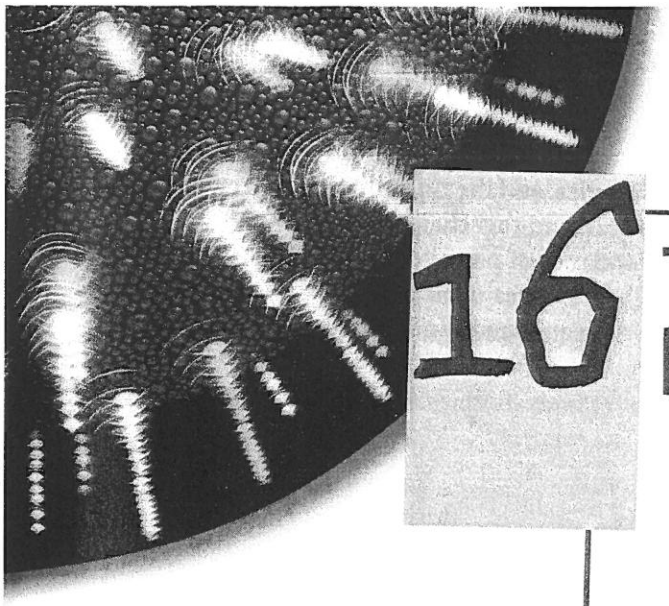


# 16 The Multicellular Parasites

Pass the Sushi, Carefully

—Headline to an article alerting consumers to the possible parasites in raw fish



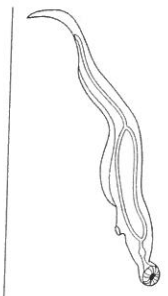
ON FEBRUARY 13, 1984, A GROUP of 18 students from the United States arrived in Kenya for various purposes of study. The weather was hot and humid, so the students decided to improvise a small swimming pool. They carefully placed rocks and branches across a small stream and within a few hours, they had their pool. The water was cool and refreshing, and they congratulated themselves on their ingenuity.

But soon a problem developed. Several students broke out with an itchy rash, and subsequently, 14 of the group became acutely ill with fever, diarrhea, malaise, and weight loss. Two of the students developed paralysis of the lower extremities and had to return home for treatment. Stool examinations revealed the eggs of *Schistosoma mansoni*, a parasitic worm. Apparently the water had been contaminated. What had begun as a pleasant day turned into a nightmare.

shis-to-so'mah

Schistosomiasis is one of the diseases caused by the multicellular parasites we shall study in this chapter. Multicellular parasites, including the flatworms and roundworms, probably infect more people worldwide than any other group of organisms. They range in size from the tiny flukes, which must be studied with a microscope, to the tapeworms, which sometimes reach 20 feet in length. In the strict sense, flatworms and roundworms are animals, but they are also studied in microbiology because of their small size and ability to cause disease. Together with the protozoa discussed in Chapter 15, they are the subject of study of the biological discipline known as **parasitology**.

shis'to-so-mi'a-sis



*Schistosoma mansoni*

Our review of the multicellular parasites will be a brief one. We shall include descriptions of the parasites, their life cycles, and the types of organisms and tissues they infect. You may note that the diseases in this chapter have few unique symptoms and are characterized by an abundance of parasites in a particular area of the body. Often the body will tolerate the parasites until the worm burden becomes immense. At that point, interference with an organ's function develops, and disease symptoms follow.

## 16.1 Flatworms

plat'e-hel-min'thēz

**Flatworms** belong to the animal phylum **Platyhelminthes**, a name derived from the Greek *platy-* for "flat" and *helminth* for "worm." All the parasites in this phylum have flattened bodies that are slender and broadly leaflike, or long and ribbonlike (FIGURE 16.1). The animals exhibit **bilateral symmetry**, meaning that when cut in the longitudinal plane, the body yields identical halves.

As multicellular animals, flatworms have tissues functioning as organs in organ systems. Many species have a gut consisting of a sac with a single opening. Complex reproductive systems are found in many animals of the group, and a large number of species have both male and female reproductive organs. These organisms are termed **hermaphroditic**.

her-maf'ro-dit'ik

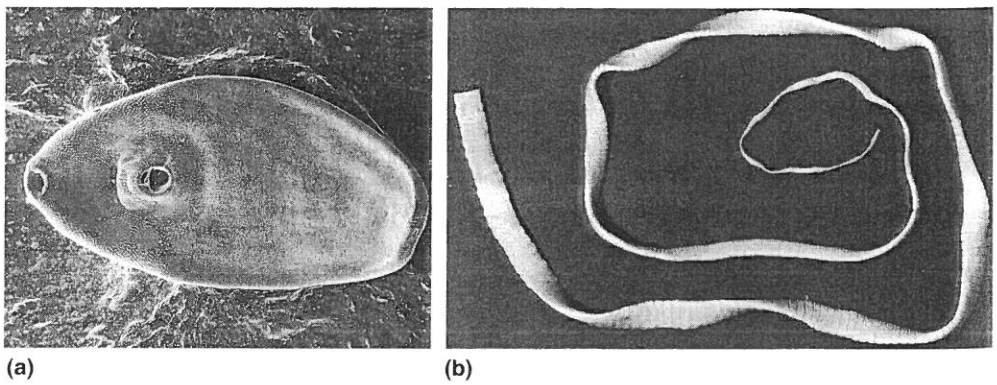
Flatworms are divided into three classes. The first class, Turbellaria, includes free-living flatworms that do not cause disease and therefore will not be covered here. The common planarian studied in general biology programs is a typical member of the Turbellaria. The second class, Trematoda, includes the flukes. We shall begin our coverage with this group of parasites. The third class, Cestoda, consists of tapeworms. These parasites will be discussed after the flukes.

tur'be-la're-ah

trem'ah-to'dah

### A GENERAL DESCRIPTION OF FLUKES

**Flukes** are leaflike parasitic worms of the class **Trematoda**. Generally, flukes have complex life cycles that may include encysted egg stages and temporary larval forms. Sucker devices are commonly present to enable the parasite to hold fast to its host. In many cases, two hosts exist: an **intermediate host**, which harbors the larval form, and a **definitive host**, or final host, which harbors the sexually mature adult form. In this chapter, we shall be concerned with parasites whose definitive host is a human.



(a) (b)

FIGURE 16.1

Two Examples of Flatworms

(a) A scanning electron micrograph of the fluke *Fasciola hepatica*. Note the flattened, broad, and leaflike shape of this parasite. *F. hepatica* thrives in the liver of humans. The ventral and oral suckers used for attachment to the tissue can be seen. (b) An unmagnified view of the tapeworm *Taenia saginata*. This flatworm is long and ribbonlike, and consists of hundreds of visible segments. *T. saginata* infects the human intestinal tract.

The life cycle of a fluke often contains several phases. In the human host, the parasite produces **fertilized eggs** generally released in the feces. When the eggs reach water, they hatch and develop into tiny ciliated larvae called **miracidia** (sing., miracidium). The miracidia penetrate **snails** (the intermediate host) and go through a series of asexual reproductive stages, often including **sporocyst** and **redia** stages. Rediae become tadpolelike **cercariae**, which are released to the water. Now the cercariae develop into encysted forms called **metacercariae**, which make their way back to humans. We shall see variations on this basic life cycle in the discussions of fluke diseases that follow.

**Miracidia:** tiny, ciliated larvae of flukes.

**Cercariae:** tadpolelike stages in the life cycles of flukes.

## BLOOD FLUKE DISEASE

Three important species of flukes invade the bloodstream in humans: ***Schistosoma mansoni, S. japonicum***, and ***S. haematobium***. The first is distributed throughout Africa and South America, the second in the Far East, and the third mainly in Africa. The WHO estimates that 250 million people worldwide are infected with *Schistosoma*, including about 400,000 individuals in the United States. The disease is called **schistosomiasis**. In some regions, the term **bilharziasis** is still used; it comes from the older name for the genus, *Bilharzia*.

shis-to-so'mah
jah-pon'ĭ-kum
hēm'ah-tōb'e-um

bil'har-zi'ah-sis
bil-har'zi-ah

Species of *Schistosoma* measure about 10 mm in length. Male and female species mate in the human liver and produce eggs that are released in the feces (FIGURE 16.2). The eggs hatch to miracidia in water, and the miracidia make their way to snails, where conversions to sporocysts and cercariae take place. The cercariae escape

