CHAPTER XI

ANNELIDA

PHYLUM — ANNELIDA

General Characteristics. The Annelida constitute a distinct phylum of worm-like forms. A study of their embryology indicates stages similar to those of lower forms such as Hydra and Planaria. Thus, the animal begins as a fertilized egg which undergoes cleavage (Fig. 303) and passes through a morula, blastula (Fig. 305) and gastrula stage. Mesoderm appears, so that Annelida are triploblastic animals. The body is bilaterally symmetrical and has antero-posterior and dorso-ventral differentiation. The intestinal tract extends from the mouth to the anus. *Within* the mesoderm is developed a true body cavity or coelome. This differs from that present in Nematodes because it is developed *in* the mesoderm; *i.e.*, the body wall is composed of structures developed from ectoderm and mesoderm, while the intestinal tract is developed from structures arising from mesoderm and endoderm. A similar *coelome* or *true body cavity* is formed during development of higher animal phyla. Within the coelome are specialized organs of circulation, excretion and reproduction.

Metamerism. The name Annelida or Annulata refers to the fact that the body is composed of a number of serially repeated portions called segments or metameres. They are also called somites, a word derived from the Greek "soma," meaning "body." Segmentation or *metamerism* is characteristic of most of the higher phyla and is thought to be of considerable evolutionary significance. Metamerism is not merely a superficial character but also finds expression in serially repeated units of the muscular, vascular, excretory and nervous systems.

Earthworm — Study of a Type

Lumbricus, a common earthworm, is suitable for a detailed study of structure of the Annelids. It is important to become familiar with the anatomy of an animal of this group because it is an introduction to the study of the morphology of more specialized animals.

External Features (Fig. 164). The worm is purplish brown in color and has about 160 segments, the number varying. At about the thirty-first, and extending backward for a few segments, is a swollen part called the *clitellum*. On each segment are *four pairs* of short bristle-like *setae*. These are locomotor organs and are of great use when the worm is in its burrow. On the ventral side of most segments or *somites* are the two openings of the paired *nephridia* or kidneys. In the grooves between the ninth and tenth, and tenth and eleventh somites, are two pairs of minute openings of the internal *seminal receptacles*. On the floor of the fourteenth somite are the two openings of the *oviducts*. On the floor of the fifteenth segment are the two openings of the *vasa deferentia*, ducts carrying sperm from the testes. At the front end of the worm is an incomplete segment, which forms a lip-like proboscis over the mouth. It is the *prostomium*. Perforated partitions extend from the body wall to the intestine. These are *septa* and appear as the ring-like lines or *annuli* on the surface, separating one segment from another.

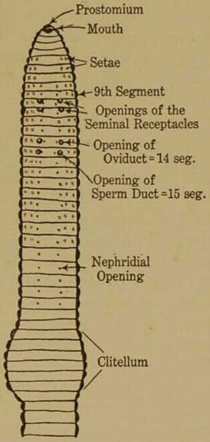

Fig. 164. — Diagram of ventral surface of anterior portion of an earthworm.

Body Wall, Coelome and Intestinal Wall (Fig. 165). On the outside of the body is a thin, non-cellular layer, the cuticle, in which are the various external openings referred to in the preceding paragraph. Within this and derived from ectoderm is the epidermis, composed of columnar-shaped cells. These form a thin membrane or epithelium covering the internal tissues. Some of the epithelial cells are *gland* cells which keep the body surface moist while others are *sensory* and therefore irritated by external stimuli, but most cells are protective. Within the body-wall epithelium is a layer of *circular muscle* and within this is a thicker layer of *longitudinal muscle.* Both muscle layers are composed of contractile cells derived from mesoderm. The cells of the circular layer occur at right angles to the longitudinal axis of the body, while those of the longitudinal layer run lengthwise of the body. The lengthening and shortening of the body is accomplished by the action of these muscles. Examination of a living worm reveals contraction waves passing over the worm, and the body at a given point is now extended and now contracted. Within the layer of longitudinal muscle is a thin cellular epithelial membrane called the *peritoneum,*

