Baron S, editor. Medical Microbiology. 4th edition. Galveston (TX): University of Texas Medical Branch at Galveston; 1996.

Chapter 86 Helminths: Structure, Classification, Growth, and Development

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General Concepts

The helminths are worm-like parasites. The clinically relevant groups are separated according to their general external shape and the host organ they inhabit. There are both hermaphroditic and bisexual species. The definitive classification is based on the external and internal morphology of egg, larval, and adult stages.

Flukes (Trematodes)

Adult flukes are leaf-shaped flatworms. Prominent oral and ventral suckers help maintain position in situ. Flukes are hermaphroditic except for blood flukes, which are bisexual. The life-cycle includes a snail intermediate host.

Tapeworms (Cestodes)

Adult tapeworms are elongated, segmented, hermaphroditic flatworms that inhabit the intestinal lumen. Larval forms, which are cystic or solid, inhabit extraintestinal tissues.

Roundworms (Nematodes)

Adult and larval roundworms are bisexual, cylindrical worms. They inhabit intestinal and extraintestinal sites.

Introduction

Helminth is a general term meaning worm. The helminths are invertebrates characterized by elongated, flat or round bodies. In medically oriented schemes the flatworms or platyhelminths (platy from the Greek root meaning “flat”) include flukes and tapeworms. Roundworms are nematodes (nemato from the Greek root meaning “thread”). These groups are subdivided for convenience according to the host organ in which they reside, e.g., lung flukes, extraintestinal tapeworms, and intestinal roundworms. This chapter deals with the structure and development of the three major groups of helminths.

Helminths develop through egg, larval (juvenile), and adult stages. Table 86-1 gives the names applied to various larval helminths. Knowledge of the different stages in relation to their growth and development is the basis for understanding the epidemiology and pathogenesis of helminth diseases, as well as for the diagnosis and treatment of patients harboring these parasites. The contributions of various stages to disease are listed in Table 86-2.

Table 86-1

Common Larval Forms of Helminths Found in Humans.

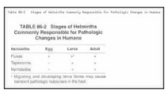

Table 86-2

Stages of Helminths Commonly Responsible for Pathologic Changes in Humans.

Platyhelminths and nematodes that infect humans have similar anatomic features that reflect common physiologic requirements and functions. The outer covering of helminths is the cuticle or tegument. Prominent external structures of flukes and cestodes are acetabula (suckers) or bothria (false suckers). Male nematodes of several species possess accessory sex organs that are external modifications of the cuticle. Internally, the alimentary, excretory, and reproductive systems can be identified by an experienced observer. Tapeworms are unique in lacking an alimentary canal. This lack means that nutrients must be absorbed through the tegument. The blood flukes and nematodes are bisexual. All other flukes and tapeworm species that infect humans are hermaphroditic.

With few exceptions, adult flukes, cestodes, and nematodes produce eggs that are passed in excretions or secretions of the host. The various stages and their unique characteristics will be reviewed in more detail as each major group of helminths is considered.

Flukes (Trematodes)

The structure of flukes is summarized in Figures 86-1 and 86-2. A dorsoventrally flattened body, bilateral symmetry, and a definite anterior end are features of platyhelminths in general and of trematodes specifically. Flukes are leaf-shaped, ranging in length from a few millimeters to 7 to 8 cm. The tegument is morphologically and physiologically complex. Flukes possess an oral sucker around the mouth and a ventral sucker or acetabulum that can be used to adhere to host tissues. A body cavity is lacking. Organs are embedded in specialized connective tissue or parenchyma. Layers of somatic muscle permeate the parenchyma and attach to the tegument.

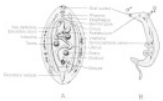

Figure 86-1

Structure of flukes. (A) Hermaphroditic fluke. (B) Bisexual fluke. (Modified from Hunter GW, Swartzwelder JC, Clyde DF: A Manual of Tropical Medicine. 5th Ed. WB Saunders, Philadelphia, 1976, with permission.)

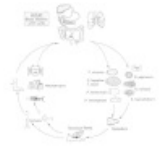

Figure 86-2

Generalized life cycle of flukes. All cycles involve snails as intermediate hosts. Hermaphroditic flukes - *Clonorchis sinensis, Fasiolopsis buski, Paragonimys westermani,* and *Heterophytes heterpphyes*. Metacercaria are infective for humans. Bisexual flukes: (more...)