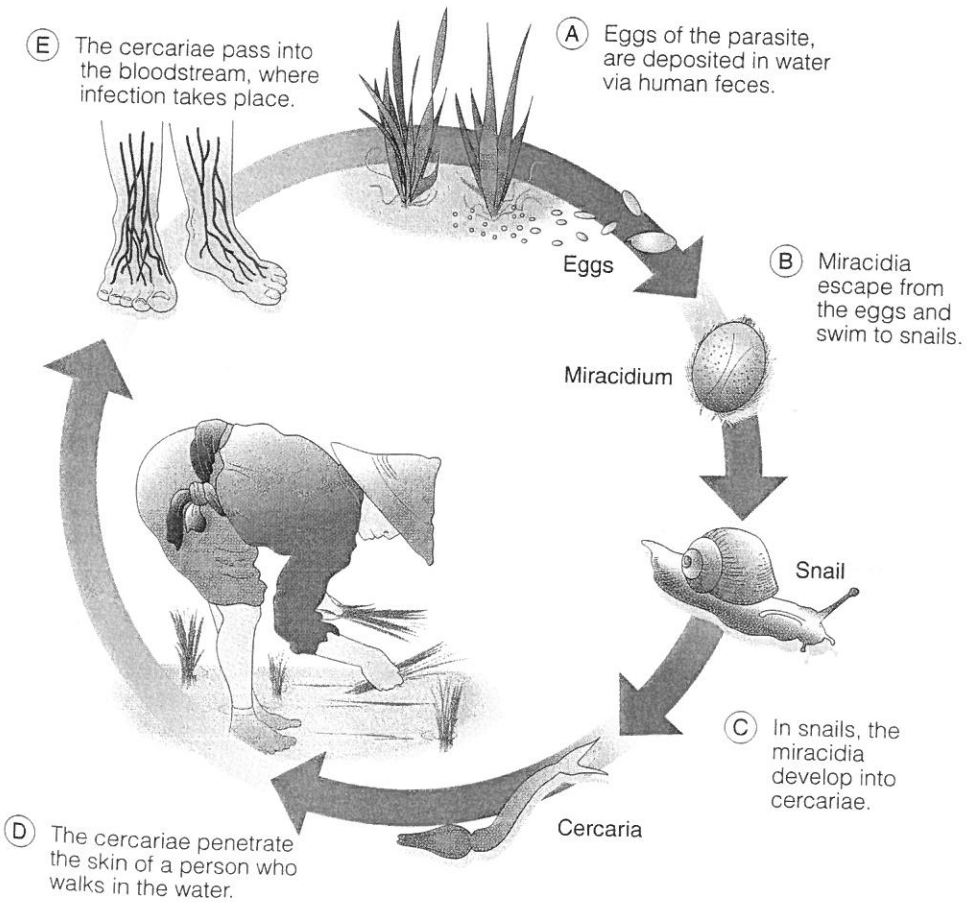



FIGURE 16.2

**The Life Cycle of the Blood Fluke, *Schistosoma mansoni***

from the snails and attach themselves to the bare skin of humans. Cercariae become young schistosomes, which infect the blood and cause fever and chills. The major effects of disease are due to eggs formed in the liver. Liver damage is usually substantial. Eggs also gather in the intestinal wall causing ulceration, diarrhea, and abdominal pain. Bladder infection is signaled by bloody urine and pain on urination. Outbreaks may have substantial consequences, as MicroFocus 16.1 explains.

Swimmer's itch: a skin condition caused by allergenic substances released by *Schistosoma* species.

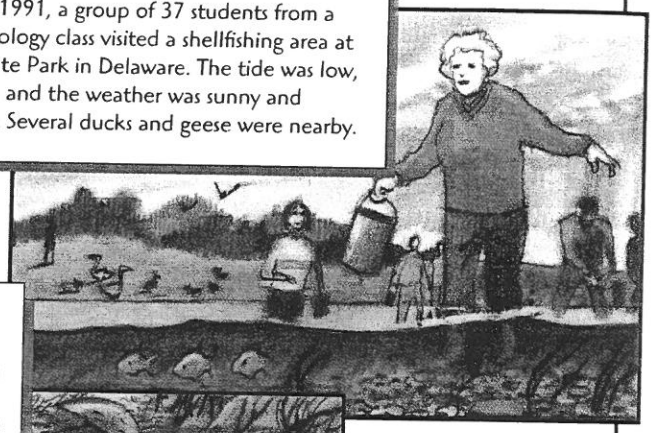
Certain species of *Schistosoma* penetrate no farther than the skin because the definitive hosts are birds instead of humans. The cercariae of these schistosomes cause dermatitis in the skin and a condition commonly known as **swimmer's itch**. After penetration, the cercariae are attacked and destroyed by the body's immune system, but they release allergenic substances that cause the itching and body rash (FIGURE 16.3). The condition, not a serious threat to health, is common in northern lakes in the United States.

TEXTBOOK CASES

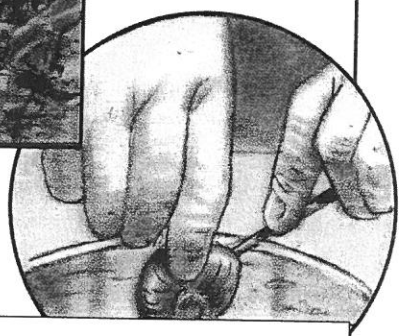
FIGURE 16.3

An Outbreak of Schistosomiasis in Delaware

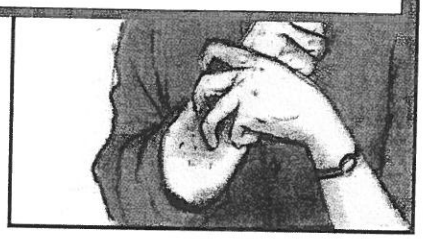
1. On October 19, 1991, a group of 37 students from a local high school biology class visited a shellfishing area at Cape Henlopen State Park in Delaware. The tide was low, the water was calm, and the weather was sunny and unseasonably warm. Several ducks and geese were nearby.



2. The students and their teacher spent about 2 hours wading in the water collecting specimens. There were many clams, oysters, and snails in the water, as well as other marine specimens of interest.



3. Within 10 days of the trip, 29 of the 37 students developed pruritic dermatitis, an itching skin condition. Eleven of the affected students visited their doctors for treatment. Eventually, 36 of the 37 individuals developed pruritis; the only unaffected student was one who did not go into the water.



4. Public health investigators examined snails from the seawater. Schistosomes normally associated with ducks, geese, and other birds were found in a small percentage of snails examined. Also, it is known that thousands of schistosomes can be released from a single snail, and the release is favored by weather conditions seen that day.

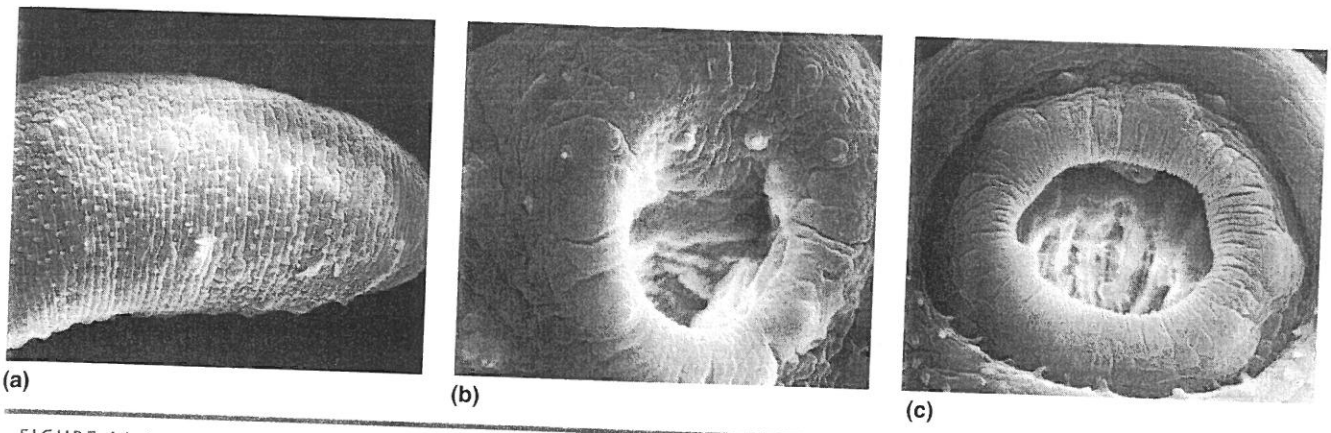



FIGURE 16.4

## The Chinese Liver Fluke

Scanning electron microscope views of *Clonorchis sinensis*, the Chinese liver fluke. (a) A whole mount showing the anterior aspect of the parasite (×2400). (b) The oral sucker device (×7000). (c) The ventral sucker device (×4800).

