The eleventh cranial nerve, the spinal accessory, supplies the sterno-mastoid and other muscles.

The twelfth cranial nerve, the hypoglossal, supplies the muscles of the tongue.

The phrenic, a branch of spinal nerve IV., which passes external to the vagus, supplies the diaphragm.

The ganglionated cervical nerve of the sympathetic nervous system, lying alongside the trachea, between the vagus and depressor nerves.

Name the Important Structures, other than Nerves, which are situated in the Neck.

The trachea ; its anterior part, the larynx, surrounded by large thyroid and ring-like cricoid cartilages.

The thyroid gland.

The oesophagus.

The external jugular vein.

The carotid artery.

Give a General Description of the Structure of the Eye, Nose, and Ear.

The eye is without a pecten. *See* description, page 203. For a description of the olfactory organ, *see* page 205. The ear has a large, coiled cochlea. *See* description, page 206.

Describe the Heart and Principal Blood-vessels of the Rabbit, and indicate the general Course of the Circulation.

The heart, within a two-layered pericardium, is situated in the middle of the thorax, in that space called the mediastinum between the pleural sacs. The three venae cavae, which convey the impure blood from the body, open separately into the right auricle ; thence the blood passes into the right ventricle, which partly surrounds the left ventricle but does not quite reach the apex. The right auriculo-ventricular opening is guarded by a membranous tricuspid valve ; its three lobes are attached by chordae tendineae to papillary muscles of the ventricle wall, and

meet together when the ventricle contracts, thus closing the opening.

The blood is driven to the lungs through the pulmonary artery; it arises from the right ventricle anteriorly, and its opening is guarded by three semilunar valves. The blood (oxygenated) returns from the lungs by two pulmonary veins, which together enter the left auricle dorsally. The large left auriculo-ventricular opening is guarded by the bicuspid or mitral valve; it consists of two membranous lobes attached by chordae tendineae to muscoli papillares on the ventricle wall. The mitral valve is closed when the left ventricle contracts; and the pure blood is driven to the body through the aorta, which arises anteriorly. The aorta opening is guarded by three semilunar valves; just beyond these the coronary arteries, which supply the heart, are given off. The aortic trunk bends to the left (aortic arch) and passes backwards, close to the backbone, as the dorsal aorta.

The following arteries arise from the aortic arch:—

1. The innominate, which divides into the right subclavian and the right common carotid, and which gives off, at its base, a left common carotid.
2. The left subclavian.

The following arteries are branches of the dorsal aorta:—

1. The coeliac.
2. The anterior mesenteric.
3. Two renals.
4. Two spermatics, or two ovarians.
5. The posterior mesenteric.
6. The median sacral or caudal (the posterior continuation of the dorsal aorta).
7. Two common iliacs, which give off internal iliacs and are continued into the hind-limbs as femorals.

The principal veins are:—

1. The right superior vena cava (=duct of Cuvier), formed by union of external jugular and subclavian, and receiving a small internal jugular (=anterior cardinal sinus) and the azygos vein (=front portion of posterior cardinal sinus).
2. The left superior vena cava is formed as above, but does not receive an azygos vein.
3. The inferior vena cava receives the hepatics, two renals, two spermatics or two ovarians, two external iliacs

(continuations of femorals), and two internal iliacs (=sciatics).

4. The portal vein, which enters the liver (hepatic portal system), is formed by the union of the lieno-gastric, duodenal, anterior and posterior mesenteric veins.

Where is the Thymus Gland situated?

In front of the heart.

Give a Short Account of the Respiratory Organs of the Rabbit.

The lungs, separated by the mediastinum, occupy the lateral portions of the thorax; they are attached at their roots only, and each is enclosed in a pleural sac. The trachea (*see page 212*) divides into the right and left bronchi, which enter the lungs (at their roots) and form a ramifying system of bronchial tubes. The diaphragm is dome-shaped and its margin is muscular; when it contracts, the dome is flattened, the thoracic cavity is consequently enlarged, and the lungs then expand (inspiration).

Describe the Urino-genital Organs of (1) the Male, and (2) the Female Rabbit.

(1) The two ovoid kidneys (metanephros) are embedded in fat on the dorsal wall of the abdomen, above the peritoneum. The ducts or ureters issue from the inner sides (at the kidney notch), and pass back to open into the bladder, the outlet of which forms the urino-genital sinus (urethra of male, vestibule of female). At the front of each kidney there is a yellow suprarenal gland.

The two testes, originally near the kidneys, descend later into the scrotal sacs, pouches of the abdominal wall. The neck of each sac is the inguinal canal. Each testis has an associated epididymis (mesonephros or Wolffian body). Through the tubes (vasa efferentia) of the epididymes, the spermatozoa pass into the vasa deferentia (Wolffian ducts), which enter the abdominal cavity, and, looping round the ureters, pass back to open separately through a sac (uterus masculinus) into the urethra. Upon the uterus masculinus and vasa deferentia are the prostate glands, and behind these are Cowper's glands. The urethra traverses the penis, which projects from the ventral surface of the body, in front of the anus.

