

M U L T I C E L L U L A R P A R A S I T E S

A number of species of parasitic worms can inhabit the human intestinal tract and cause disease. While not microorganisms, they are studied and diagnosed using microscopic and immunologic techniques familiar to microbiologists. Some invade tissue and others do not, so that their presence in the body is often called an infestation rather than an infection. These worms, or **helminths**, are divided into two groups, the **roundworms** and the **flatworms**, and the flatworms are further divided into the **tapeworms** and the **flukes**. Tapeworms are ribbon-shaped and segmented, while flukes are generally shorter and leaf-shaped. Tapeworms differ from the other parasitic helminths in that they lack a digestive tract; they absorb nutrients through their skin. In most instances the helminths themselves are difficult to find and examine, so that they are identified by the microscopic appearance of their eggs, or ova, which are often present in the host's feces in large numbers. The ova of each helminth species are distinctive and can be identified on the basis of size, shape, thickness of the outer covering, embryonation, and other features. Some helminths have complex life cycles, involving one or more **intermediate hosts** where early stages of development occur, and a **definitive host** where the sexually mature forms occur. Generally, helminths have male and female forms, but most of the flatworms are **hermaphroditic**, meaning that both male and female sex organs reside in the same worm.

Diseases Due to Intestinal Roundworms

Some notable examples of diseases due to roundworms (nematodes) are discussed in this section. Pinworm disease, whipworm disease, and ascariasis are acquired by ingesting ova. Hookworm disease and strongyloidiasis are contracted by skin penetration by worm larvae, and trichinosis by eating undercooked meat containing worm larvae.

Pinworm Disease (Enterobiasis)

Pinworm disease, enterobiasis, is caused by the pinworm, *Enterobius vermicularis*. It is the most common helminth disease seen

by American physicians, and pinworms infest more than 200 million people worldwide.

Symptoms

About one-third of individuals infested with *E. vermicularis* are asymptomatic. The most common symptom in adults is anal itching, sometimes accompanied by vaginal irritation. Sleeplessness, nightmares, nervousness, irritability, anal pain, and weight loss are common in affected children.

Causative Agent.

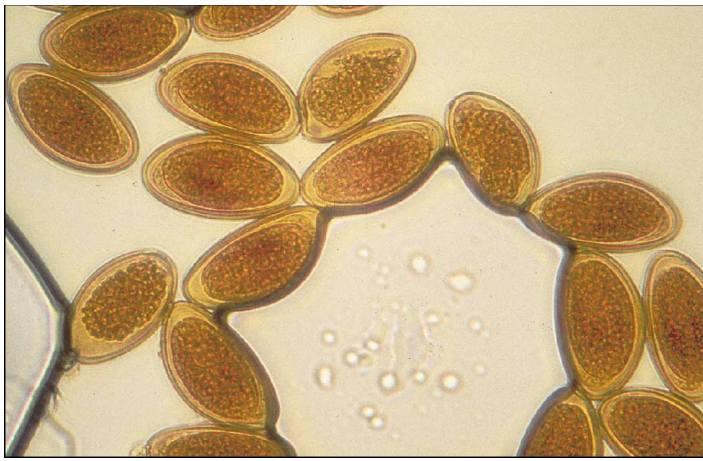
Enterobius vermicularis is a tiny roundworm; the females average about 10 mm in length, and the males, 2 to 3 mm. The female has a sharply pointed tail end, which inspired its popular name pinworm. The worms can often be detected in the anal area by using a flashlight about 2 hours after retiring, or early in the morning. Ova can be collected from the anal area by pressing transparent tape against the anus. The pinworm ova are elongated and have a distinctive appearance, flat on one side and containing a larval worm (**figure 24.26a**).

Pathogenesis

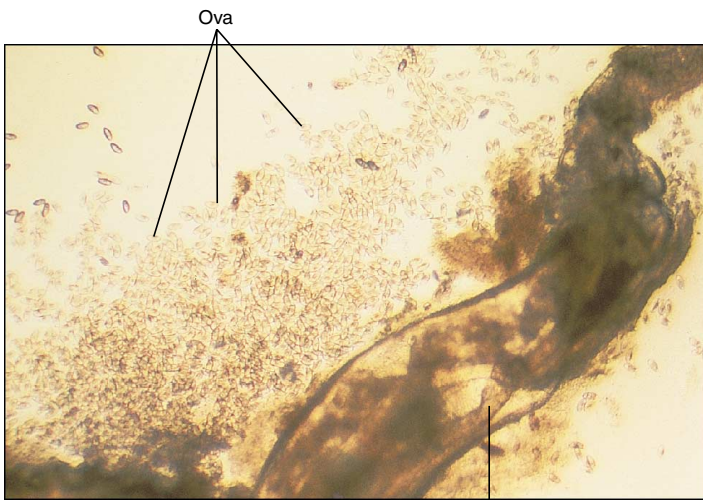
The worms live mainly in the upper part of the large intestine. They may, however, migrate throughout the intestinal and female genital tracts during their 1- to 2-month life span, feeding on bacteria and other intestinal material. Tiny ulcerations and inflammation occur where the worms attach to the intestinal epithelium. The male worms die soon after mating. The mature females containing 5,000 to 15,000 ova migrate out of the anus, usually while their host is sleeping, deposit their eggs in a sticky matrix, and die. Figure 24.26b shows the enormous numbers of ova present in a single worm. The sensation caused by worms exiting the anus leads to scratching, bleeding, and bacterial infection. If the anal area is not kept clean, eggs deposited there hatch, and the larval worms crawl through the anus, enter the intestine, and perpetuate the infestation.