## CHINESE LIVER FLUKE DISEASE

The **Chinese liver fluke** is so named because it infects the liver and is common in many regions of the Orient, especially China, southern Asia, and Japan. The organism is named ***Clonorchis sinensis***. It has oral and ventral sucker devices (FIGURE 16.4) and is hermaphroditic, with a complex reproductive system.

klo-nor'kis si-nen'sis

*Clonorchis sinensis*

Eggs of *C. sinensis* contain complete miracidia, which emerge after the eggs enter water. The miracidia penetrate snails and change into sporocysts, which then produce a generation of elongated rediae. These rediae become cercariae, which escape from the snail and bore into the muscles of fish, the second intermediary host. Now the cercariae develop into encysted metacercariae, and humans acquire the metacercariae by consuming raw or poorly cooked fish. Public health officials recommend heating fish to a minimum of 50°C for 15 minutes to destroy the cysts. In

### MicroFocus 16.1

### INVASION

In the late 1940s, clashes between the nationalist Chinese, headed by Chiang Kai-Shek, and the communist Chinese, led by Mao Tse Tung, heated up to the point of open warfare. After months of fighting, the communist forces drove Chiang's troops off the Chinese mainland and onto the island of Taiwan (then called Formosa). It soon became apparent to world leaders that a communist invasion of Taiwan was imminent.

But invading an island takes a certain type of training. Therefore, communist generals gathered their troops by the hundreds of thousands in a swampy area near the southern coast of mainland China to learn the methods of amphibious warfare. Unbeknown to them, however, the area was infested with parasites and snails, and within days, over 30,000 men were infected with *Schistosoma*. The troops suffered severe fever, liver damage, and intestinal distress, and Chinese leaders were forced to postpone their assault on Taiwan for several months.

The delay was critical because it gave the nationalist Chinese precious extra time to prepare for invasion. In addition, intelligence reports of the impending invasion reached U.S. President Harry Truman, and he sent ships from the Seventh Naval Fleet to the waters off Taiwan to preserve the neutrality of Chiang's forces. Eventually, these and other factors persuaded the communist Chinese to abandon their assault, and the republic of Taiwan was left intact.

We shall never know whether the invasion would have succeeded or what the political ramifications might have been. Indeed, some historians point out that the United States was preparing to back the nationalist Chinese, while the former Soviet Union was readying itself to support the communists. One thing does appear certain: A worm played a significant role in the turn of world events.

humans, the metacercariae become adults and migrate from the small intestine up the bile duct to the gall bladder and liver, where infection takes place.

The effect of *C. sinensis* on humans depends on the extent of infection. Substantial infection in the gall bladder may lead to duct blockage and poor digestion of fats. There may also be damage to the liver as eggs accumulate in the tissues of this organ (FIGURE 16.5). Often the patient is without symptoms because of the low number of parasites. Cats, dogs, and pigs may also carry the metacercaria cysts.

**Gall bladder:** the pouch on the underside of the liver that stores bile.

## OTHER FLUKE DISEASES

fas'e-o-lop'sis boo'ski

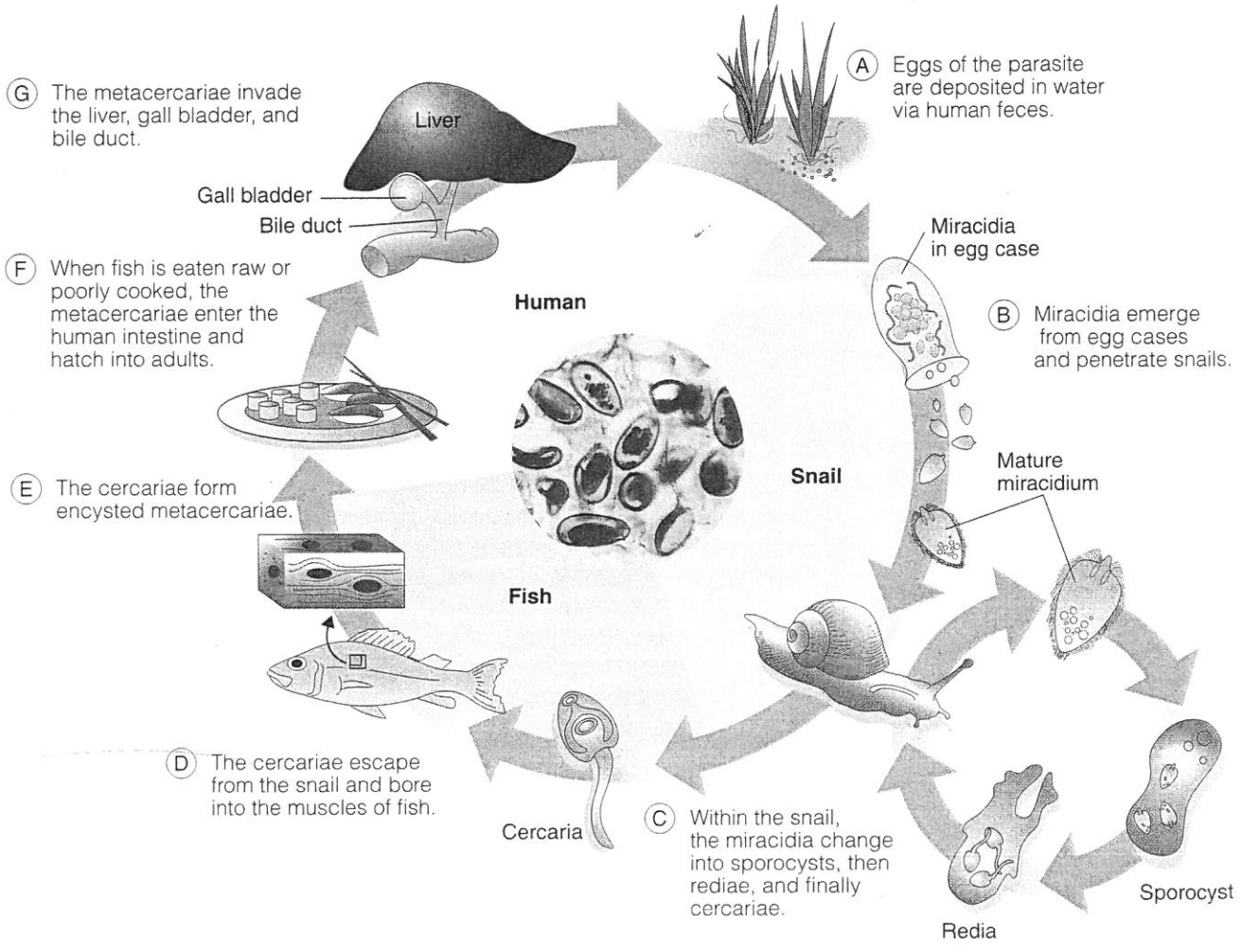
*Fasciolopsis buski*

The **intestinal fluke** of humans is known as ***Fasciolopsis buski***, a large fluke that can be as long as 8 cm. The parasite lives in the duodenum, where it causes diarrhea and intestinal blockage. From the feces, eggs enter water in such places as rice paddies and drainage ditches, and miracidia emerge. Snails are the next host for the

FIGURE 16.5

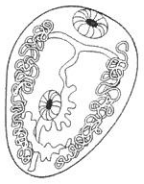
### The Life Cycle of the Chinese Liver Fluke, *Clonorchis sinensis*

The photograph shows eggs of *C. sinensis* in human tissue. The thick protective covering of the eggs is evident.



miracidia, and cercariae escape from the snail and swim to blades of grass and vegetation where metacercariae form. Such plants as water chestnuts and water bamboo are likely to be contaminated. Consumption of these vegetables raw or poorly cooked leads to human infection.

The human **lung fluke** is ***Paragonimus westermani.*** This parasite is common in the Orient and South Pacific. Its eggs are coughed up from the lung, swallowed, and then excreted in the feces. Cercariae develop in snails, and metacercariae later form in crabs. Infection follows when people eat the poorly cooked crabmeat, and the flukes pass from the intestine to the blood to the lungs. Difficult breathing and chronic cough develop as the parasites accumulate in the lungs. Fatalities are possible.



*Paragonimus westermani*

par'ah-gon'ĭ-mus wes'ter-man-i

The human **liver fluke** is ***Fasciola hepatica***, a leaflike flatworm common in sheep and cattle. Eggs from the animal reach the soil in feces, and if snails are present, the conversions to cercariae and encysted metacercariae follow. Parasite cysts gather on vegetation such as watercress, and ingestion by humans follows. The parasites penetrate the intestinal wall and migrate to the liver, where tissue damage may be substantial, especially if fluke numbers are high.

fah-si-o'lah

*Fasciola hepatica*

## A GENERAL DESCRIPTION OF TAPEWORMS

**Tapeworms** belong to the third class of flatworms, **Cestoda**. These worms have long, flat bodies consisting of a head region and a ribbonlike series of segments called **proglottids**. The head region, called the **scolex**, contains hooks or suckerlike devices that enable the worm to hold fast to infected tissue. Behind the scolex is a neck region in which new proglottids are formed. These new proglottids constantly push the mature proglottids to the rear. The most distant ones, called **gravid proglottids**, are filled with fertilized eggs. As they break free, they spread the eggs of the tapeworm.