(2) The urinary organs of the female are essentially the same as those of the male. The two ovaries are small. Each of the oviducts (Müllerian ducts) has three distinct regions, namely, the anterior narrow Fallopian tube (with its funnel-like opening close to the ovary), the median uterus, and the posterior vaginal portion. The vaginal portions of the two oviducts are united, forming the vagina, which opens into the beginning of the vestibule. The opening of the vestibule is the vulva; it is ventral, in front of the anus.

Development of Mammals.

Give a general Account of the Developmental History of the Rabbit.

The ovum is fertilised in the Fallopian tube, and, on its way to the uterus, undergoes total (holoblastic) segmentation; the result is a sphere of cells (morula), some of which are smaller than the others. The small cells grow rapidly and form an outer layer (ectoderm) enclosing the larger inner cells. That layer extends; but the inner cells remain attached to it at one spot only (embryonal area), and a large cavity is formed. This stage is the blastocyst.

The knot of inner cells (future embryo) spreads out, becomes two-layered (ectoderm and endoderm); the embryonic ectoderm becomes continuous with the vesicle wall ectoderm, which is lined internally by an extension of endoderm. The primitive streak, medullary groove, head fold, mesoderm and other parts are developed in much the same way as in birds (*cf.* Chick, page 248); and the embryo is folded off, remaining connected by a narrow stalk with the extra-embryonic portion of the vesicle, which is a yolk-sac without yolk (umbilical vesicle). The amnion is formed mainly by the tail folds, otherwise its development is as in birds. (*See* Chick, page 248.)

The blastocyst becomes attached to the wall of the uterus by small projections, trophoblastic villi, which arise on the lower surface of the yolk-sac. As the embryo grows bigger, the upper wall of the yolk-sac is pressed down until (cavity obliterated) it is in contact with the lower wall, which then disappears, is absorbed. Thus the upper (vascular) wall becomes closely connected with the uterus wall (*temporary yolk-sac placenta*). But the principal attachment of the vesicle to the wall of the uterus is by the horse-shoe-shaped patch of thickened trophoblast around the sides and hind

end of the embryo; this is the ectoplacenta, and its outer layer is plasmodial.

The uterine sub-mucosa thickens, becomes folded; two of the folds are the placental lobes, of loose connective tissue with blood capillaries. The epithelium of the lobes is deeply pitted (uterine crypts) to form branched glands. The ectoplacental plasmodium forms irregular processes, which firmly fuse with the surface of the placental lobes; and the glandular epithelium of the lobes then degenerates and disappears. As the ectoplacental processes burrow in, they come into close contact with the dilated sinus-like uterine capillaries and destroy their walls. Simultaneously, mesoblast of somatopleure grows in between folds formed on the lower surface of the ectoplacenta.

Meanwhile the allantois has spread rapidly between the amnion folds, and over the back of the embryo; and its outer (mesoblast) wall fuses with the mesoblast of the false amnion beneath the ectoplacenta. In that way the allantoic blood-vessels are brought into close relation with the uterine sinus-like capillaries. The folds of mesoblast containing the vessels deeply invade the ectoplacenta, cutting it up into columns; there is an interlocking of foetal with maternal vessels, and only thin endothelium is left between these when the ectoplacental plasmodium is finally absorbed. The true (allantoic) placenta, thus formed, is the organ by which the developing embryo breathes and is nourished; and its formation is partly maternal (deciduous portion of sub-mucosa of uterus), partly foetal (ectoplacenta portion of false amnion, and the nutritive and respiratory allantois).

Parturition: The placenta of the Rabbit is deciduate, i.e., the maternal portion (decidua) as well as the foetal portion comes away with the young at birth. The separation is brought about by strong contractions of the uterine muscles.

What is the Umbilical Cord?

The cord-like portion of the placenta issuing from the umbilicus or navel of the foetus; and consisting of the yolk-sac stalk and the corresponding portion of the allantois with vessels, and within an amniotic sheath.

A Classification of the Mammalia.

Sub-class **PROTOTHERIA** (Monotremes). Primitive egg-laying Mammals.

Examples, *Ornithorhynchus* (Duckmole).
Echidna (Spiny Ant-eater).
Proechidna.

Sub-class **METATHERIA** (Marsupials). Mammals which carry their young in a marsupium or pouch.

Order **Polyprotodontia**. Incisors numerous, canines large, grinders with sharp cusps. Carnivorous or insectivorous.

Examples, *Didelphys* (Opossum).
Dasyurus (Dasyure).
Thylacinus (Tasmanian Wolf).
Myrmecobius (Banded Ant-eater).
Notoryctes (Marsupial Mole).
Perameles (Bandicoot).

Order **Diprotodontia**. Fewer and unequal incisors, canines small or absent, grinders with blunt cusps or ridges. Generally herbivorous.

Examples, *Phascolomys* (Wombat).
Phalanger.
Tarsipes.
Phascolarctus (Koala, or "native bear").
Macropus (Kangaroo).

Sub-class **EUTHERIA**. The highest Mammals. A true (allantoic) placenta. Without a pouch.

Order "Edentata."