Epidemiology

Scratching deposits *E. vermicularis* ova on the fingers and under the fingernails. Because of the enormous numbers of ova, clothing,



(a) 100 μ m



(b) 0.5 mm

Figure 24.26 Pinworm, *Enterobius vermicularis* (a) Microscopic view of the ova, showing flattened side and developing worm larva. (b) Body of the adult worm surrounded by thousands of its ova.

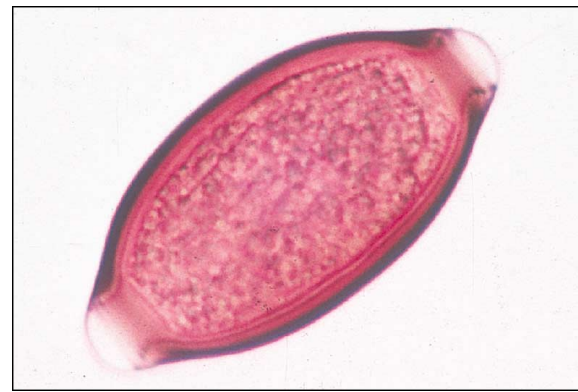
bedding, various surfaces, and even the air in the household become contaminated. Inhaled and ingested ova are swallowed and hatch in the small intestine, and the larval worms reach maturity in 2 to 6 weeks. Ova can survive for about a week in cool moist conditions, but they quickly die if conditions are hot and dry. Enterobiasis occurs worldwide and, unlike most other helminth diseases, is more common in temperate climates and does not spare upper socioeconomic groups. Humans are the only host for *E. vermicularis*.

Prevention and Treatment

Hygienic habits and good ventilation minimize the risk of acquiring *E. vermicularis*. Treatment is easy because effective medications are available, but preventing reinfection is difficult. All members of a household must be treated simultaneously, even those without symptoms. Clothing and bedding should be washed in hot water, and household surfaces thor-



(a)



(b) 20 μ m

Figure 24.27 Whipworm, *Trichuris trichiura* (a) The slender anterior portion is embedded in the mucous membrane, while the thicker portion protrudes into the intestinal lumen. (b) Ovum. Notice the long oval shape, thick wall, and plugs at each end.

oughly cleaned. Ideally, heat in the household should be turned up and all members take a vacation for a week.

Whipworm Disease (Trichuriasis)

Whipworm disease, trichuriasis, affects an estimated 500 to 800 million people in warm and wet regions of the world where people defecate on the ground or use human feces for fertilizer.

Symptoms

Most infestations, even with as many as 100 worms, are asymptomatic. Very heavy infestations can cause anemia from blood loss, weight loss, abdominal pain, diarrhea, and protrusion of the bowel through the rectum from forcefully straining to expel the worms.

Causative Agent

The causative agent of trichuriasis is the whipworm, *Trichuris trichiura*. The worms are 3 to 5 cm long, with a slender anterior portion and a short, thicker posterior portion, hence the name whipworm (**figure 24.27a**). The unmistakable ova can be found by microscopic examination of the feces (**figure 24.27b**).

Pathogenesis

Trichuriasis is contracted by ingesting the mature *T. trichiura* ova. The ova hatch in the small intestine, and the emerging larvae burrow into pockets in the intestinal epithelium. Here they develop for about a week, then return to the bowel lumen and migrate to the large intestine. They become sexually mature and start producing eggs in 1 to 2 months. The slender anterior region of the worm is inserted into the intestinal mucosa, with the thicker portion protruding into the bowel lumen. The intestinal epithelium is damaged by the penetrating worm, causing blood loss and an inflammatory response. Sometimes people infested with *T. trichiuria* develop hives because of allergy to worm antigens.