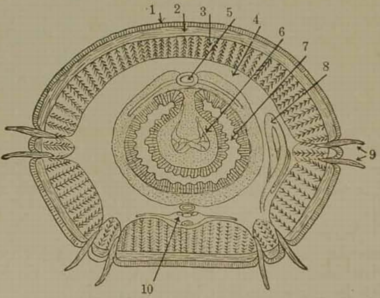

FIG. 165. — Cross-section of body of earthworm. 1 — Epidermis; 2 — Circular muscles; 3 — Longitudinal muscles; 4 — Body cavity or coelome; 5 — Dorsal blood vessel; 6 — Typhlosole; 7 — Intestinal cavity; 8 — Nephridium; 9 — Setae; 10 — Ganglion. (From section and after model by Ward.)

forming the internal lining of the body wall. The *septa* are covered on each surface with *peritoneum,* and these two layers inclose a thin layer of muscle and connective tissue. The intestinal tract is lined with *columnar epithelial* cells derived from endoderm. The coelomic surface of the intestine is composed of a layer of special peritoneal cells called *chloragogue cells.* They extend into a fold of the intestine along the dorsal mid-line, forming the core of the *typhlosole.* Between the chloragogue cells and the internal epithelium is a thin layer containing muscle cells and connective tissue. Body wall, septa and intestine are well provided with blood vessels and nerve fibers.

Digestive Tract (Fig. 166). The mouth opening or buccal cavity leads into the *pharynx*, a spindle-shaped tube, largely muscular and functioning in the swallowing of food. Behind the pharynx is the *oesophagus*, a thin-walled tube concealed by adjacent organs. The oesophagus extends from about the sixth to the fourteenth segment. Posterior to the oesophagus is a large saccular, thin-walled *crop*, extending from about the fourteenth to the seventeenth segment. Posterior to the crop is a large pouch, the thick, muscular *gizzard*, extending from the seventeenth to the nineteenth segment. Posterior to the gizzard is the smaller tubular *stomach-intestine* which extends throughout the rest of the body to the *anus*. In the dorsal wall of the stomach-intestine is infolded a long ridge called the *typhlosole*, which increases the internal surface of the intestine and contains cells which probably function in digestion and absorption. Small *calciferous glands* occur along the sides of

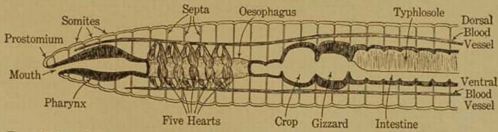

FIG. 166. — Diagram of sectional view of anterior portion of the earthworm.

the oesophagus near the rear, and secrete into it an alkaline fluid which neutralizes acid food. The earthworm feeds at night, eating earth with small bits of plant and animal matter. Food passing into the crop is softened there, after which it is passed into the gizzard, where the muscular action of the gizzard walls grinds up the food between the grains of sand which are eaten with the food. Thence it passes to the stomach-intestine, where different types of enzymes simplify it into compounds which can be absorbed into the cells of the intestine and probably thence into the coelomic fluid and blood vessels. Undigested material is discharged posteriorly from the *anus*.

Circulatory System (Fig. 166). The earthworm (annelid) is the first animal we have studied which possesses blood and blood vessels. There are a few long trunk blood vessels from which branches extend to the organs in their vicinity. There are five of these main trunks: first, the *dorsal vessel*, which runs along the upper surface of the intestinal tract; second, the *ventral vessel*, which is underneath the intestine; and third (Fig. 165), the *sub-neural vessel,* located underneath the nerve cord and two small *lateral neural vessels* one along each side of the nerve cord. The lateral branches of these upper and lower main trunks connect with each other in various ways by means of branches terminating in a smaller network of capillaries located in the tissues, thus forming a complete system. In the neighborhood of the oesophagus, on each side, are five pairs of large vessels (Fig. 166) which connect the dorsal vessel with the ventral vessel. These are called the "hearts." The dorsal vessel and the hearts are contractile. Valves in the dorsal vessel and in the hearts insure the flow of blood forward in the dorsal vessel, and a great part of it is carried down by the "hearts" to the ventral vessel. In general, the blood flows toward the rear in the ventral vessels but forward in the dorsal vessels. The nervous system is especially well supplied with blood. The blood consists of a liquid *plasma* which contains a few minute *colorless cells.* The red color of the blood is due to the presence of a protein-iron compound called *hemoglobin,* which is dissolved in the plasma and has the power of absorbing oxygen from the air and carrying it to all cells of the body.