Examples, *Bradypus* (Three-toed Sloth). Forests of South America.
Choloepus (Two-toed Sloth). Forests of South America.
Myrmecophaga (Ant-eater, or Ant-bear). Tropical South and Central America.
Dasyus (Armadillo). South America.

Order **Effodientia**.

Examples, *Manis* (Pangolin, or Scaly Ant-eater). Africa and Eastern Asia.
Orycteropus (Cape Ant-eater, or Aard-vark). Africa.

Order Insectivora.

- Examples, Erinaceus (Hedgehog). Dentition $\frac{3133}{2123}$.
 Placenta deciduate. Palearctic, Ethiopian
 and Oriental Regions.
 Sorex (Shrew). Europe, Asia, N. America.
 Talpa (Mole). Palearctic Region.
 Galeopithecus (Flying-shrew). Malay
 Archipelago and Phillipines.

Order Carnivora.

Sub-order Fissipedia. Digits separate. With carnassial teeth.

- Examples, Felis (Cat, Lion, Tiger, Leopard, Puma or
 Cougar, Jaguar). Digitigrade.
 Viverra (Civet).
 Herpestes (Mongoose).
 Hyaena (Hyaena). Digitigrade.
 Canis (Dog, Wolf, Jackal, Fox). Digitigrade.
 Ursus (Bear). Plantigrade.
 Procyon (Raccoon). Plantigrade.
 Lutra (Otter).
 Mustela or Putorius (Weasel).

Sub-order Pinnipedia. Aquatic Carnivores. Limbs fin-like, the
 digits webbed or bound together by integument. Without
 distinct carnassial teeth.

- Examples, Otaria (Sea-lion). Antarctic, Pacific Coasts of
 America and Asia. Dentition $\frac{3, 1, 4}{2, 1, 4}, \frac{1 \text{ or } 2}{1}$.
 Trichechus (Walrus). Upper canines are
 large tusks. Arctic Seas.
 Phoca (Seal). Dentition $\frac{3141}{2141}$. Arctic, N.
 Atlantic and Pacific.

Order Cetacea.

Sub-order Mystacoceti (Whalebone Whales).

- Examples, Balaena (Greenland or Right Whale). Arctic.
 Balaenoptera sibbaldi (Sibbald's Rorqual).
 The largest of the whales (length 60 to
 85 feet), and, incidentally, the largest of
 living animals. Atlantic and Arctic.

Sub-order Odontoceti (Toothed Whales). Without whalebone.

- Examples, Physeter (Sperm Whale, or Cachalot).
 Southern Seas.
 Phocaena (Porpoise). Atlantic and Pacific.
 Delphinus (Dolphin). In all seas.

Order Ungulata.

Sub-order Sub-ungulata. Three to five functional digits. Plantigrade.

Examples, Hyrax, syn. Procavia (Coney). Rodent-like and plantigrade. Africa.

Elephas (Elephant). India, Africa.

Sub-order Ungulata vera (True Ungulates). Never more than four functional digits. Digitigrade.

Division Artiodactyla (Even-toed Ungulates).

Section Bunodontia. The crowns of the molars have separate cusps (bunodont). Four separate digits. Stomach simple.

Examples, Hippopotamus (Hippopotamus). Semi-aquatic. Rivers and swamps, Africa.

Sus (Pig). Digits II. and V. small, not reaching ground. Dentition $\frac{3134}{3134}$.

Dicotyles (Peccary). America.

Section Selenodontia, Ruminants. The cusps of the molars modified as partly longitudinal and partly transverse crescents (selenodont). The teeth are often hypsodont, i.e., having long crowns (e.g., Ox, Sheep). Upper jaw usually without incisors. Metacarpals and metatarsals of 3rd and 4th digits generally fused ("cannon-bone"); 2nd and 5th digits vestigial or absent. Deer, giraffe, cattle, sheep and goats walk on the nails (hoofs) of their 3rd and 4th digits; camels walk on their terminal phalanges. Stomach complex, adapted for ruminating.

Examples, Camelus (Camel). Dentition $\frac{1133}{3123}$. Central

Asia and Arabia.

Auchenia (Llama, Alpaca, etc.). S. America. Tragulus (Chevrotain). India, Ceylon, Indo-Malaya.

Cervus (Deer). Throughout the world, except Ethiopian and Australian Regions.

Giraffa (Giraffe). Dentition $\frac{0033}{3133}$. Africa.

Okapia (Okapi). A short-necked giraffe. Congo (Semliki Forest), Central Africa.

Antilocapra (Prong-buck). The horns (epidermal sheaths) are branched, and are shed annually. North America.

Antilope (Antelope). India, Africa.

Bos (Ox) }
Ovis (Sheep) } Dentition $\frac{0033}{3133}$
Capra (Goat) }

Division Perissodactyla (Odd-toed Ungulates).

Examples, Tapirus (Tapir). Dentition $\frac{3143}{3133}$. Central and South America, Malay.
 Rhinoceros (Rhinoceros). Africa, India, Indo-Malaya.
 Equus (Horse).
 Phenacodus. Extinct (Eocene). Five digits on fore and hind limbs. Probably a remote predecessor of the Horse.