**Scolex:**
the head region of a tapeworm.

**Gravid proglottids:**
segments filled with fertilized eggs at the back end of a tapeworm.

Tapeworms generally live in the intestines of a host organism. In this environment they are constantly bathed by nutrient-rich fluid, from which they absorb their food. Tapeworms have adapted to a parasitic existence and have lost their intestines, but they still retain well-developed muscular, excretory, and nervous systems.

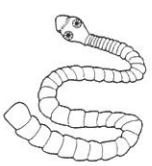
Tapeworms are widespread parasites that infect practically all mammals, as well as many other vertebrates. Since they are more dependent on their hosts than flukes, tapeworms have precarious life cycles. Tapeworms have a limited range of hosts, and the chances for completing the cycle are often slim. With rare exceptions, tapeworms require at least two hosts, as we shall see in the following examples of tapeworm diseases.

## BEEF AND PORK TAPEWORM DISEASES

Humans are the definitive hosts for both the **beef tapeworm** ***Taenia saginata*** and the **pork tapeworm** ***Taenia solium***. People infected with one of these tapeworms expel numerous gravid proglottids daily. The proglottids accumulate in the soil and are consumed by cattle or pigs. Embryos from the eggs travel to the animal's muscle, where they encyst. Humans then acquire the cysts in poorly cooked beef or pork.

tā'ne-ah saj-in-ah'tah

so'le-um



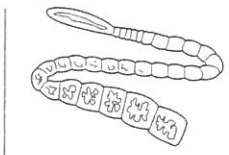
*Taenia saginata*

The beef tapeworm may reach 25 feet in length, while the pork tapeworm length averages 20 feet. Each tapeworm may have up to 2000 proglottids. Attachment via the scolex occurs in the small intestine, and obstruction of this organ may result. In most cases, however, there are few symptoms other than mild diarrhea, and a mutual

tolerance may develop between parasite and host. The notion that a tapeworm causes severe emaciation is largely unfounded.

## FISH TAPEWORM DISEASE

di-fil'o-both're-um



*Diphyllobothrium latum*

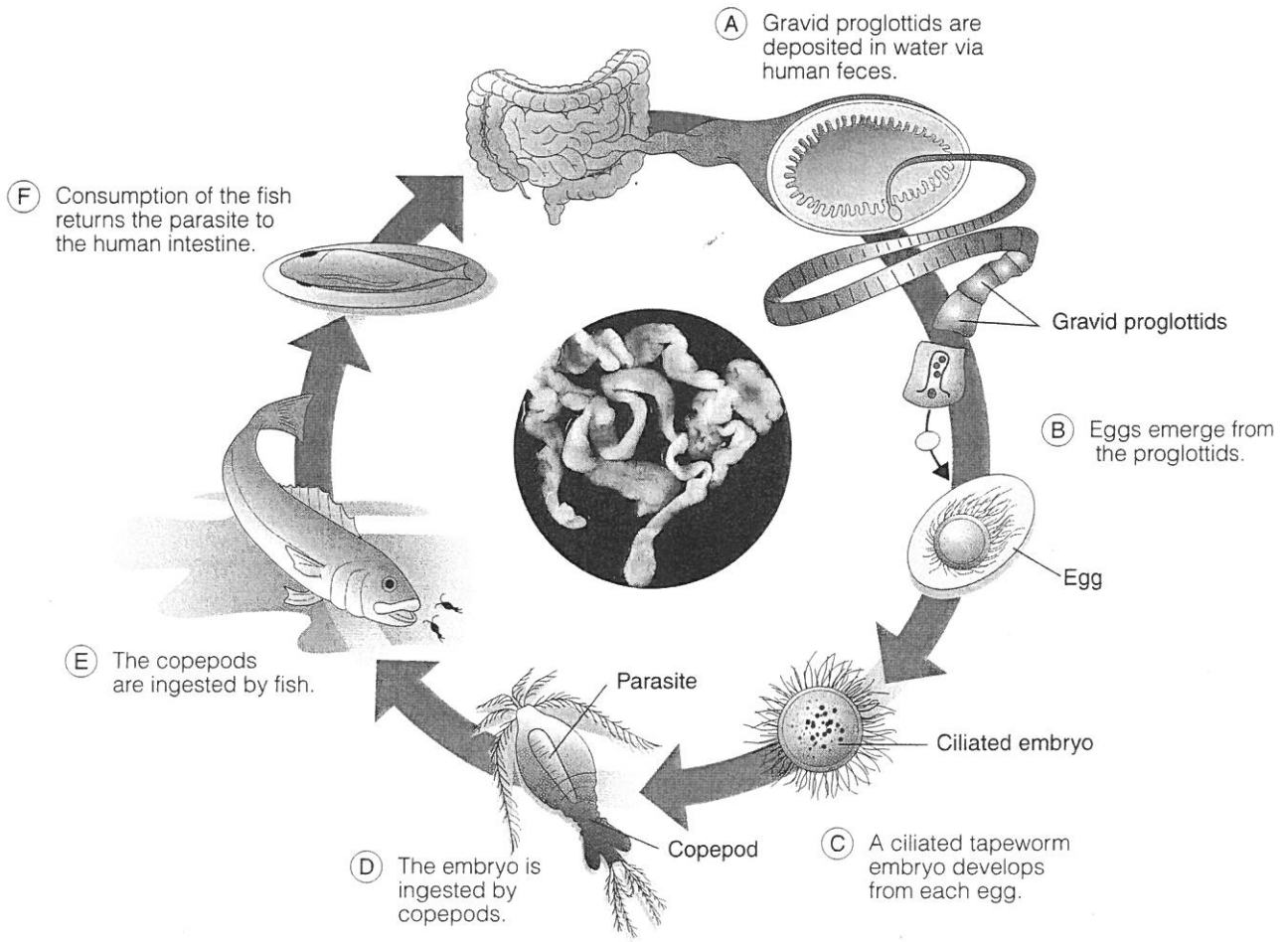
The **fish tapeworm** is the longest human parasite, some species measuring 60 feet in length. The parasite is named ***Diphyllobothrium latum.*** Its life cycle is complex and includes two intermediate hosts: a small shrimplike crustacean called a **copepod** and a fish (FIGURE 16.6). The copepod acquires tapeworm embryos from proglottids excreted into water by humans. Next the copepod is eaten by fish such as minnows, and the embryo finds its way to the fish muscle. Minnows may be eaten by larger fish such as trout, perch, and pike, and the embryos are passed along. Consumption of raw or poorly cooked fish by humans completes the cycle.

Infections with fish tapeworms occur throughout the world. In the United States, infections are most common in the Great Lakes region. Obstruction of the

FIGURE 16.6

### The Life Cycle of the Fish Tapeworm, *Diphyllobothrium latum*

The photograph shows *D. latum* isolated from a human patient.



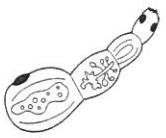
small intestine may occur, and anemia may develop in the patient, possibly due to the parasite's consumption of vitamin $B_{12}$ needed for red blood cell formation. Cooking at 50°C for 15 minutes is generally sufficient to destroy the cysts, but the recent popularity of raw fish dishes has contributed to a rise in the incidence rates of the disease.

## OTHER TAPEWORM DISEASES

The **dwarf tapeworm** ***Hymenolepis nana*** is so named because it is only 25 mm long. The most common tapeworm in humans worldwide, *H. nana* lives in the small intestine, where it holds fast with four sucker devices and a row of small hooks. Eggs released in the feces spread among humans by contaminated food or contact with objects or an infected individual. People living in the southeastern United States often experience infections.

*Hymenolepis nana*

Dogs and other canines such as wolves, foxes, and coyotes are the definitive hosts for the **dog tapeworm** called ***Echinococcus granulosus*** (FIGURE 16.7). Eggs reach the soil in feces and spread to numerous intermediary hosts, one of which is humans. Contact with a dog may also account for transmission. In humans, the parasites travel by the blood to the liver, where they form thick-walled **hydatid cysts**. Surgery may be necessary for their removal. Completion of the life cycle takes place when a dog consumes infected animal liver, such as after a kill. Dog food is another possible source of cysts. The adult tapeworm then emerges to parasitize the dog.