Epidemiology

Infection is by the fecal-oral route. Each mature female worm produces about 5,000 ova per day. These ova are eliminated with the feces and can contaminate hands and foods, but they are not immediately infectious. The ova require about 3 weeks in a warm, moist, and shady place before they are capable of parasitizing a new host. The worms can live 3 to 8 years, so that repeated ingestions of eggs can cause a large buildup of the numbers of the worms in a person's intestine. Also, because of the long life of *T. trichiura*, the worms are frequently found in people who traveled to endemic areas years ago. Humans are the only reservoir for *T. trichiura*.

Prevention and Treatment

Trichuriasis is prevented by proper disposal of human feces and other sanitary measures. Several medications provide safe and effective treatment of the disease.

Ascariasis

Ascariasis is a helminthic disease caused by *Ascaris lumbricoides*, the largest and most prevalent human roundworm. Worldwide, an estimated 1 billion people are infested.

Symptoms

Most cases of ascariasis are asymptomatic. Many individuals infested with the worms, however, develop one or more bouts of fever, trouble breathing, coughing, and wheezing. Some infested people have the frightening experience of vomiting up a large worm, or passing one in their feces; others develop abdominal pain when the worms obstruct the intestine or gallbladder.

Causative Agent

Ascaris lumbricoides (see figure 24.28) is a roundworm prevalent worldwide in areas where human feces contaminate the soil. Female worms are enormous, ranging from 20 to 45 cm long and 3 to 6 mm wide, while males are somewhat smaller. The ova are nearly spherical, with a thick wall and irregular outer surface (see figure 24.28). The life cycle of *A. lumbricoides* is complex. The ova released by mature females are eliminated with the host's feces. The tiny worm larva inside the ova must develop in soil or other location outside the host's body for at least 1½ weeks before they can survive and mature in a new host. After being swallowed by the new host, the ova hatch in the duodenum. At this point, the tiny larval worms do some-

thing totally unexpected. Instead of staying in the intestine, they burrow through the intestinal epithelium, enter the circulatory system, and are carried throughout the body. Those that reach the lungs push through the capillary walls into the alveoli. Here they undergo further development, reach 1 to 2 mm in length, and shed their covering twice to get ready for the rest of their journey. After about 10 days, they move out of the alveoli into the air passages of the lungs, and they are coughed up and swallowed (figure 24.28). The developmental changes that take place in the lungs make them resistant to stomach juices, and so they pass safely through the stomach into the small intestine. They mature to adulthood after about 2 months in the upper small intestine, feeding on intestinal contents. They live about 1 year.

Pathogenesis

Large masses of worms can obstruct the intestine, while wandering worms can obstruct or perforate various organs. Except for the larval worms that reach the lung, circulating larvae lodge in capillaries throughout the body and die, causing an inflammatory and immune response and consequent aches, pains, and fever. The larval penetration into the lungs causes microscopic bleeding, which if widespread, can predispose one to bacterial pneumonia; lesser amounts of damage provoke inflammatory and immune responses, coughing, wheezing, and pain.

Roundworms of some species of animals can penetrate human tissues but cannot complete their life cycle. Instead, their larvae wander through the tissues and eventually die, causing an intense inflammatory reaction. Preschool children are especially susceptible to this condition, called **visceral larva migrans**, because of their tendency to put rocks and dirt into their mouths. If the material is contaminated with certain roundworm ova, the eggs hatch, and the larvae migrate through body tissues. One example is *Toxocara canis*, an intestinal roundworm of dogs that resembles *A. lumbricoides*. This helminth can cause damage to various organs of a child, even blindness when its larvae lodge in the eyes.

Epidemiology

Humans are the only natural hosts of *A. lumbricoides*. A closely similar helminth of pigs can sometimes infect people. The helminth female produces more than 200,000 ova daily. These ova are remarkably resistant to heat, cold, drying, and disinfectants. Moreover, the ova remain infectious for up to 10 years, contaminating soil, dust, and food. In many areas of the world, human feces is used as fertilizer for food crops, and children defecate outdoors causing extensive soil contamination. Young children commonly place soiled objects into their mouth, and they are prone to eat soil if they are anemic or iron deficient. Children may have 50 or more worms, the record being well over 1,000.

Prevention and Treatment

Prevention of ascariasis depends on hygienic practices and sanitary disposal of human feces. Effective and safe medications are available for treating the disease.