Order Sirenia ("Sea-cows").

Examples, Manatus (Manatee). Coastal waters of, and estuaries of rivers flowing into tropical Atlantic.
 Halicore (Dugong): Coastal waters of Indian and Pacific Oceans: coasts of Australia and E. Africa, and the Red Sea.

Order Rodentia. Incisors rootless. Without canines. Generally plantigrade.

Sub-order Duplicidentata (Two pairs of upper incisors).

Example, Lepus (Rabbit, Hare). See pages 251 to 260.

Sub-order Simplicidentata (One pair of upper incisors).

Examples, Sciurus (Squirrel).

Mus (Mouse, Rat).

Castor (Beaver). Europe, North America.

Hystrix (Porcupine). Palaearctic, Ethiopian and Oriental Regions.

Cavia (Guinea-pig).

Hydrochoerus (Capybara). Aquatic. South America. The largest living Rodent.

Order Chiroptera (Bats).

Examples, Pteropus (Fox-bat). A fruit-eating bat.

Dentition $\frac{2132}{2133}$. Madagascar, India, Australia, etc.

Vesperugo (Pipistrelle). An insectivorous bat.

Desmodus. A vampire, or blood-sucking bat. Incisors large and gouge-shaped; molars abortive or absent.

Order Primates.

Sub-order Lemuroidea (Lemurs).

Examples, Lemur (Lemur).
 Tarsius. Indo-Malaya.

Sub-order Anthropeida. *See page 273.*

Section Platyrrhini. Broad-nosed (New World) Monkeys.
See page 273.

Family Hapalidae (Marmosets). Small monkeys. Tail long, bushy, not prehensile. Digits with curved claws, except great toe with a flat nail. Thumb not opposable. Only two molars on each side. Dentition $\frac{2132}{2132}$.

Example, Hapale (Marmoset). Forests of Neotropical Region.

Family Cebidae (American Monkeys). Tail generally long, often prehensile. Digits with flat or curved nails. Thumb opposable. Three molars on each side. Dentition $\frac{2133}{2133}$.

Example, Cebus (Capuchin). Neotropical Region.
The organ-grinder's monkey.

Section Catarrhini. Narrow-nosed (Old World) Monkeys.
See page 273.

Family Cercopithecidae (Baboons, etc.). Muzzle dog-like. Generally with cheek pouches. Tail not prehensile. Arms shorter than legs. Digits with nails. Thumb (when present) and great toe are opposable. With ischial callosities of skin, often brightly coloured. Caecum is without a vermiform appendix. Dentition $\frac{2123}{2123}$.

Examples, Cynocephalus, syn. Papio (African Baboon).
Frequents rocky ground.
Macacus (Macaque). Asia, N. Africa,
Gibraltar.

Family Simiidae or Anthropomorphae (Anthropoid Apes). Without cheek pouches. Tailless. Arms longer than legs. Semi-erect or erect gait. Thumb and great toe are opposable. Caecum has a vermiform appendix. Dentition $\frac{2123}{2123}$.

Examples, Hylobates (Gibbon).	} <i>See page 274</i>
Simia (Orang-utan).	
Gorilla (Gorilla).	
Anthropithecus (Chimpanzee).	
Pithecanthropus erectus. Extinct.	

Family Hominidae. Homo sapiens (Man).

Sub-Class Prototheria (Monotremes).

State briefly the Chief Distinctive Characters of the Prototheria (Monotremes). Give examples, and mention their Distribution.

* cf. Reptiles. † cf. Birds.

Vertebrae without epiphyses*†. Odontoid process is at first separate from axis. Skull bones ankylosed (sutures obliterated).† Without teeth (except young *Ornithorhynchus*). Shoulder girdle like that of lizards*; coracoids well developed and articulated with sternum, clavicles beneath precoracoids and closely applied to a T-shaped interclavicle. Epipubic bones on pubes. Acetabulum incompletely ossified† (*Echidna*). A tarsal spur, containing the duct of a gland. A large anterior commissure; corpus callosum small or absent. A cloaca*†. The right auriculo-ventricular valve partly muscular† (*Ornithorhynchus*). Testes within abdomen. Genital ducts, ureters, and bladder open separately into urinogenital sinus. Penis beneath ventral wall of cloaca, and protruding from it behind. Right ovary small and not functional†. Oviducts large, without distinct regions, and separate†. Ova large with tough shells (segmentation meroblastic)*†. Oviparous*† (*Echidna* carries egg in a ventral skin pouch of the abdomen). The young, when hatched, receive milk from the mother; mammary glands (without mammae or teats) open into slight depressions.

Ornithorhynchus (The Duckmole). East and South Australia, and Tasmania. Burrows in banks of lakes and rivers. Is semi-aquatic; its fore-feet (with claws) are webbed, and its flattened jaws (with horny plates), covered with skin, form a large duck-bill. Mode of feeding, duck-like. Fur short and soft, eyes small, tail flat.

Echidna (The Spiny Ant-eater). East Australia, Tasmania, New Guinea. Nocturnal. Burrowing. Snout slender and tubular. Covered with stout spines amidst hair.