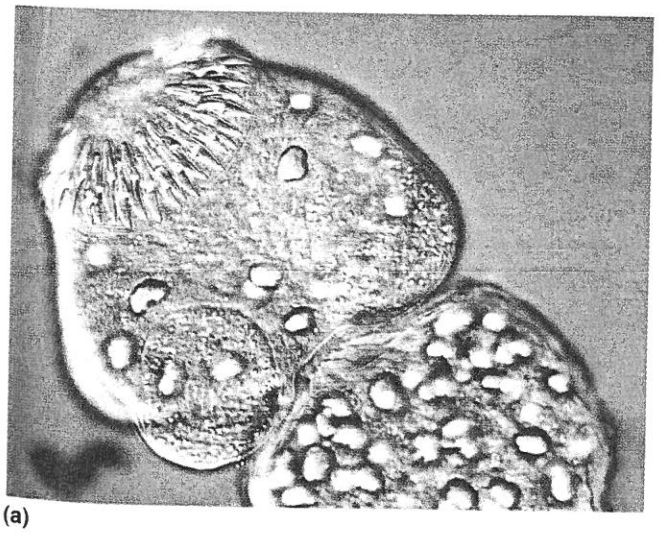
*Echinococcus granulosus*

The flatworm diseases of humans are summarized in TABLE 16.1.

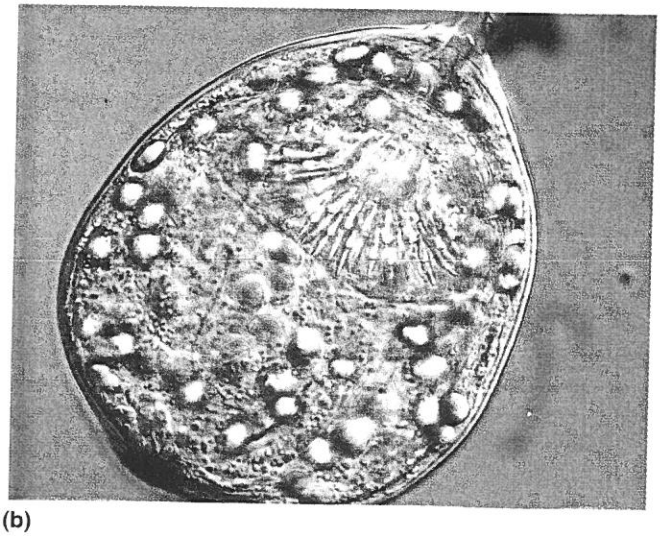
FIGURE 16.7

### The Dog Tapeworm

Two views of the dog tapeworm *Echinococcus granulosus*, as seen by phase-contrast microscopy. (a) The head region, or scolex, of *E. granulosus*. The hooks at the end of the scolex are used to attach to the infected tissue; the indentations at the base of the scolex emphasize its presence. (b) The hydatid cyst of *E. granulosus* isolated from a lung section of a 31-year-old woman immigrant from the Sudan. (Both magnifications ×580.)



(a)



(b)

16.2

# Roundworms

**Roundworms** occupy every imaginable habitat on Earth. They live in the sea, in freshwater, and in soil from polar regions to the tropics. Good topsoil, for example, may contain billions of roundworms per acre. They parasitize every conceivable type of animal and plant, causing both economic damage and serious disease.

The roundworms are a subgroup of the phylum **Aschelminthes**, from the Greek *asc-* for "sac" and *helminth* for "worm." The sac refers to a digestive tract set apart from the internal muscles in a saclike or pouchlike arrangement, a feature not found in flatworms. In reality, the sac is a tubular intestine open at the mouth and anus. Food can thus move in one direction, a substantial improvement over the blind sac arrangement in Platyhelminthes. This is one reason the Aschelminthes are considered to be more evolutionarily advanced than the Platyhelminthes.

ask'hel-min'thēz

plat'e-hel-min'thēz

Roundworms have separate sexes. Following fertilization of the female by the male, the eggs hatch to larvae that resemble miniature adults. Growth then occurs by cellular enlargement and mitosis. Damage in hosts is generally caused by large worm burdens in the intestines, blood vessels, or lymphatic vessels (FIGURE 16.8). Also, the infestation may result in nutritional deficiency or damage to the muscles.

Roundworms have been traditionally known as **nematodes** because they are threadlike (*nema* is Latin for "thread"). Indeed, in some texts the phylum of roundworms is called **Nematoda**, and in other books it is referred to as **Nemathelminthes**.

**Nematode:** an alternate name for a roundworm.

ne-mah-to'dah
ne'mat-hel-min'thēz

## PINWORM DISEASE

The widely encountered **pinworm** is a roundworm called ***Enterobius vermicularis***. This worm is the most common helminthic parasite in the United States, with an estimated 30 percent of children and 16 percent of adults serving as hosts. The male and female worms live in the distant part of the small intestine and in the large intestine, where the symptoms of infection include diarrhea and itching in the anal region. The female worm is about 10 mm long, and the male is about half that size.

en'ter-o'be-us ver'mik-u-la'ris

*Enterobius vermicularis*

The life cycle of the pinworm is relatively simple. Females migrate to the anal region at night and lay a considerable number of eggs. The area itches intensely, and scratching contaminates the hands and bed linens with eggs. Reinfection may then take place if the hands are brought to the mouth or if eggs are deposited in foods by the hands. The eggs are swallowed, whereupon they hatch in the duodenum and mature in the regions beyond.

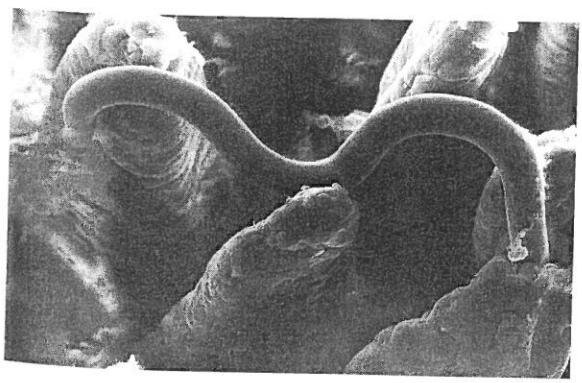


FIGURE 16.8

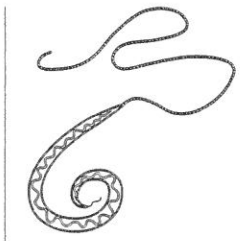
### The Roundworm *Trichinella spiralis*

A scanning electron micrograph of the roundworm *Trichinella spiralis* in human intestinal tissue. This parasite is the cause of trichinosis. In the photograph, the worm is emerging from one intestinal villus and entering another villus.

Diagnosis of pinworm disease may be accurately made by applying the sticky side of cellophane tape to the area about the anus and examining the tape microscopically for pinworm eggs (FIGURE 16.9). Several drugs are effective for controlling the disease, and all members of an infected person's family should be treated because transfer of the parasite has probably taken place. Even without medication, however, the worms will die in a few weeks, and the infection will disappear as long as reinfection is prevented.

## WHIPWORM DISEASE

trik-u'ris trik-e-u'rah



*Trichuris trichiura*

The **whipworm** ***Trichuris trichiura*** acquired its name from the observation that its anterior end is long and slender like a buggy whip. Infection takes place in the human intestine, especially near the junction of the small and large intestines, as shown in FIGURE 16.10. Damage to the intestinal lining may be severe, and appendicitislike pain is sometimes experienced, with some anemia resulting from ingestion of blood by the parasite.

The female whipworm is approximately 40 mm long; the male is shorter with a characteristically curled tail. Eggs eliminated in the human feces hatch to larvae after