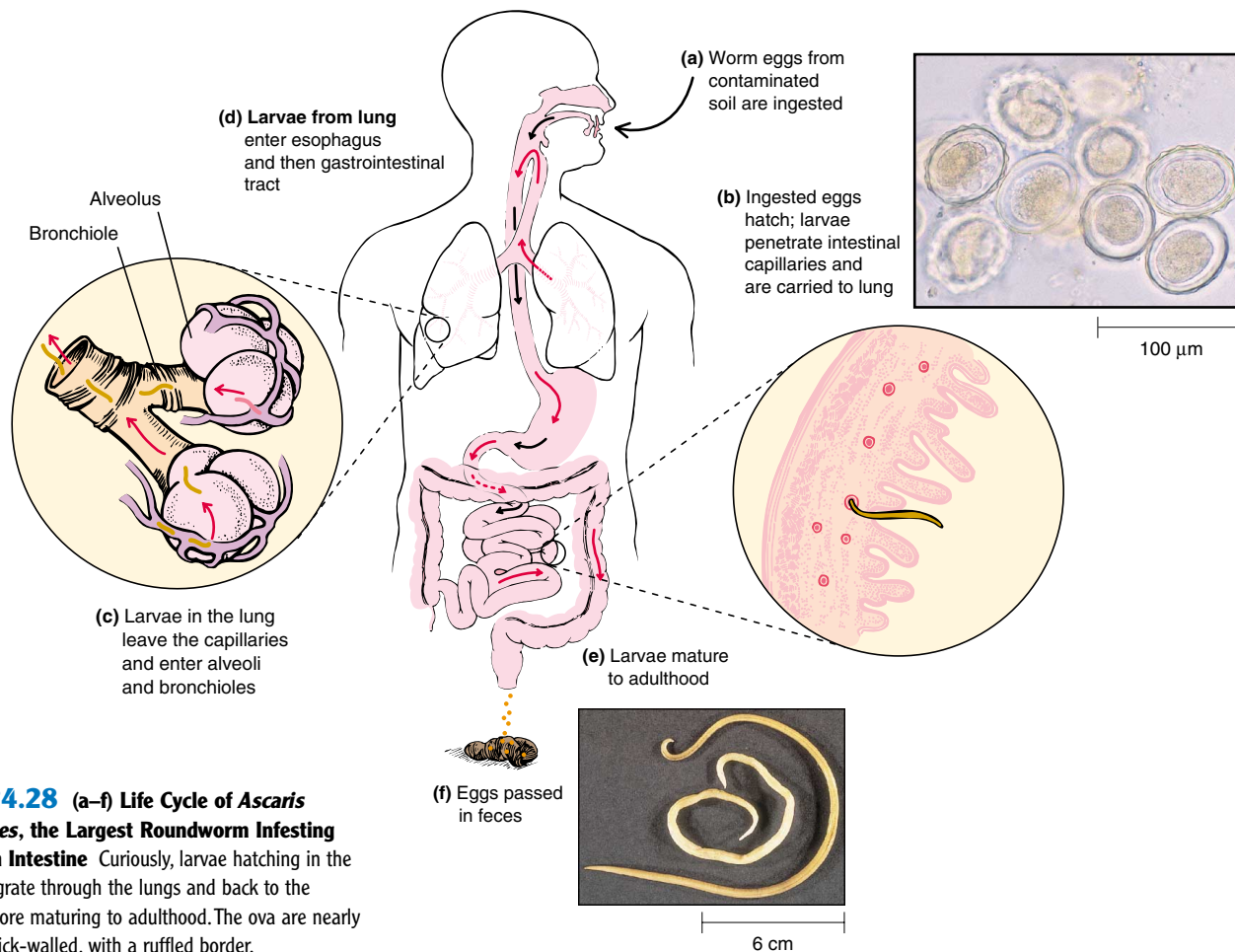


Figure 24.28 (a–f) Life Cycle of *Ascaris lumbricoides*, the Largest Roundworm Infesting the Human Intestine. Curiously, larvae hatching in the intestine migrate through the lungs and back to the intestine before maturing to adulthood. The ova are nearly spherical, thick-walled, with a ruffled border.

Hookworm Disease

Hookworms infest about 900 million people in warm, wet areas around the world where people defecate on the ground and do not wear shoes. Hookworm disease was once common in the southeastern United States. Asymptomatic individuals are still seen in most states, but they have contracted their hookworms in other countries.

Symptoms

The vast majority of hookworm infestations are asymptomatic. An itchy foot rash commonly occurs at the site of skin penetration by the worms. Cough, fever, and shortness of breath can occur, and later, diarrhea, nausea, and vomiting. The most important symptoms of hookworm disease are mental and physical retardation in children.

Causative Agents

Necator americanus and *Ancylostoma duodenale* account for most cases of human hookworm disease. The worms are about 10 mm long and live in the small intestine, attaching by means of small hooks or plates located about their mouth. The hookworm life cycle is shown in **figure 24.29**. The female worm

releases her eggs, and they are discharged with the feces, contaminating soil in places that lack toilets. The eggs hatch in the soil, releasing tiny larvae that develop in the soil and become infectious. These larvae generally penetrate the skin of a person's feet, wiggle their way into the bloodstream, and are carried to the heart and lungs. In the lungs, as in ascariasis, they push through the capillary walls into the alveoli, migrate into the bronchial tubes, and then enter the gastrointestinal system when lower respiratory tract secretions are coughed up and swallowed. Once in the small intestine, the larvae attach and mature to complete their life cycle.