Respiratory System. There is no special respiratory system. Capillaries are near enough to the surface of the moist skin so that the hemoglobin of the blood may absorb oxygen, which is thus circulated throughout the body. The worm would die from oxygen starvation if the skin dried up. Carbon dioxide is discharged from the circulating blood through the skin.

Excretory System (Figs. 165–167). A pair of excretory organs or *nephridia* occur in most somites. A *nephridium* is a coiled tube, located in the lateral lower portion of the coelome between the intestine and body wall. The anterior end is a ciliated funnel called a *nephrostome.* From the nephrostome, the tubular kidney passes back through the septum *behind the nephrostome* into the rear somite where most of the kidney lies. In this somite the kidney has several coils and its posterior end opens to the outside on the floor of this somite. Part of the coiled tube is lined with cilia. The cilia create a current which draws fluid into the nephridium from the contents of the body cavity. Some part of this fluid is waste matter. Gland cells, forming the body of the tubule, probably also abstract waste matter from the blood capillaries which closely invest the tubule. Within the tubule, the current, created by the cilia, transports these wastes out through the excretory pore.

Nervous System (Figs. 165 and 167). In the earthworm there is a centralization of nerve cells. Underneath the intestine is a long white cord, the ventral nerve cord. In each segment the cord presents a swelling, a *ganglion.* Under the pharynx, the nerve cord ends with the *sub-pharyngeal ganglion.* From the sides of this, lateral cords extend up on either face of the front of the pharynx ending above in the *bilobed suprapharyngeal ganglion* or *brain* located in the third somite. From each ganglion, nerves extend out into adjacent organs and tissues.

A nerve cell (Fig. 168) consists of three parts; first, a larger, cell-like part or *cyton,* which contains cytoplasm and the nucleus; second, a series of short, branching roots or *dendrites,* and third, the *axone* or thread-like process which serves mainly to conduct the impulses. The nerve-cell body is a sort of relay station or battery. The nerve-cell axones are the "wires" along which the nerve "current" runs. Dendrites of one nerve cell "pick up" impulses from the terminal branches of the axone of another nerve cell with which the first is associated. The connection between the two is called a *synapse.* The ganglia noted above are aggregations of nerve-cell bodies and their connecting or synaptic branches. The nerve cord is a linear arrangement of ganglia and

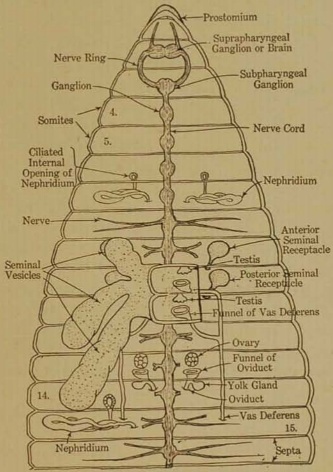

FIG. 167. — Anatomy of earthworm. (Modified from model by C. H. Ward.)

connecting nerve axones. The nerves which extend to the tissues from the ganglia are bundles of axones. The brain of higher forms is a larger and more complex aggregation of nerve cell bodies and processes.

There are three types of nerve cells. First, those that conduct impulses from the sensory surface to the ganglia of the nerve cord. Such nerve cells are called sensory or *afferent* because they convey impulses, aroused by external stimuli, toward the central system. Second, other nerve cells conduct impulses from the ganglion out to a muscle, causing it to contract, or to a gland, causing it to secrete. They are *motor* or *efferent* nerves. Third, within the cord are also *association* cells whose processes connect cells in one ganglion with those of another ganglion. By *nerve impulse* is meant some sort of physico-chemical change which progresses along the nerve fiber.