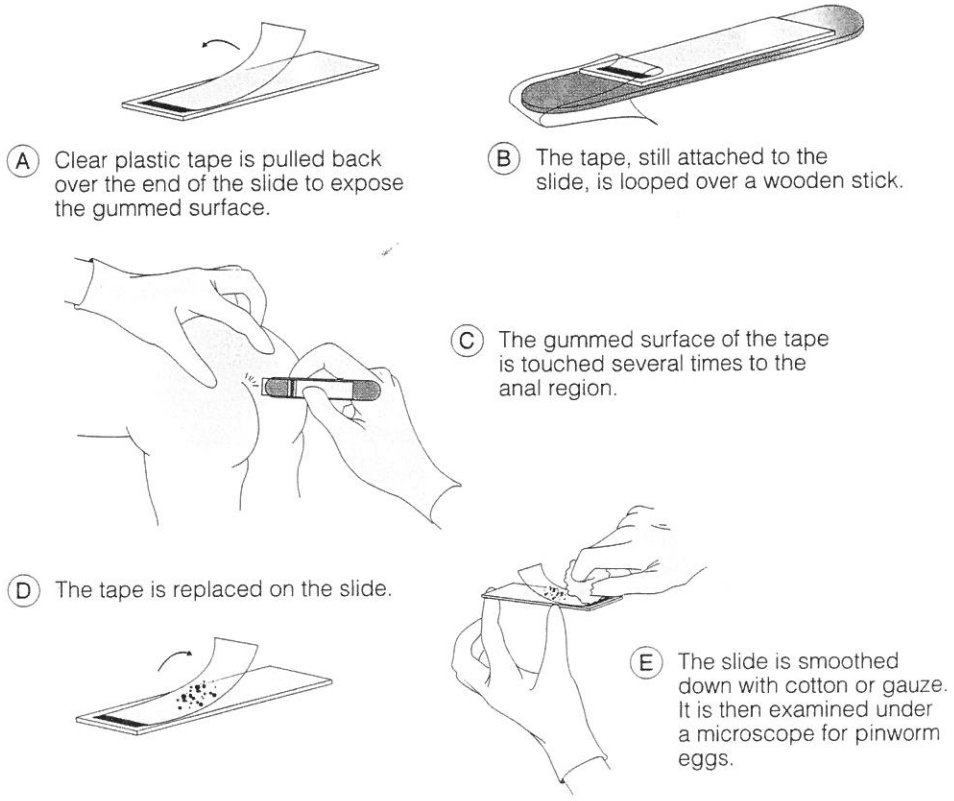



FIGURE 16.9

### Diagnosing Pinworm Disease

The transparent tape technique used in the diagnosis of pinworm disease.

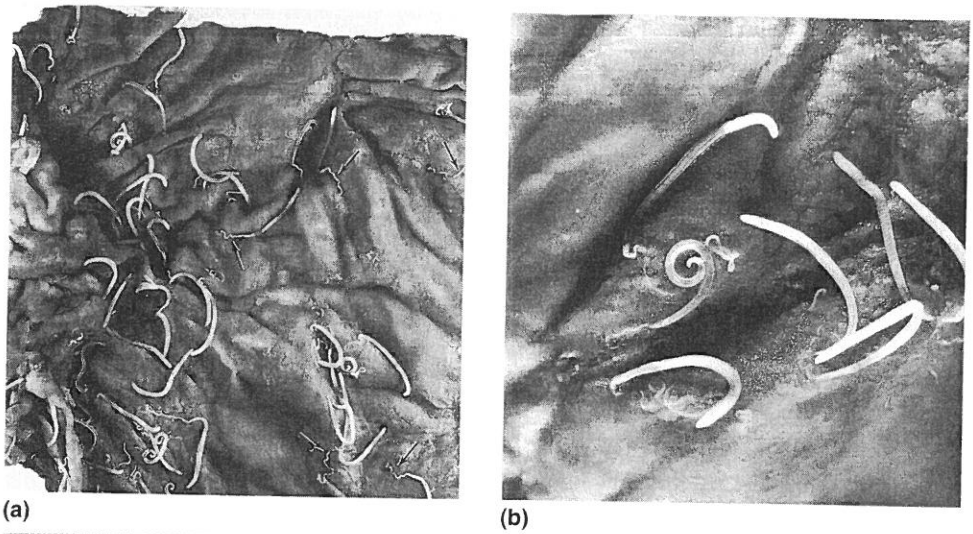



FIGURE 16.10

The Whipworm *Trichuris trichiura*

(a) A view of the whipworm *Trichuris trichiura* in human intestinal tissue. The worms are relatively small compared to other roundworms discussed in this chapter. Whipworms have a long slender form resembling a buggy whip. (b) A closer view.

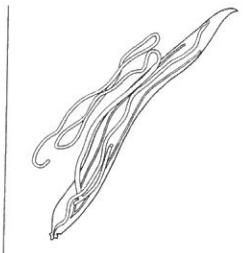
about two weeks in the soil. Transmission occurs by soil-contaminated food and water as well as by contact with soiled hands. Whipworm disease is encountered where the environment is hot and moist (such as in the tropics), and where poor sanitary facilities exist. Patients often have concurrent infections with other parasites. Diagnosis depends on the identification of eggs in the feces.

## ROUNDWORM DISEASE

Infection with "roundworms" usually implies infection with ***Ascaris lumbricoides***. One of the largest intestinal nematodes, the female *A. lumbricoides*, may be up to 1 foot long, and the male, 8 inches long. The parasite resembles an earthworm and is the most wormlike of the helminthic parasites.

as'kah-ris lum'brĭ-koid'ēz

A female *Ascaris* is a prolific producer of eggs, sometimes generating over 200,000 per day. The eggs are fertilized and passed to the soil in the feces, where they hatch to larvae. The larvae then attach to plants and are ingested. In many parts of the world, human feces, or nightsoil, is used as fertilizer for crops. This adds to the spread of the parasite. Contact with contaminated fingers and consumption of water containing soil runoff are other possible modes of transmission.



*Ascaris lumbricoides*

After the larvae have been consumed, the tiny worms grow in the small intestine. Abdominal symptoms develop as the worms reach maturity in about 2 months. Intestinal blockage may be a consequence when tightly compacted masses of worms accumulate, and perforation of the small intestine is possible. In addition, roundworm larvae may pass to the blood and infect the lungs, causing pneumonia. If the larvae are coughed up and then swallowed, intestinal reinfection occurs.

Pneumonia: a disease of the lung tissues.

Except for pinworms, *A. lumbricoides* is the most prevalent multicellular parasite in the United States. The WHO estimates that hundreds of millions of people are infected worldwide. Tropical and subtropical regions are the primary foci of disease,

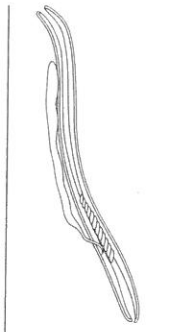
but areas of the southwestern United States are heavily infested because eggs remain viable in the moist clay soil of this region.

## TRICHINOSIS

**Trichinosis** is a term familiar to anyone who enjoys pork and pork products, because packages of pork usually contain warnings to cook the meat thoroughly to avoid this disease. Ironically, trichinosis is common where living standards are high enough for pork to be eaten routinely, but the disease is rare where pork is a luxury.

trik'ĭ-nel'ah spir-al'is

Trichinosis is caused by the small roundworm ***Trichinella spiralis***. The worm lives in the intestines of pigs and several other mammals. Larvae of the worm migrate through the blood and penetrate the pig's skeletal muscles, where they remain in cysts. When raw or **poorly cooked pork** is consumed, the cysts pass into the human intestines and the worms emerge. Intestinal pain, vomiting, nausea, and constipation are common symptoms.



*Trichinella spiralis*

Complications of trichinosis occur when *T. spiralis* larvae migrate to the muscles and form cysts. The patient commonly experiences pain in the breathing muscles of the ribs, loss of eye movement due to cyst formation in the eye muscles, swelling of the face, and hemorrhaging in various body tissues. Some sufferers also develop a cough and skin lesions, and the larvae may invade the brain, where they cause paralysis. Paralysis and death occurred in a man in New York in 1985 after he contracted trichinosis by consuming pork inadvertently ground with beef. The man had a habit of nibbling the meat while preparing hamburgers.

**Cyst:**
a dormant, highly resistant form of an organism such as a protozoan or multicellular parasite.

The cycle of trichinosis is completed as cysts are transmitted back to nature in the human feces (FIGURE 16.11). Consumption of human waste and garbage then brings the cysts to the pig. Modern methods of agriculture provide standardized feed for pigs, but many pigs are still exposed to the cysts. Consumers should be aware that poorly cooked pork is the principal source of the approximately 150 cases of trichinosis reported in the United States annually. Pickling, smoking, and heavy seasoning are not adequate substitutes for thorough heating, but freezing greatly reduces larval viability. Routine inspection of pigs for *T. spiralis* cysts is not common practice in slaughterhouses, and thus the burden for the prevention of trichinosis falls to the consumer. In 1986, the U.S. government approved the use of low-dose irradiation of fresh pork to combat trichinosis.

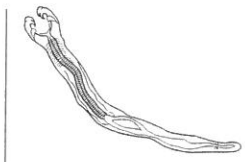
## HOOKWORM DISEASE

**Hookworms** are roundworms that have a set of hooks or sucker devices for firm attachment to tissues of the host. Two hookworms, both about 10 mm in length, may be involved in human disease. The first is the **Old World hookworm**, ***Ancylostoma duodenale***, which is found in Europe, Asia, and the United States; the second is the **New World hookworm**, ***Necator americanus***, which is prevalent in the Caribbean islands (where it may have been brought by slaves from Africa).

an'kĭ-los'to-mah du-od-in-al'e

ne-ka'tor a-mer-i-ca'nus

Hundreds of millions of people around the globe are believed to be infected by hookworms. These parasites live in the human intestine, where they suck blood from the tissues. Hookworm disease is therefore accompanied by blood loss and is generally manifested by anemia. Cysts may also become lodged in the intestinal wall, and ulcerlike symptoms may develop.