Pathogenesis

Hookworms feed by sucking the blood of the host. More than 1,000 worms may be found in a single person, and the constant loss of blood frequently produces anemia. Children who acquire hookworms may be undernourished already, and the anemia resulting from hookworm disease may cause weakness, fatigue, and physical and mental retardation. Initial attachment of the worms can cause nausea and vomiting. Migration of the larvae through the lungs causes microscopic bleeding and inflammatory and immune responses that result in coughing, wheezing, and shortness of breath. The itchy rash, called ground itch, that

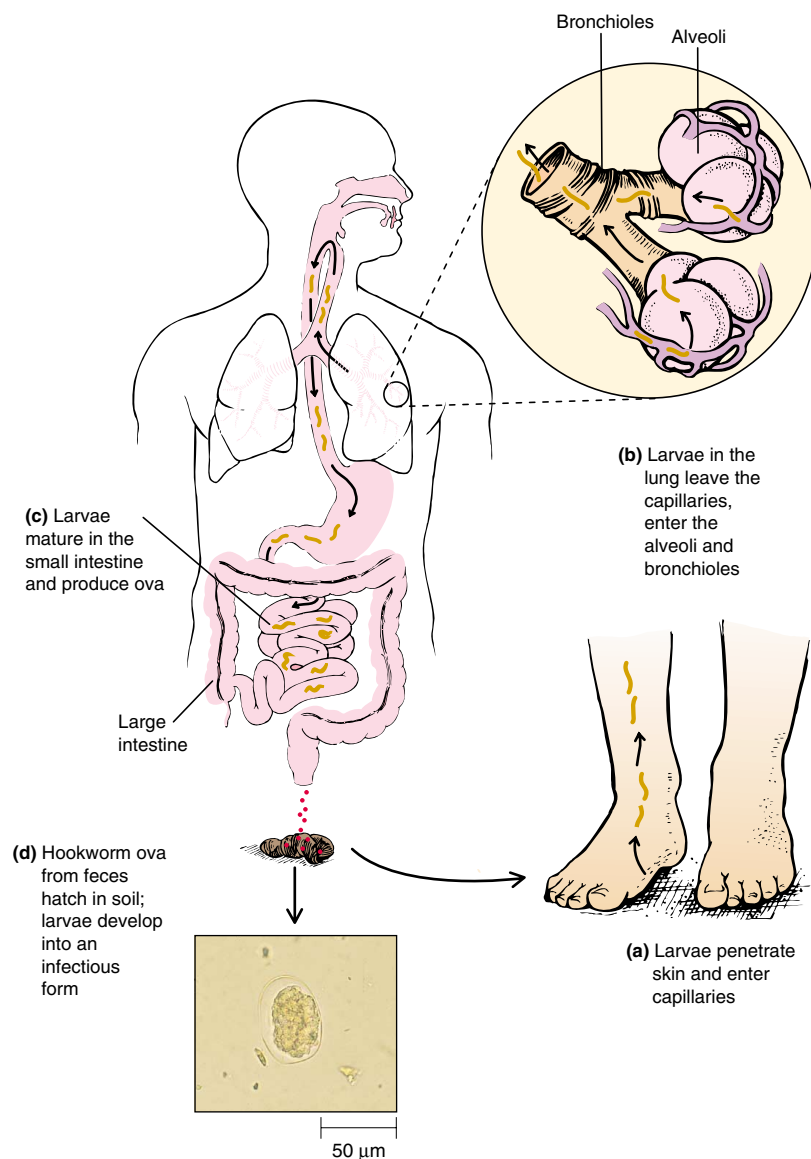


Figure 24.29 (a–d) Life Cycle of a Hookworm Infection begins with penetration of the skin by the worm larvae. The micrograph shows the thin-walled ovum containing the developing worm embryo.

often develops between the toes at the site of larval penetration, is probably an allergic response to repeated exposures.

The larvae of dog and cat hookworms can contaminate soil and penetrate the skin, especially of people such as plumbers that sometimes have to crawl in dirt under buildings. The larvae wander just under the skin surface, causing itchy red tracts (**figure 24.30**) that advance as much as 1 to 2 cm per day for a month or more, before dying. This condition is called **cutaneous larva migrans**.

Epidemiology

Hookworm disease occurs around the world in temperate and tropical climates where the soil is moist, human feces is deposited on the ground, and people are barefooted. Each female worm can produce 25 million ova in her lifetime of 2 to 10 years.

Prevention and Treatment

Prevention of hookworm disease depends on sanitary disposal of human feces and wearing shoes. Highly effective medications are available to eliminate the infestation.