Flukes have a well-developed alimentary canal with a muscular pharynx and esophagus. The intestine is usually a branched tube (secondary and tertiary branches may be present) consisting of a single layer of epithelial cells. The main branches may end blindly or open into an excretory vesicle. The excretory vesicle also accepts the two main lateral collecting ducts of the excretory system, which is of a protonephridial type with flame cells. A flame cell is a hollow, terminal excretory cell that contains a beating (flamelike) group of cilia. These cells, anchored in the parenchyma, direct tissue filtrate through canals into the two main collecting ducts.

Except for the blood flukes, trematodes are hermaphroditic, having both male and female reproductive organs in the same individual. The male organ consists usually of two testes with accessory glands and ducts leading to a cirrus, or penis equivalent, that extends into the common genital atrium. The female gonad consists of a single ovary with a seminal receptacle and vitellaria, or yolk glands, that connect with the oviduct as it expands into an ootype. The tubular uterus extends from the ootype and opens into the genital atrium. Both self- and cross-fertilization occur. The components of the egg are assembled in the ootype. Eggs pass through the uterus into the genital atrium and exit ventrally through the genital pore. Fluke eggs, except for those of schistosomes, are operculated (have a lid).

The blood flukes or schistosomes are the only bisexual flukes that infect humans (Fig. 86-1). Although the sexes are separate, the general body structure is the same as that of hermaphroditic flukes. Within the definitive host, the male and female worms inhabit the lumen of blood vessels and are found in close physical association. The female lies within a tegumental fold, the gynecophoral canal, on the ventral surface of the male. The medically important flukes belong to the taxonomic category Digenea. This group of flukes has a developmental cycle requiring at least two hosts, one being a snail intermediate host. Depending on the species, other intermediate hosts may be involved to perpetuate the larval form that infects the definitive human host.

Flukes go through several larval stages, each with a specific name, before reaching adulthood. Taking into account variations among species (see Fig. 86-2), a generalized life cycle of digenetic flukes runs the following course. Eggs are passed in the feces, urine, or sputum of humans and reach an aquatic environment. The eggs hatch, releasing ciliated larvae, or miracidia, which either penetrate or are eaten by a snail intermediate host. In rare instances land snails may serve as intermediate hosts. A saclike sporocyst or redia

stage develops from a miracidium within the tissues of the snail.

The sporocyst gives rise either to rediae or to a daughter sporocyst stage. In turn, from the redia or daughter sporocyst, cercariae develop asexually and migrate out of the snail tissues to the external environment, which is usually aquatic.

The cercariae, which may possess a tail for swimming, develop further in one of three ways. They either penetrate the definitive host and transform directly into adults, or penetrate a second intermediate host and develop as encysted metacercariae, or they encyst on a substrate, such as vegetation, and develop there as metacercariae. When a metacercarial cyst is ingested, digestion of the cyst liberates an immature fluke that migrates to a specific organ site and develops into an adult worm.

Tapeworms (Cestodes)

As members of the platyhelminths, the cestodes, or tapeworms, possess many basic structural characteristics of flukes, but also show striking differences. Figure 86-3 shows the general features of the structure and development of tapeworms.

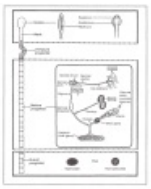

Figure 86-3

Structure of tapeworms. (Modified from Jeffery HC, Leach RM: Atlas of Medical Helminthology and Protozoology. Churchill Livingstone, Edinburgh, 1968, with permission.)

Whereas flukes are flattened and generally leaf-shaped, adult tapeworms are flattened, elongated, and consist of segments called proglottids. Tapeworms vary in length from 2 to 3 mm to 10 m, and may have three to several thousand segments.

Anatomically, cestodes are divided into a scolex, or head, which bears the organs of attachment, a neck that is the region of segment proliferation, and a chain of proglottids called the strobila. The strobila elongates as new proglottids form in the neck region. The segments nearest the neck are immature (sex organs not fully developed) and those more posterior are mature. The terminal segments are gravid, with the egg-filled uterus as the most prominent feature.