*Necator americanus*

The life cycle of a hookworm involves only a single host, the human (FIGURE 16.12). Hookworm eggs are excreted to the soil, where the larvae emerge as long,

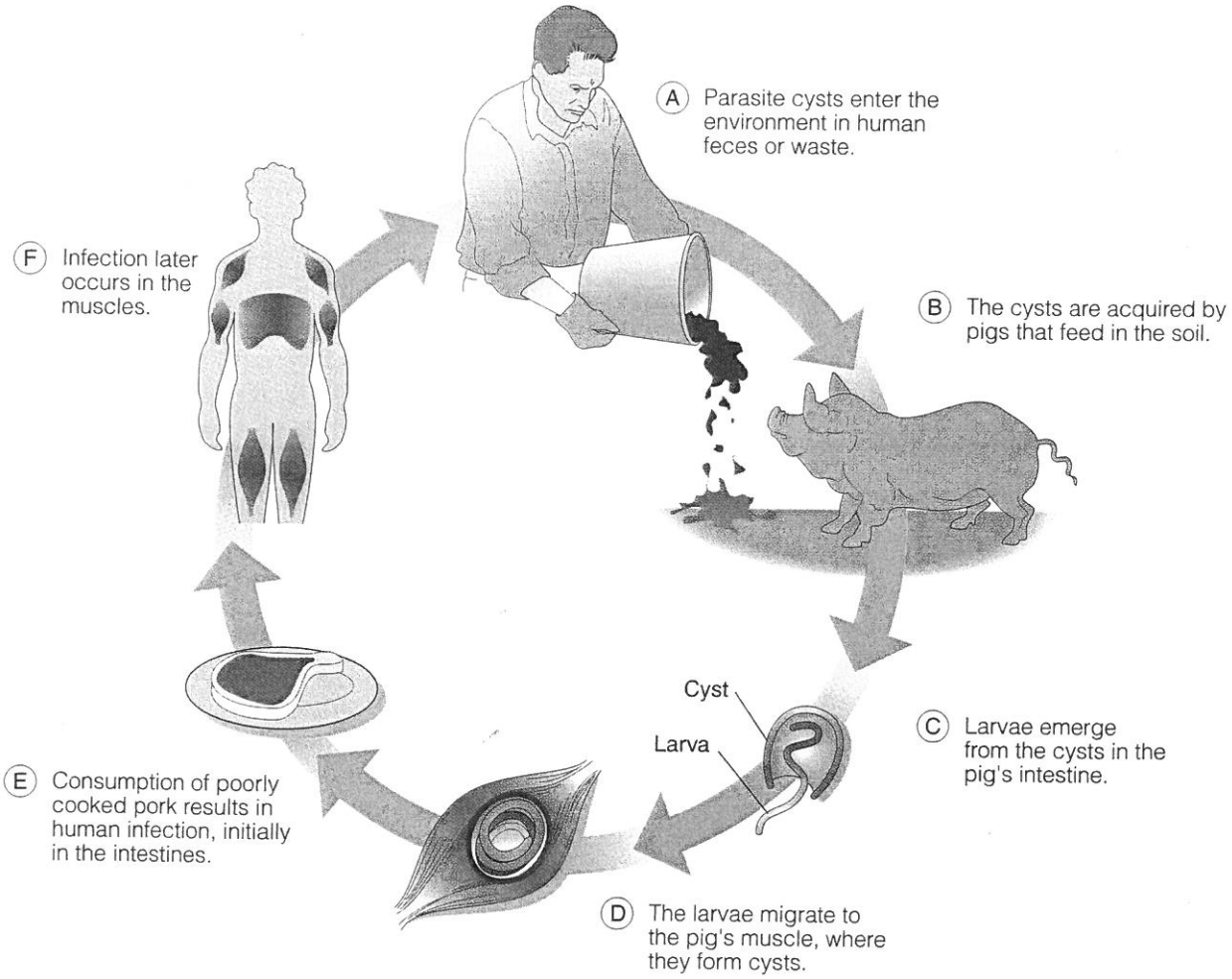



FIGURE 16.11

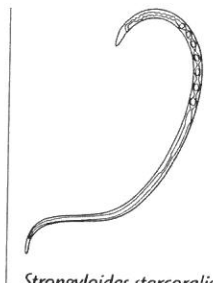
The Life Cycle of *Trichinella spiralis*

rodlike **rhabditiform** larvae. These later become threadlike **filariform** larvae that attach themselves to vegetation in the soil. When contact with bare feet is made, the filariform larvae penetrate the skin layers and enter the bloodstream. Soon they localize in the lungs and are carried up to the pharynx in secretions, then swallowed into the intestines.

rab-dit'ĭ-form

fil-ar'i-form

Hookworms are common where the soil is warm, wet, and contaminated with human feces. The disease is prevalent where people go barefoot. Drugs may be used to reduce the worm burden, and the diet may be supplemented with iron to replace that lost in the loss of blood. It should be noted that dogs and cats also harbor hookworm eggs and pass them in the feces.



*Strongyloides stercoralis*

stron'jĭ-loi-di'ah-sis
stron'ji-loi'dez ster-ko-ral'is

## STRONGYLOIDIASIS

Strongyloidiasis is caused by ***Strongyloides stercoralis***, a parasite that resembles hookworms in appearance, distribution, and life cycle. Adult worms inhabit the small intestine, especially the duodenum, where they cause abdominal pain, nausea,

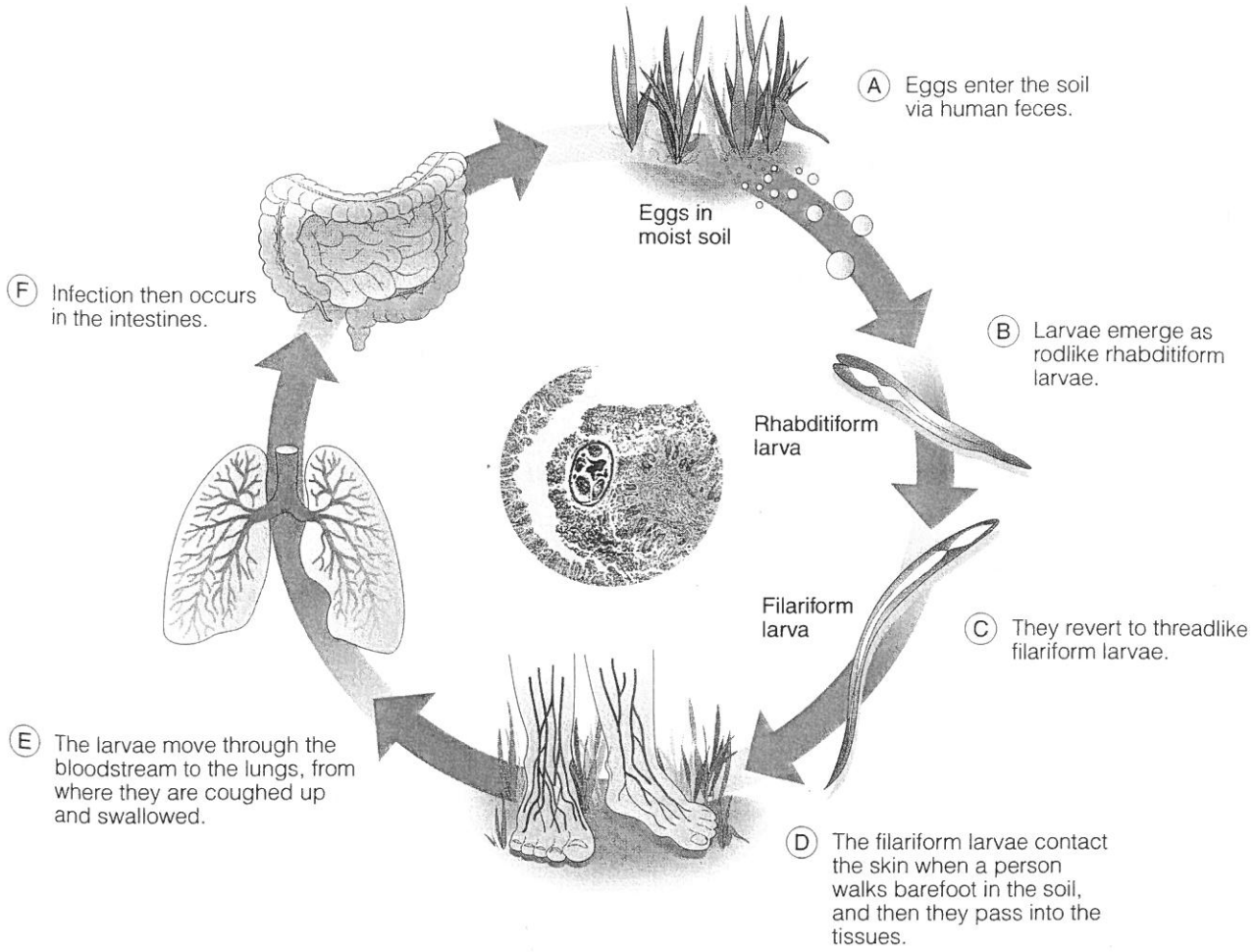


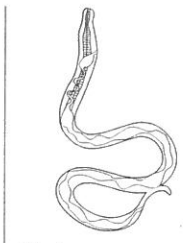

FIGURE 16.12

**The Life Cycle of the Hookworms *Ancylostoma duodenale* and *Necator americanus***

The photograph shows an egg lodged in intestinal tissue.

vomiting, and diarrhea alternating with constipation. Pulmonary symptoms mimic the pneumonia induced by hookworms. A drug called thiabendazole provides effective therapy.