Proechidna. New Guinea.

Sub-Class Metatheria (Marsupials).

Mention the Principal Characteristic Features of the Metatheria (Marsupials).

Angle of lower jaw (i.e., lower posterior end of jaw) is inflected. Only one functional set of teeth (monophyodont); more incisors on the upper than on the lower jaw, and number (for each side) may exceed three. Precoracoids are small processes of scapula. Pubes generally bear epipubic bones (sesamoids). A large anterior commissure; corpus callosum small or absent. The ureters open into the bladder. Anus usually situated well within the urinogenital sinus ("cloaca"), and one sphincter muscle surrounding both openings. Scrotum in front of the penis. Two uteri and two vaginae; upper portions of vaginae frequently united, and at junction a vaginal

pouch is often developed which may become a median vagina (three vaginae). A yolk-sac placenta, functional as such; the allantoic placenta, when present (e.g., *Perameles*), is small. Gestation period short; young, born prematurely and unable to suck, are nursed in the pouch or marsupium (on lower part of abdomen), and the mother, by compressing her belly muscles, forces the milk through her (temporary) teats into their throats.

Write short Notes on the following Marsupials, stating Special Features and Distribution:—Didelphys, Thylacinus, Myrmecobius, Notoryctes, Perameles, Tarsipes, Macropus.

Didelphys (Opossum). Arboreal. Tail prehensile. Pouch generally absent. Dentition, $\frac{5134}{4134}$. N. and S. America.

Thylacinus (Tasmanian Wolf). Dog-like. Carnivorous (canines large.) $\frac{4134}{3134}$.

Myrmecobius (Banded Ant-eater). Squirrel-like. Long extensile tongue. Without a pouch. Dentition $\frac{4, 1, 3, 5 \text{ or } 6}{3, 1, 3, 5 \text{ or } 6}$ = the largest number of teeth known in any heterodont mammal.

Notoryctes (Marsupial "Mole"). Burrowing and mole-like; a good example of "convergence" (i.e., forms not related, yet exhibiting similar characters acquired through similar habits). Deserts of S. Australia.

Perameles (Bandicoot). Burrowing. Insectivorous. An allantoic placenta. Australia, Tasmania, New Guinea.

Tarsipes. Angle of mandible not inflected. Australasia.

Macropus (Kangaroo). Herbivorous. Tail long, and used for supporting body. Hind limbs long, adapted for leaping. Foot has four digits; hallux absent, second and third toes slender and bound together by integument (syndactylous), fourth toe very large. Dentition $\frac{3, 0 \text{ or } 1, 2, 4}{1, 0, 2, 4}$. Australia, Tasmania, New Guinea.

Sub-Class Eutheria.

Briefly state the Chief Distinctive Features of the Eutheria. -

Small anterior commissure; large corpus callosum. Anus and urinogenital opening separate. The vaginae fused as one. A true (allantoic) placenta, deciduate or non-deciduate (i.e., the maternal part of placenta does not come away at birth, because the ectoplacenta is not inseparably fused with the uterine placental lobes). A *pro-*

visional yolk-sac placenta (in *Insectivora*, *Rodentia*, *Cheiroptera*, etc.). Gestation period considerable; young, when born, able to suck. Without a marsupium or pouch.

NOTE.—For Orders “Edentata,” Effodientia, and *Insectivora* see *Classification*, pages 261, 262.

Order Carnivora.

Indicate some of the Special Features of the Carnivora.

Most are carnivorous, preying upon other animals. The manus and pes have at least four digits, with well developed claws, which in some forms (e.g., the *Felidae*) are retractile within sheaths. Clavicles incomplete or absent. Teeth heterodont, and with roots. Stomach simple; caecum small, or absent. A bicornuate uterus. Placenta deciduate.

The following are special features of the Carnivore skull:—

1. Prominent **occipital and sagittal crests** for insertion of powerful neck and jaw muscles.
2. Strong **zygomatic arch**, widely bent outwards (*cf.* powerful muscles of lower jaw).
3. **Glenoid fossa** deep, and with a prominent **post-glenoid process**, which prevents slipping of the lower jaw when prey is seized.
4. Large rounded **tympanic bullae** (flattened in the Bear tribe).
5. An **ossified tentorium**, a vertical projection of dura mater which descends between cerebrum and cerebellum.
6. Large **canine teeth**.
7. Specialised **carnassial or sectorial teeth**, for breaking and stripping fresh bone. (The last premolars of upper jaw, and first molars of lower jaw in the *Canidae*.)

Mention some Examples of (1) Cat-like, (2) Dog-like, and (3) Bear-like Carnivores, and give their Dental Formulae and Distribution.