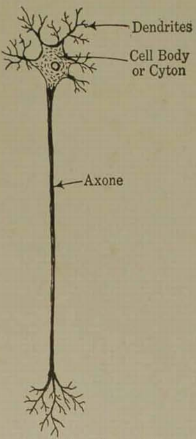

FIG. 168. — Nerve cell or neuron.

Reflex Mechanism. A ganglion with its sensory and motor nerve cells constitutes part of a simple reflex apparatus (Fig. 169). An external stimulus affects an afferent nerve cell which has a part terminating in a sensory cell in the skin of the worm. In some cases a peripheral process of a *sensory nerve cell* begins in the skin. This portion of a reflex mechanism which receives the stimulus is called a *receptor*. The receptor sends an impulse into the ganglion. Here it is transferred to a motor cell. This cell is called an *adjustor*, because it adjusts or may modify the incoming impulse. The muscle aroused to action by the efferent impulse of the adjustor cell is called an *effector* and is the terminal part of the reflex apparatus. The movements and activities of the earthworm are simple reflexes or combinations of them. The earthworm is sensitive to various forms of external stimuli. Special epidermal cells of the skin, particularly toward the anterior and posterior ends of the worm, form sense organs which are connected with afferent nerves. These two portions of the body are especially sensitive.

Reproduction System and Reproduction (Fig. 167). A pair of *ovaries* is located on the anterior septum of the thirteenth somite. Behind them in the same segment are the funnel-like openings of the short *oviducts* which open to the outside of the body on the floor of the fourteenth somite. In the ninth, tenth, eleventh and twelfth segments are large sac-like organs. These sacs are known as the *seminal vesicles*. They serve to store sperm. Spermatozoa are secreted by two pairs of *testes*. There is one pair in the tenth

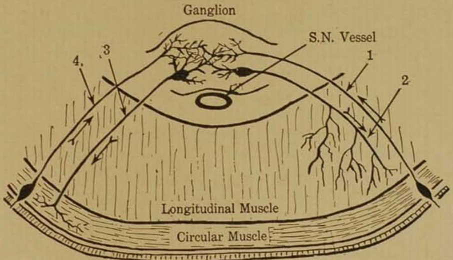

FIG. 169. — Diagram of reflex mechanism in earthworm. 1 and 4 — Sensory neurons (Receptors) 2 and 3 — Motor neurons (Adjustors), Muscles are effectors. An impulse coming in over 1, may *go out* over 2 or 3 or both and *may* extend in the nerve cord forward and backward. S. N. — Subneural Vessel.

and one pair in the eleventh segment. One pair of sperm funnels in the tenth and one pair in the eleventh segments, each just behind the testes, are connected by branch tubes which join and form the long tubular *vasa deferentia*. They convey sperm from the seminal vesicles to the outside of the worm. In the tenth segment is a pair of *sperm receptacles* and in the eleventh segment is another pair also. They do not communicate with the body cavity but only by pores to the outside of the body. These openings have already been located.

In the breeding season, two worms come together with the heads pointing in opposite directions. The ventral surface of that part of the body from the clitellum forward (*i.e.*, approximately segments 37 to 1) of one worm is in contact with a similar portion of the other worm. Mucus is freely secreted from glands in the skin of these two regions. The mucus hardens and forms a *common tube* about both worms. The body wall and the mucus also form *temporary ducts* for the passage of spermatic fluid. This is pumped out of the openings of the *vas deferens* of each worm, down along the temporary ducts to a cavity under the clitellum of the same worm. This space is just opposite the openings of the sperm receptacles of the other worm. Sperm fluid is sucked into the receptacles. There are two pairs of temporary sperm ducts. They prevent self-fertilization. After exchange of spermatozoa, the worms separate.

Later on, eggs are laid. At this time the clitellum secretes a fluid which hardens, forming a band-like ring or *girdle* about the clitellum. The worm works this girdle forward. As it passes the oviduct openings, eggs are discharged into a space between the body wall and the inner face of the girdle. As the girdle passes the opening of the sperm receptacles, sperm from the other worm are discharged among the eggs. Thus *fertilization* is effected. The girdle continues being worked forward and finally is slipped off the front end of the worm. The front and rear edges of the girdle come together forming a closed sac or *cocoon* in which development continues. The cocoons are placed a few inches below the surface of the earth. It is said that only one worm hatches from the cocoon in the case of the species, *Lumbricus terrestris*. It is small and immature at the time of hatching.