Strongyloidiasis

Strongyloidiasis, the disease caused by *Strongyloides stercoralis*, occurs in a spotty distribution in warm, wet areas of the world, with an estimated 400,000 cases in the southeastern United States and Puerto Rico. This disease differs from most other helminthic diseases in that it perpetuates itself indefinitely in the absence of reexposure to the causative agent.

Symptoms

Most infections are asymptomatic, but abdominal pain, diarrhea, recurrent rashes on the buttocks and lower back, and respiratory symptoms can occur with heavy infestations.

Causative Agent

The adult *Strongyloides stercoralis* (**figure 24.31**), sometimes called a threadworm, is only about 2 mm long. Its life cycle is similar to that of hookworms with two important exceptions: (1) the worms can multiply sexually in the soil; and (2) ova produced by intestinal worms hatch before they are discharged in the feces. These intestinal larvae can mature to an infectious form, penetrate the intestine or the anal skin, and thereby perpetuate the infection indefinitely.

Pathogenesis

Most individuals with strongyloidiasis are asymptomatic because their immune system limits tissue invasion. Heavy infestations, however, can damage the lungs and intestine, sometimes leading to invasion by bacterial pathogens. Recurrent rashes result from hypersensitivity to the larvae at the sites of penetration. In people who are debilitated, alcoholic, or immunosuppressed, massive numbers of the worms arise, penetrating all parts of the body, including the brain. These massive infections are rapidly fatal unless treated.

Epidemiology

Strongyloidiasis occurs in much the same distribution as hookworm, but favoring tropical areas. Since the organisms can multiply in soil, contaminated areas may remain infectious even when there are no new deposits of human feces. Human infections can last for a lifetime, and they can be transmitted to other people through close physical contact. Many American soldiers contracted the disease during World War II while imprisoned in Southeast Asia.

Prevention and Treatment

Prevention of strongyloidiasis is the same as for hookworm disease. Effective medications are available but require a longer



Figure 24.30 Cutaneous Larva Migrans, an Occupational Hazard of Plumbers and Others Who Crawl Under Buildings Where Dog or Cat Feces Have been Deposited Larval hookworms from the feces penetrate and wander under the skin, causing serpentine tracts of inflammation before dying.



100 μ m

Figure 24.31 *Strongyloides stercoralis* Larva in Feces The adult worm is only about 2 mm long, and has a life cycle similar to hookworms. Unlike other intestinal roundworms, however, *S. stercoralis* can multiply in the soil and in the body of a single host.

period of treatment than for hookworm, and even so, relapses may occur.

Trichinosis (Trichinellosis)

Trichinosis, also known as trichinellosis, differs from all the roundworm diseases discussed previously in that it is contracted by eating inadequately cooked meat. Since pork is a leading source of infection, the incidence of the disease has fallen markedly in the United States over the years due largely to federal regulations on how pigs raised commercially are fed. Nevertheless, the potential for large outbreaks of the disease still exists because the meat of a number species of animals can be infectious.

Symptoms

Trichinosis is characterized by abdominal pain and diarrhea, followed in about a week by fever, muscle pain, swelling around the eyes, and sometimes a rash. Occasional cases are fatal

because of damage to the heart or brain. The disease occurs worldwide except for Australia and some Pacific Islands.

Causative Agent

The cause of trichinosis is usually *Trichinella spiralis*, a 1 to 4 mm long roundworm that lives in the small intestine of meat-eating animals, especially rats, pigs, bears, dogs, and humans. Its life cycle is shown in **figure 24.32**. The female worm discharges her living young into the lymph and blood vessels of the host's intestine without an intervening egg stage, and those larvae are carried to all parts of the body. Most of the larvae are killed by body defenses, but some survive in the muscles of the host where they become encased with scar tissue. The worms then stay alive for months or years within the muscle. If the flesh of an infested pig or other carnivorous animal is eaten by humans or other animals, the digestive juices of the new host release the larvae, permitting them to burrow into the new host's intestinal lining. The larvae then mature, and the females begin producing larvae in the new host to complete the life cycle of the worm. Each female adult *Trichinella* may live 4 months or more and produce 1,500 young.

Pathogenesis

The penetration of larval worms into the host's tissues is responsible for the symptoms of trichinosis. Abdominal pain and diarrhea begin within the first week after eating meat containing *T. spiralis*, when the worms mature and begin discharging their larvae. Fever, muscle pain, rash, and facial swelling result from inflammatory and immune reactions to larvae lodged in various tissues. Only larvae that penetrate skeletal muscle survive.

Epidemiology

In trichinosis, the same animal generally serves as both the definitive and the intermediate host, human beings one hopes being the exception. Almost all warm-blooded carnivores can be hosts for *T. spiralis*. Many cases of the disease have been contracted from the meat of wild animals, including bear, wild boar, walrus, and cougar.