Strongyloidiasis is of importance to Americans because many Vietnam veterans were exposed to the parasites in Southeast Asia. In a 1981 study, for example, doctors tested 530 veterans of Pacific wars for the parasite and found that 43 harbored it in their stools. In some cases, this was almost 40 years after the initial infection. Many reported regular 5-day episodes of itchy skin rash, another sign of the disease.



*Wuchereria bancrofti*

fil'ah-ri'ah-sis
voo'ker-e're-ah ban-krof'ti

## FILARIASIS

**Filariasis** is a parasitic disease caused by a roundworm named ***Wuchereria bancrofti.*** The worm breeds in the tissues of the human lymphatic system and causes extensive inflammation and damage to the lymphatic vessels and lymph glands. After years of infestation, the arms, legs, and scrotum swell enormously and become distorted with fluid. This condition is known as **elephantiasis** because of the gross

deformity of tissues and the resemblance of the skin to elephant hide (FIGURE 16.13).

The female form of *Wuchereria bancrofti* is about 100 mm long. Its fertilized eggs give rise to tiny eel-like microfilariae, which enter the human bloodstream. The microfilariae are then ingested by **mosquitoes** during a blood meal, where they develop into infective larvae passed along to another human during the next blood meal. The larvae subsequently grow to adults and infect the lymphatic system. Infection is limited to the number of larvae injected by the mosquito, since microfilariae cannot grow to adulthood without first passing through the mosquito.

Filariasis is prevalent where mosquitoes are plentiful, such as in the hot, humid climates of Central and South America and the Caribbean islands. Missionaries, emigrants, and visitors from these areas often carry the worms in their tissues.

FIGURE 16.13

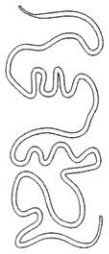
**The Effect of Filariasis**

Elephantiasis of the leg caused by the parasite *Wuchereria bancrofti*. The worm breeds in the tissues of the lymphatic vessels and damages them. As fluid accumulates, the legs swell and become distorted.

## GUINEA WORM DISEASE

The **Guinea worm** is a roundworm, thought to have been introduced to Africa, India, and the Middle East by navigators who plied the sealanes between these areas and South Pacific islands such as New Guinea. The worm's scientific name is ***Dracunculus medinensis.*** drah-kung'ku-lus med-i-nen'sis

The male Guinea worm is small, but the female may be up to 80 cm in length. Often the worm lies just below the skin of humans and causes swellings that resemble varicose veins. It causes a skin ulcer through which larvae are discharged into water. A small shrimplike crustacean called a **copepod** picks up the larvae and transmits them to another human when the copepod is consumed in water. Alternately, the copepod is eaten by fish, which then transmit the larvae (MicroFocus 16.2). Once in humans, the larvae migrate to the human skin and grow to adults.



*Dracunculus medinensis*

MicroFocus 16.2

### WELCOME TO NEW YORK CITY!

The Guinea worm had long been a parasite among Scandinavian fishermen and their families. Individuals acquired the worm by drinking water that contained infected crustaceans, or by eating fish that had previously eaten the crustaceans. For the Guinea worm, New York City appeared to be a long way off, but a somewhat circuitous route made the transition possible during the 1800s.

Scandinavians immigrated to the United States in substantial numbers during the nineteenth century. They settled along the shores of the Great Lakes, and, as their feces made their way into the lakes, the Guinea worm followed along. Eventually, fish from the Great Lakes became infected with larvae of the worm.

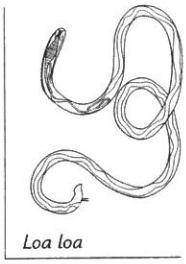
As the years passed, substantial commerce in fish developed between the Midwest and New York City. Jewish homemakers were particularly fond of pike, pickerel, and carp from the Great Lakes, and they used the fish to make a delicacy called gefilte fish. Carefully they pressed minced fish, eggs, and seasonings into balls and boiled the mixtures. During cooking, however, they often tasted the gefilte fish to see if it was done. While sampling the uncooked fish, they unwittingly acquired roundworm larvae and became new hosts for the Guinea worms. The transition was complete.

Guinea worm infection is now rare in New York City or elsewhere in the United States. Sanitary practices, fish inspection, and the commercial production of gefilte fish have limited the spread of the worm. Gefilte fish is still popular among Jewish people, but the unwanted hitchhikers have largely been eliminated.

The Guinea worm exposes itself through the skin ulcer and thus can be removed by careful winding on a stick. This primitive but time-honored method must be performed cautiously and slowly. The site of the ulcer burns intensely, and the fever and local burning are often described as "fiery." Partly because of this perception, it is believed that the "fiery serpents" mentioned in the Bible's Book of Numbers may have been Guinea worms. Also, the stick with worms wound around it may be the source of the serpent on a staff that is the symbol of healing used by the medical profession.

As of 1990, Guinea worm disease affected an estimated 5 million people in 17 African countries and parts of India and Pakistan. By that time, eradication programs had been established in Ghana and Nigeria to interrupt the spread of the disease by providing safe sources of drinking water, by teaching populations at risk to boil or filter contaminated water, and by treating drinking water with chemicals. By the end of the century, prospects were raised for complete eradication in the near future.

## EYEWORM DISEASE

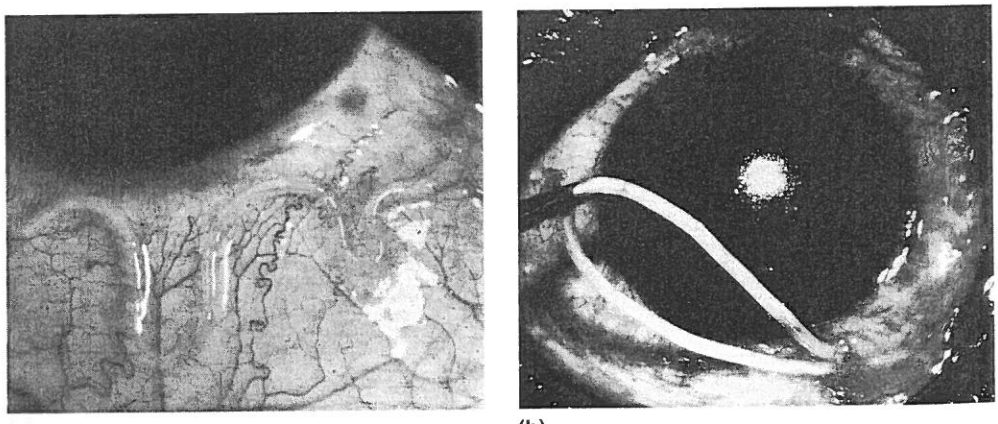


*Loa loa*

The **eyeworm** is a type of roundworm called ***Loa loa***. This parasite, native to West and Central Africa, is about 60 mm long. It is often found in insects such as deerflies and horseflies and is injected into the subcutaneous tissues of humans during an insect bite. The parasite may remain in the connective tissues for many months.

*Loa loa* is called the eyeworm because it is often attracted to the surface of the eye by warm temperatures. Commonly, it appears on the cornea (FIGURE 16.14). Here it causes conjunctivitis and painful irritation of the eye muscles. Swellings of the extremities are also observed. The parasite returns to the subcutaneous tissues as the skin temperature cools.

TABLE 16.2 summarizes the human diseases caused by roundworms.



(a) (b)

FIGURE 16.14

### The Eyeworm *Loa loa*

Two views of the human eye showing infection with *Loa loa*, the eyeworm. (a) The worm is seen below the conjunctiva along the white of the eye. (b) The worm is being removed from the eye.