- | | |
|--|-------------------|
| 1. Cat (<i>Felis</i>). | }
3131
3121 |
| Lion (<i>Felis</i>). Africa, N.-W. India, W. Asia. | |
| Tiger (<i>Felis</i>). Asia, Java, Sumatra. | |
| Leopard (<i>Felis</i>). Africa, Asia, Ceylon, Java, Sumatra, Borneo. | |
| Puma or Cougar (<i>Felis</i>). N. and S. America. | |
| Jaguar (<i>Felis</i>). N. and S. America. | |
| Civet (<i>Viverra</i>). Africa and India. | |
| Mongoose (<i>Herpestes</i>). Spain, Africa, India. | |
| Hyaena (<i>Hyaena</i>). Africa and Asia. Dentition, | 3141
3131 |

2. Dog (*Canis*).
 Wolf (*Canis*). Palaeartic and Nearctic Regions. } 3142
 Jackal (*Canis*). Palaeartic and Oriental Regions. } 3143
 Fox (*Canis*).
3. Bear (*Ursus*). Brown Bear of Palaeartic Region, Polar Bear,
 and Grizzly Bear of North America. Dentition, $\frac{3142}{3143}$.
 Raccoon (*Procyon*). N. and S. America.
 Otter (*Lutra*).
 Weasel (*Mustela*, syn. *Putorius*).
- NOTE.—For Sub-Order Pinnipedia see *Classification*, page 262.

Order Cetacea.

State briefly the Principal Features of the Cetacea, and give Examples.

Aquatic. Naked; a few hairs (bristles) present on upper lip (of foetus). No external neck; the cervical vertebrae thin and fused. A horizontal caudal fin (flukes). The digits of the forelimbs enclosed in a common integument (flippers); hind limbs vestigial or absent. Pelvis vestigial. Clavicles absent. Teeth (Toothed Whales) are homodont (uniform) and monophyodont (one set only); in Whalebone Whales (teeth present in foetus only) numerous horny plates (baleen or "whalebone") hang down from palate into buccal cavity. Nasal organ rudimentary; external nares opening by a single blow-hole (on head, far back) through which the whale, rising to the surface to breathe, powerfully expels a current of hot air, and this condenses ("spouting" or "blowing"). External openings of ears extremely small; also the eyes, which are without nictitating membranes and lachrymal glands. The panniculus adiposus forms a great layer of blubber beneath the thick skin. Teats beside genital aperture; the milk is forced into the mouth of the young one. Mostly gregarious, going in herds or "schools." For examples, see *Classification*, page 262.

Order Ungulata.

Give the General Characters of the Ungulata.

Mainly herbivorous. Typically digitigrade, walking or running on their digits, the nails of the digits forming hoofs encasing the terminal phalanges. Teeth diphyodont. Clavicles absent. Uterus bicornuate. Placenta non-deciduate or deciduate.

Indicate the Chief Features of Elephants.

Thick integument (pachyderm). Hair scanty. Snout produced as a long muscular prehensile proboscis or trunk. Five digits, united by integument; only the nails or hoofs showing externally. The

skull bones contain air-spaces, which are in communication with the nose. The two upper incisors are long ivory tusks. Canines absent. The grinders are very large; one or at most two are developed at a time, but the succession numbers six for each side of each jaw. Dental formula is either $\frac{1033}{0033}$ or $\frac{1006}{0006}$. The two teats are pectoral.

Indian Elephant.

Enamel ridges on (worn) grinders are parallel.

Tusks (incisors) well developed in male only.

Five nails on manus, four on pes. End of trunk has only one "lip."

External ears moderately large.

African Elephant.

Enamel ridges on (worn) grinders are lozenge-shaped.

Tusks well developed in both sexes.

Four nails on manus, three on pes. End of trunk has two "lips" of equal size.

External ears very large.

State the Principal Distinguishing Characters of the Artiodactyla.

An even number of digits (even-toed); third and fourth digits large and of equal size, the others vestigial or absent. Astragalus articulates with navicular and with greater part of cuboid. Femur without a third trochanter. Horns, when present, are either outgrowths of frontal bones, or epidermal horny sheaths on basal bony cores. Stomach complex; caecum small. Teats few and in the groin, or numerous and along the abdomen. Placenta non-deciduate.

How do the Horns of the Cervidae (Deer) differ from those of the Bovidae (Antelopes, Cattle, Sheep, Goats)?

The horns (antlers) of Deer are outgrowths of the frontal bones. During growth the horns are covered by the vascular skin or "velvet"; and when the limit of growth is attained, a circular ridge (the burr) is developed near the base of each horn, and the "velvet" covering them peels off. Annually the antlers are shed (at the burr) and re-grown from the remaining stumps.

The horns of Antelopes, Cattle, Sheep, etc., are never branched (except *Antilocapra*), and are hollow horny (epidermal) sheaths covering basal bony cores (outgrowths of frontal bones). The horn and core are permanent, are never shed.

Describe the Stomach of a Ruminant (e.g., Sheep), and explain the Process of Rumination or "Chewing the Cud."

The distinct sac-like regions of the "stomach" are the large rumen or paunch, the reticulum (with a honeycombed mucous membrane), the psalterium or manyplies, so-called from the numerous deep leaf-like folds of its inner lining, and the abomasum or reed, which has a ridged inner wall lined with the glandular epithelium that secretes the gastric juice.