The scolex contains the cephalic ganglion, or “brain,” of the tapeworm nervous system. Externally, the scolex is characterized by holdfast organs. Depending on the species, these organs consist of a rostellum, bothria, or acetabula. A rostellum is a retractable, conelike structure that is located on the anterior end of the scolex, and in some species is armed with hooks. Bothria are long, narrow, weakly muscular grooves that are characteristic of the pseudophyllidean tapeworms. Acetabula (suckers like those of digenetic trematodes) are characteristic of cyclophyllidean tapeworms. Differential features of pseudophyllidean and cyclophyllidean tapeworms are listed in Table 86-3. Most human tapeworms are cyclophyllideans.

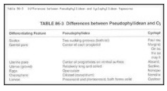

Table 86-3

Differences between Pseudophyllidean and Cyclophyllidean Tapeworms.

A characteristic feature of adult tapeworm is the absence of an alimentary canal, which is intriguing since all of these adult worms inhabit the small intestine. The lack of an alimentary tract means that substances enter the tapeworm across the tegument. This structure is well adapted for transport functions, since it is covered with numerous microvilli resembling those lining the lumen of the mammalian intestine. The excretory system is of the flame cell type.

Cestodes are hermaphroditic, each proglottid possessing male and female reproductive systems similar to those of digenetic flukes. However, tapeworms differ from flukes in the mechanism of egg deposition. Eggs of pseudophyllidean tapeworms exit through a uterine pore in the center of the ventral surface rather than through a genital atrium, as in flukes. In cyclophyllidean tapeworms, the female system includes a uterus without a uterine pore (Fig. 86-3). Thus, the cyclophyllidean eggs are released only when the tapeworms shed gravid proglottids into the intestine. Some proglottids disintegrate, releasing eggs that are

voided in the feces, whereas other proglottids are passed intact.

The eggs of pseudophyllidean tapeworms are operculated, but those of cyclophyllidean species are not. Eggs of all tapeworms, however, contain at some stage of development an embryo or oncosphere. The oncosphere of pseudophyllidean tapeworms is ciliated externally and is called a coracidium. The coracidium develops into a procercoid stage in its micro-crustacean first immediate host and then into a plerocercoid larva in its next intermediate host which is a vertebrate. The plerocercoid larva develops into an adult worm in the definitive (final) host. The oncosphere of cyclophyllidean tapeworms, depending on the species, develops into a cysticercus larva, cysticercoid larva, coenurus larva, or hydatid larva (cyst) in specific intermediate hosts. These larvae, in turn, become adults in the definitive host. Figure 86-4 illustrates these larval forms and representative life cycles.

Figure 86-4

Generalized life cycle of tapeworms. *Hymenolepsis nana, Hdiminuta, Taenia saginata, T solium, Diphyllobothrium latum, Dipylidium craninum*. Note hexacanth embryos. Cysticercus larva in cow and pig; procercoid larva in copepod, plerocercoid (sparganum) (more...)

Roundworms (Nematodes)

Figure 86-5 shows the structure of nematodes. In contrast to platyhelminths, nematodes are cylindrical rather than flattened; hence the common name roundworm. The body wall is composed of an outer cuticle that has a noncellular, chemically complex structure, a thin hypodermis, and musculature. The cuticle in some species has longitudinal ridges called alae. The bursa, a flaplike extension of the cuticle on the posterior end of some species of male nematodes, is used to grasp the female during copulation.

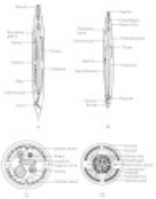

Figure 86-5

Structure of nematodes. (A) Female. (B) Male. Transverse sections through the midregion of the female worm (C) and through the esophageal region (D). (Modified from Lee DL: The Physiology of Nematodes. Oliver and Boyd, Edinburgh, 1965, with permission.) (more...)

The cellular hypodermis bulges into the body cavity or pseudocoelom to form four longitudinal cords—a dorsal, a ventral, and two lateral cords—which may be seen on the surface as lateral lines. Nuclei of the hypodermis are located in the region of the cords. The somatic musculature lying beneath the hypodermis is a single layer of smooth muscle cells. When viewed in cross-section, this layer can be seen to be separated into four zones by the hypodermal cords. The musculature is innervated by extensions of muscle cells to nerve trunks running anteriorly and posteriorly from ganglion cells that ring the midportion of the esophagus.

The space between the muscle layer and viscera is the pseudocoelom, which lacks a mesothelium lining. This cavity contains fluid and two to six fixed cells (celomocytes) which are usually associated with the longitudinal cords. The function of these cells is unknown.