The fertilized egg divides, passing through a blastula stage and later a gastrula stage (Fig. 170). This elongates somewhat and a mouth is formed by an ingrowing tube at the blind end of the gastrula. The solid mesoderm which has formed between the ectoderm and endoderm develops spaces in it. These spaces are the embryonic beginnings of the coelome. As the worm grows the body cavity increases also. The mesoderm partitions between the coelomic segments become the septa, later.

Behavior. The earthworm exhibits very definite responses to stimuli of various sorts, such as bright light, chemical and mechanical stimuli. The body attempts to draw away from irritating objects. Some stimuli, such as food, may produce a positive reaction. Experiments indicate that the earthworm is not altogether a simple machine. Under certain circumstances it exhibits an ability to learn by experience and to remember for a short time. In an experiment by Yerkes, an earthworm was set free on the surface of earth which filled a box. Avoiding the light, it crawled here and there, finding one or the other of two burrows, one of which contained a pair of electrodes. If it started down the electrified burrow, it received a slight shock which caused it to withdraw. It crawled around and tried the burrows again and again.

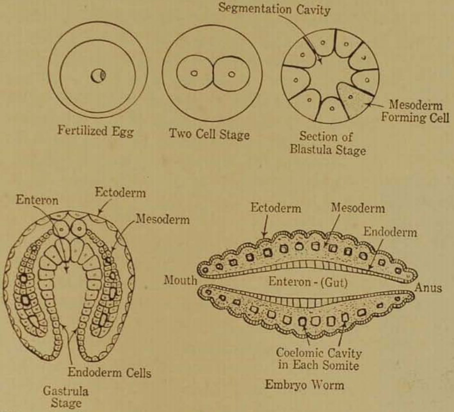

FIG. 170. — Development of earthworm. After Sedgwick and Wilson, *General Biology*, Henry Holt and Co. Reprinted by permission.

After a certain number of trials it "learned" to crawl immediately into the "safe" burrow when released. In other words, it had the nervous organization which enabled it to profit by experience.

Regeneration. The earthworm possesses great powers of regeneration. A large piece removed from the front end of the body will regenerate a new tail at the hinder end, and in time become a completely organized worm. Such experiments suggest the persistence of asexual powers of reproduction among these forms, or in other words, regeneration is related to asexual reproduction so common in lower forms.

Economic Importance. Charles Darwin studied carefully the effects of earthworms on soil. His book on the "Formation of Vegetable Mold through the Action of Worms" was written after studies extending over forty years. He estimated that a certain garden patch contained a population of 50,000 worms to the acre. In forming burrows, the earthworm ingests the earth, which is carried into the alimentary canal. Whatever food there is, is digested and absorbed. The undigested residue, with the soil particles, is passed along and finally discharged from the anus around the entrance to the burrow. In this way earthworms slowly and in small amounts turn over the soil. Darwin estimated that eighteen tons of subsoil per acre are spread out to sun and air (and thus sterilized) every year by earthworms. Moreover, the formation of burrows carries air into the soil and moisture is retained more easily. In thirty years' time, a stony field was entirely covered with new turf, and most of this was accomplished by the action of earthworms.

Fig. 171.—Nereis. Note regenerating posterior end. (Photo by Schechter.)

Classification

Most Annelids belong to the Class *Chaetopoda*. They are fresh-water or marine or land forms. Most of them are segmented; they also have appendages on the segments. This class is divided into two subclasses:

(*a*) **The Polychaeta.** *Nereis*, an example (Fig. 171), is called the sand or clam worm and is used as bait by sea fishermen. It lives in burrows in sand or mud along the seashore. Nereis possesses lateral flat appendages called parapodia (alongside feet). The parapodia serve as propelling organs and as gills. Nereis is, in some respects, more highly differentiated than Lumbricus in that there are two pairs of eyes, and tentacles and biting jaws at the head end. Many Polychaets reproduce *asexually* by budding. In others there are two regions of the body, an anterior sexless and posterior sex region. The posterior sex region separates from the anterior in which event the anterior part produces another posterior sex region again. Polychaeta are dioecious.