The food, mixed with saliva, but not masticated, passes down the gullet or oesophagus into the paunch. Afterwards the softened food, the "cud," is regurgitated and thoroughly chewed; and, in a semi-fluid state, it is again swallowed. It passes down a special groove or gutter of the gullet wall, which gutter is continued, away from the paunch, and along the upper part of the reticulum, to the manyplies. The food is filtered in the manyplies and then passed on into the abomasum, the stomach proper.

See Classification, page 263.

State the Principal Distinguishing Characters of the Perissodactyla.

An odd number of digits (odd-toed), which tends to be reduced; third digit of manus and pes is larger than the others; second and fourth digits (Rhinoceros) and also the fifth (Tapir) may be present; first digit is always absent. Astragalus pulley-like (for articulation with tibia), and its distal surface is articulated with navicular and a part of the cuboid. Femur has a third trochanter. Horns, when present (as, e.g., Rhinoceros), are epidermal growths (without bony cores), and are median. Stomach simple; caecum large. Teats inguinal, i.e., in the groin. Placenta non-deciduate.

Describe the Teeth and Limbs of the Horse.

Dentition $\begin{matrix} 3143 \\ 3143 \end{matrix}$; or $\begin{matrix} 3133 \\ 3133 \end{matrix}$, as the small first premolar soon falls

out. The canines are generally absent in the mare. There is a considerable gap between the front and back teeth. The incisors are chisel-shaped, with a deep pit on the crown; the grinders are modifications of the lophodont type (*see page 251*), they have elongated blunt cusps, and are hypsodont (i.e., having long crowns). The upper molars have six cusps, and the intermediate two are crescentic; the lower molars have four cusps, the intermediate two being absent. When the tubercles become worn down, the crown shows folded double laminae or ridges of enamel embedded in the cement.

Fore-limb.—Humerus with two trochanters. Ulna (with olecranon process) fused with radius. Carpus ("knee") consists of seven bones (trapezium being absent), arranged in two rows of three, with the pisiform projecting behind from the upper row. The horse walks on the nails (hoofs) of its third or middle digits, the only functional ones. Attached to the sides of the long metacarpal (*cannon bone*) are the splint-like rudiments of the second and fourth digits. The first phalanx is the *pastern*, the second is the *coronet-bone*, and the third is the *coffin-bone*, within the hoof.

Hind-limb.—Femur has a trochanter major and a lower third trochanter. Tibia ankylosed with thin fibula. Between femur and tibia is the *stifle-joint*, in front of which is the patella. Tarsus (*hock*) consists of six bones. The metatarsal and phalanges are the

same as the corresponding parts of the fore-limb. The joint between the cannon-bone and pastern of each limb has small sesamoids behind, and is covered by a horny growth which bears a tuft of hair; this is the *fellock*.

See Classification, page 264.

NOTE.—For Orders Sirenia and Rodentia, *see Classification, page 264.*

Order Cheiroptera (Bats).

Mention some of the Special Features of the Cheiroptera (Bats).

The fore-limbs are modified as wings. The wing is an extension of the skin (the patagium) stretching from the shoulder to the base of the thumb and between the elongated digits of the hand, and continued between the limbs and to the tail (when present). The bones of the fore-limbs are very long; the ulna is rudimentary, there are six carpals and five digits, four of which have long metacarpals bearing two long phalanges. The short thumb and the (5) digits of each foot have claws. The hind-limbs are turned outwards, consequently the knees are directed backwards; the pubes show a corresponding inclination outwards, and do not generally form a ventral symphysis. The clavicles are long. The retina of the eye is poorly developed; the sense of touch is superlative. Nocturnal, and almost cosmopolitan in distribution.

See Classification, page 264.

Order Primates.

State the Chief Characteristic Features of the Primates.

Mainly arboreal; and mostly gregarious and uniparous. Plantigrade. Limbs free from body and long. Hands and feet usually have five digits, and are more or less prehensile; the thumb, or the great toe, or both, being opposable to the other digits. All or some of the nails are flat. Orbits directed forwards, and (except Lemurs) completely shut off from temporal fossa (by ingrowth of frontal and jugal to meet alisphenoid). Clavicles always well developed. Brain large, and generally well convoluted. Testes in a scrotum; penis pendent. Two breast mammae (certain Lemurs have additional teats on abdomen). Placenta deciduate (except most Lemurs). Sub-tropical and tropical distribution.

Mention the Features which distinguish the Lemuroidea (Lemurs) from the Anthropoidea. Where are Lemurs found?

Small furry creatures, somewhat like monkeys, but with fox-like faces. Arboreal and mostly nocturnal. Orbit is only encircled by a bony rim (except *Tarsius*, in which the orbit is almost entirely shut off from the temporal fossa). Lachrymal foramen is outside the orbit. Upper incisors separated in middle line (except *Tarsius*). Second digit of foot has a claw, the others generally have flat nails.

Cerebral hemispheres do not cover cerebellum. Generally two pectoral mammae; and there may be additional teats on the abdomen. Uterus bicornuate. Placenta non-deciduate (except *Tarsius*).

Madagascar (chiefly), Africa, India, and Malay Archipelago.