Prevention and Treatment

Prevention of trichinosis depends on thorough cooking of meat so that all parts reach at least 170°F (77°C). Pigs raised commercially must by law be fed only cooked garbage to ensure that they do not receive meat scraps containing viable *Trichinella* larvae. Government inspection of meat does not detect *Trichinella* infestation. Larvae in pork are generally killed at 5°F (−15°C) or lower for 3 weeks if the meat is less than 15 cm thick. Wild game, however, often harbors *Trichinella* species that are not killed by freezing. Medication is available that can probably prevent the disease in persons who have eaten meat shown to contain *Trichinella*, but there is no effective treatment.

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Parasitic worms are divided into the roundworms (nematodes) and the flatworms. Flatworms are further divided into tapeworms (cestodes) and flukes

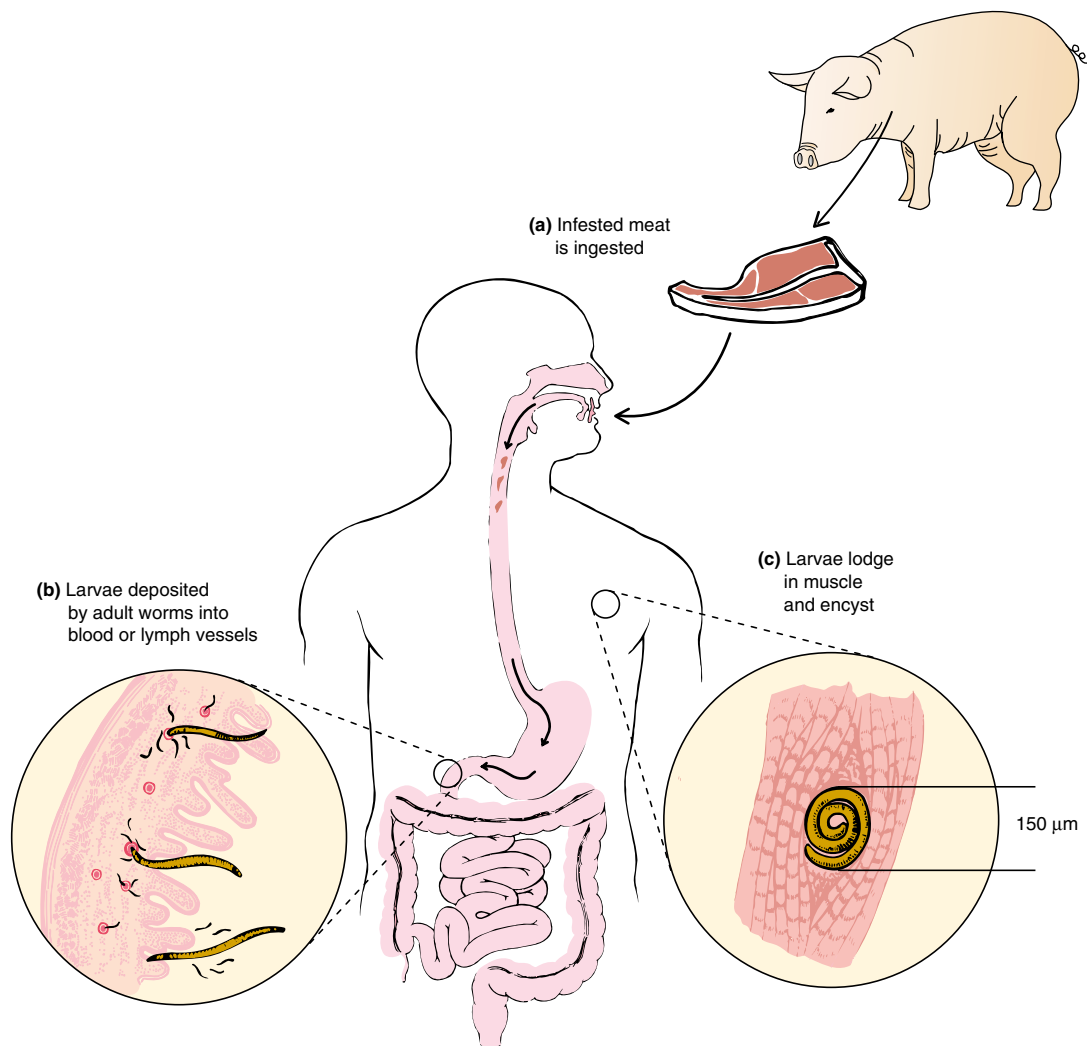


Figure 24.32 (a–c) Life cycle of *Trichinella spiralis*, the Cause of **Trichinosis** Most cases of the disease result from eating inadequately cooked pork or bear meat.