The alimentary canal of roundworms is complete, with both mouth and anus. The mouth is surrounded by lips bearing sensory papillae (bristles). The esophagus, a conspicuous feature of nematodes, is a muscular structure that pumps food into the intestine; it differs in shape in different species.

The intestine is a tubular structure composed of a single layer of columnar cells possessing prominent microvilli on their luminal surface.

The excretory system of some nematodes consists of an excretory gland and a pore located ventrally in the mid-esophageal region. In other nematodes this structure is drawn into extensions that give rise to the more complex tubular excretory system, which is usually H-shaped, with two anterior limbs and two posterior limbs located in the lateral cords. The gland cells and tubes are thought to serve as absorptive bodies, collecting wastes from the pseudocoelom, and to function in osmoregulation.

Nematodes are usually bisexual. Males are usually smaller than females, have a curved

posterior end, and possess (in some species) copulatory structures, such as spicules (usually two), a bursa, or both. The males have one or (in a few cases) two testes, which lie at the free end of a convoluted or recurved tube leading into a seminal vesicle and eventually into the cloaca.

The female system is tubular also, and usually is made up of reflexed ovaries. Each ovary is continuous, with an oviduct and tubular uterus. The uteri join to form the vagina, which in turn opens to the exterior through the vulva.

Copulation between a female and a male nematode is necessary for fertilization except in the genus *Strongyloides,* in which parthenogenetic development occurs (i.e., the development of an unfertilized egg into a new individual). Some evidence indicates that sex attractants (pheromones) play a role in heterosexual mating. During copulation, sperm is transferred into the vulva of the female. The sperm enters the ovum and a fertilization membrane is secreted by the zygote. This membrane gradually thickens to form the chitinous shell. A second membrane, below the shell, makes the egg impervious to essentially all substances except carbon dioxide and oxygen. In some species, a third proteinaceous membrane is secreted as the egg passes down the uterus by the uterine wall and is deposited outside the shell. Most nematodes that are parasitic in humans lay eggs that, when voided, contain either an uncleaved zygote, a group of blastomeres, or a completely formed larva. Some nematodes, such as the filariae and *Trichinella spiralis*, produce larvae that are deposited in host tissues.

The developmental process in nematodes involves egg, larval, and adult stages. Each of four larval stages is followed by a molt in which the cuticle is shed. The larvae are called second-stage larvae after the first molt, and so on (Fig. 86-6). The nematode formed at the fifth stage is the adult. Figure 86-7 summarizes the life cycles of several intestinal nematodes.

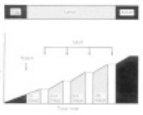

Figure 86-6

Stages in the development of nematodes. (Adapted from Lee DL: The Physiology of Nemotodes. Oliver and Boyd, Edinburgh, 1965, with permission.)

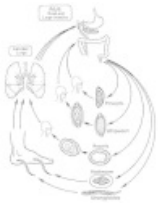

Figure 86-7

Generalized life cycle of intestinal nematodes.

References

1. Ash L, Orihel TC: Parasites: A Guide to Laboratory Procedures and Identification. American Society of Clinical Pathologists, Chicago, 1987 .
2. Bogitsh BJ and Cheng TC: Human Parasitology. WB Saunders, Philadelphia, 1990 .
3. Castro GA: Trematodes: schistosomiasis. p 1710. In Kelly WN (ed): Textbook of Internal Medicine. JB Lippincott, Philadelphia, 1989 .
4. Hunter GW, Swartzwelder JC, Clyde DF: A Manual of Tropical Medicine. 5th Ed. WB Saunders, Philadelphia, 1976 .
5. Jeffrey HC, Leach RM: Atlas of Medical Helminthology and Protozoology. Churchill Livingstone, Edinburgh, 1968 .
6. Lee DL: The Physiology of Nematodes. Oliver and Boyd, Edinburgh, 1965 .
7. Smyth JD: The Physiology of Trematodes. Oliver and Boyd, Edinburgh, 1966 .
8. Schmidt GD, Roberts LS: Foundations of Parasitology. 3rd Ed. Times Mirror/Mosby College Publishers, St Louis, 1985 .
9. Zamen V: Atlas of Medical Parasitology. Lea&Febiger, Philadelphia, 1979 .

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