Give the Distinctive Features of the Anthropoidea.

Cerebral hemispheres generally cover cerebellum. Cranial cavity large. Orbit completely separated from temporal fossa. Lachrymal foramen is intra-orbital. Never more than two incisors on each side of each jaw; bunodont premolars (2 cusps) and molars (usually 4 cusps). Radius and ulna freely movable one on the other in pronation and supination. Stomach usually simple. Uterus simple.

Point out the Chief Differences between the Platyrrhini and the Catarrhini.

Section Platyrrhini.	Section Catarrhini.
A broad cartilaginous internasal septum.	A narrow internasal septum.
Tympanic bone simple, without a bony tube (external auditory meatus).	Tympanic bone has a bony tube.
A tympanic bulla.	Without a tympanic bulla.
The orbital portion of the jugal and the alisphenoid meet the parietal, consequently the squamosal does not join the frontal.	The frontal meets the squamosal, consequently the jugal does not join the parietal.
Three premolars; $\frac{2132}{2132}$ or $\frac{2133}{2133}$.	Two premolars $\frac{2123}{2123}$.
Without cheek pouches.	With cheek pouches (except Apes).
Without ischial callosities.	With ischial callosities (except Orang-utan, Gorilla and Chimpanzee).
Tail often prehensile.	Tail not prehensile.
New World.	Old World.
<i>See Classification, page 265.</i>	<i>See Classification, page 265.</i>

Write short Notes descriptive of the following:—Hylobates, Simia Gorilla, Anthropopithecus, Pithecanthropus.

The slender **Gibbons** (*Hylobates*) have teeth closely resembling those of Man; and, like Man, they walk erect (when on the ground), holding aloft their exceptionally long arms. They have flat nails on the thumb and great toe only; and, unlike other Anthropoid

Apes, they have small ischial callosities. Omnivorous. Height, three feet, or nearly so; length of arm the same. Distribution, S.-E. Asia, especially the Malay Archipelago.

The **Orang-utan** (*Simia*) walks on its knuckles and the outer edges of its feet. It has a high and rounded cranium; and it is the ape whose brain presents structurally the closest approach to that of Man. Its canine teeth are large. It has, like Man, twelve ribs. It lives almost constantly in the trees (forests of Borneo and Sumatra), forming a rough kind of nest for itself amongst the branches; and it is exclusively vegetarian. Heavily built. Height of male about $4\frac{1}{2}$ feet; the arm reaches to the ankle.

The **Gorilla**, the largest of the apes, is massive in build, and attains a height of about $5\frac{1}{2}$ feet. The male is larger than the female. The arms reach to the middle of the lower leg. It walks on the soles of the feet and the backs of the (closed) hands; it is able to stand (and walk) without the support of the arms. The ridges of its skull are strongly developed; the canine teeth are very large. It feeds chiefly on fruit, and lives in the forests of Western Equatorial Africa.

The **Chimpanzee** (*Anthropopithecus*) "does not exceed 5 feet in height." The arms reach slightly below the knee. It walks on the soles of the feet (or the closed toes) and the backs of the (closed) hands; but frequently without the support of the arms. The skull is without prominent ridges, and the canine teeth are relatively smaller than those of the Gorilla. In many ways (e.g., the curvature of the backbone) the Chimpanzee is the ape most like Man. It lives in the forests of West and Central Equatorial Africa.

Pithecanthropus erectus is an extinct form, remains of which were found in Java (Early Pleistocene). It is supposed to be intermediate between the Anthropoid Apes and Man.

See *Classification*, page 265.

State the Chief Structural Features which distinguish Man from the Anthropoid Apes.

The curvature of the spine, the perfect adaptation of the legs to support the body, the big toe not opposable and not prehensile, are features associated with the characteristic erect posture. Relatively, the arms are shorter and the legs longer than those of Apes. The brain is much larger and more complex than that of any Ape. The skull is without sagittal and occipital (lambdoidal) crests or ridges, and its frontal region is distinctively large. The teeth, $\frac{2123}{2123}$, form an even series, the canines not projecting conspicuously. The hairy covering of the body is greatly reduced.

Name the Zoo-geographical Regions.

Palaeartic = Europe, Africa and Arabia north of the Tropic of Cancer, Asia (except India, Burmah, Siam and S.-E. China), Japan, Iceland, Azores, and the Cape Verde Islands.

Ethiopian = Africa and Arabia south of the Tropic of Cancer, Madagascar, Mauritius, Seychelles, etc.

Oriental = India, Burmah, Siam, S.-E. China, and certain islands of the East Indian Archipelago, including Sumatra, Java, Bali, Borneo, and the Phillipines.

Australian = Australia, Tasmania, and the Austro-Malayan islands, from Lombok and Celebes on the west to the Solomon Islands on the east, the principal one being Papua or New Guinea. New Zealand and Polynesia are usually included in this Region.

Neotropical = Mexico, Central America, West Indies, South America, Galapagos Islands, Juan Fernandez, and the Falkland Islands.

Nearctic = North America (except Mexico) and Greenland.

The Palaeartic and Nearctic together form the **Holarctic** Region.



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