(*b*) **The Oligochaeta.** These are mostly fresh-water or terrestrial forms which are hermaphroditic. They have neither parapodia, tentacles nor well-defined sense organs, although the front end of the body is very sensitive to external stimuli. There are over twice as many Polychaets as Oligochaets. Lumbricus is an Oligochaet.

The **Hirudinea** or leeches comprise another interesting group. These are found in fresh water; and have a body form resembling flat-worms, but are segmented. Some are predaceous, eating other Annelids, snails, etc. Some of them are external parasites, sucking blood of aquatic Vertebrates. In the blood-sucking leeches (Fig. 172) the animal liberates a secretion which prevents the coagulation of the blood. Extracts of the desiccated bodies of this leech contain such anti-coagulating material. This is known in medicine as *hirudin*, and is employed in certain cases in which the non-coagulation of the blood is an essential part of medical treatment.

FIG. 172.—Hirudo, leech.

Summary. The Annelids exhibit three theoretically important features which relate them to higher groups. *First — Coelome.* The true body cavity between intestine and body wall is lined throughout with tissues which develop from mesoderm. It is filled with coelomic fluid containing dissolved food compounds absorbed from the intestinal tract, and oxygen; also wastes of metabolism such as water, carbon dioxide and nitrogenous compounds. Movements of the body circulate the coelomic fluid, thus enabling tissues bathed by it to absorb foods from it and to discharge into it wastes to be excreted by the nephridia located in it. But far more important is the fact that from mesoderm are developed organs of circulation, excretion and reproduction — all of which are afforded a space in which to develop. As to *absence* or *presence* of coelome, metazoa are divided into (*a*) the *Acoelomata*, including the Porifera, Coelenterata, Platyhelminthes; and (*b*) *Coelomata*, including Annelida, Echinoderms, Mollusca, Arthropoda and Chordata. Nemathelminthes and Trochelminthes are doubtfully assigned to one group or the other for the reason given in the previous chapter.

Second — Metamerism. Segmentation is very characteristic of (*a*) Annelids, (*b*) of the great group of the Arthropoda and (*c*) of the Chordata as well. It has been *suggested* that the metameric body of such forms as Annelids, Arthropods and Vertebrates evolved by a *linear integration* of *separate individuals*. Some systems, such as that of digestion, have lost almost all traces of ancestral conditions, while others, like the ganglionated nerve cord, still exhibit evidences of metamerically repeated parts, *i.e.*, formed by an end-to-end fusing of nerve cords of hypothetically ancestral individual animals.

The *development* of metamerism in the *individual* has been worked out by the embryologist, but the *evolution* of metamerism is still quite theoretical. The embryological evidence is opposed to the "end to end" theory just indicated.

Third — Trochophore. This name is given to a larval stage occurring in the development of some primitive Annelids. As shown by Fig. 173 the trochophore larva is somewhat bi-convex or bi-conical in shape. Around the equatorial region is a band of cilia and the larva is free-swimming. At one place on the ciliated margin is the mouth which leads into an oesophagus, stomach and intestine which ends in an anus at the tip of the more elongated "cone." At the opposite apical end is a sensitive "eye-spot." The trochophore larva also has a pair of simple nephridia.

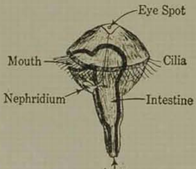

Fig. 173. — Trochophore larva of Polygordius. From Newman (after Whitman), *Outlines of General Zoology*. Copyright 1924, by The Macmillan Co. Reprinted by permission.

Certain marine worm-like animals related to the flat-worms have a larva similar to this. The trochophore also resembles certain *adult* rotifers. Moreover, most mollusks, in their development, pass through a trochophore phase. All these facts are interpreted as embryological evidence which indicates the phylogenetic (evolutionary) relationship of flat-worms, Rotifers, Annelids and Mollusks.

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