(trematodes). Roundworm diseases include pinworm, whipworm, and ascariasis contracted by ingesting worm ova; hookworm disease and strongyloidiasis, contracted through skin penetration by the worm larvae; and trichinosis, acquired by ingesting inadequately cooked meat containing encysted worm larvae.

- Why might asymptomatic strongyloidiasis pose a serious threat to an individual who develops immunodeficiency?
- Would you be surprised to see new cases of ascariasis turning up 3 years after all the inhabitants of a Southeast Asian village began using outhouses to deposit their feces? Why or why not?

Diseases Due to Intestinal Flatworms

This section gives some examples of diseases due to tapeworms, cestodes, and an example of a disease caused by a very large intestinal fluke, or trematode. ■ cestodes, p. 317 ■ trematodes, p. 318

Tapeworm Disease

Tapeworms can exceed 10 m (more than 30 ft.) in length and have a ribbonlike appearance. Their structure is quite distinctive in that there is no digestive tract. The head end, called a **scolex**, is only 1 to 2 mm in diameter and is merely an attachment device to anchor the organism so that it is not eliminated by peristalsis. The neck region continuously produces segments called **proglottids** that become more mature the further they are from the scolex. The proglottids are little more than hermaphroditic egg factories; depending on the species, ova are discharged from an opening in the proglottid, or the proglottid separates from the rest of the worm and releases its ova by breaking apart. People become infested with tapeworms by eating inadequately cooked red meat or fish. Three important tapeworms are the beef tapeworm, the pork tapeworm, and the fish tapeworm. Beef, pork, and fish refer to the sources of human infection, not where the adult worms exist; human beings are the definitive host for all three.

Symptoms

Most tapeworm victims have few or no symptoms. An occasional individual will develop vomiting and abdominal pain.

Rarely, weakness, unsteadiness, mental abnormalities, tumorlike swellings, blindness, or epilepsy occur.

Causative Agents

The tapeworms *Taenia saginata* or beef tapeworm, *Taenia solium* or pork tapeworm, and *Diphyllobothrium latum* or fish tapeworm can be distinguished by the structure of their scolices, their proglottids, and their ova. *Taenia saginata* and *T. solium* each have a single intermediate host, cattle and pigs, respectively, while *D. latum* has two or more.

Cattle ingest *T. saginata* ova when they feed on pasture contaminated with feces from people who carry the adult worm. The ova hatch in the cattle intestines, releasing larvae that burrow through the intestinal wall and lodge in the flesh of the animals. Here each of the parasites develops into a **cysticercus**, a cystic structure containing an immature scolex. When the inadequately cooked beef is eaten by a person, the cysticercus is released from the meat by digestive enzymes, matures, attaches to the intestinal wall, and soon develops into an egg-producing adult tapeworm. The life cycle for the pork tapeworm, *Taenia solium*, is similar except pigs rather than cattle are the intermediate host. Cysticerci in inadequately cooked meat represent the only source of adult worms in people.

The intermediate hosts of *D. latum* are water fleas and fish, whereas the definitive host, the mature egg-producing form, occurs in humans; bears, dogs, and other animals can be definitive hosts for the same or similar tapeworms. When ova of *D. latum* passed with a person's feces enter fresh water, they soon release ciliated larvae, which are devoured by water fleas (**figure 24.33**). The larvae lose their cilia, claw their way into the water flea's body using tiny hooks, absorb nutrients from the flea's blood, and increase in size. These larvae can develop further only if the water flea is eaten by a fish. In a fish's muscle, the organism continues developing and becomes infectious for humans. Usually, however, it gets passed from one fish to another as bigger fishes eat smaller ones, before being eaten by the human host. In the human host, the flesh of the fish is digested away by stomach juices, releasing the worm-like larva. It attaches to the small intestine, rapidly matures, and begins producing ova.

Pathogenesis

Symptoms of tapeworm disease can arise from the presence of adult worms in the intestine. Nausea, vomiting, and abdominal pain sometimes arise because the worms partly obstruct the intestine. Also, large fish tapeworms can absorb almost 100% of vitamin B₁₂ from

intestinal juices, depriving the host of this essential vitamin and causing anemia, weakness, unsteadiness, and other manifestations of nervous system malfunction.

The intermediate developmental forms of tapeworms can also infect humans and cause symptoms. This occurs in the case of *D. latum* when infected water fleas are accidentally ingested, as might happen with drinking lake water. Infection can also result from the practice of applying raw meat or fish to open wounds in the mistaken belief that the meat will aid recovery. If larvae are present in the flesh, they penetrate the tissues via the wound.

Pork tapeworms are the most dangerous of the three types, because its eggs may hatch before being discharged in the persons's feces or ova contaminating fingers or foods can be ingested and hatch. Larvae emerging from the ova do the same as they would do in a pig. Although humans are a poor excuse

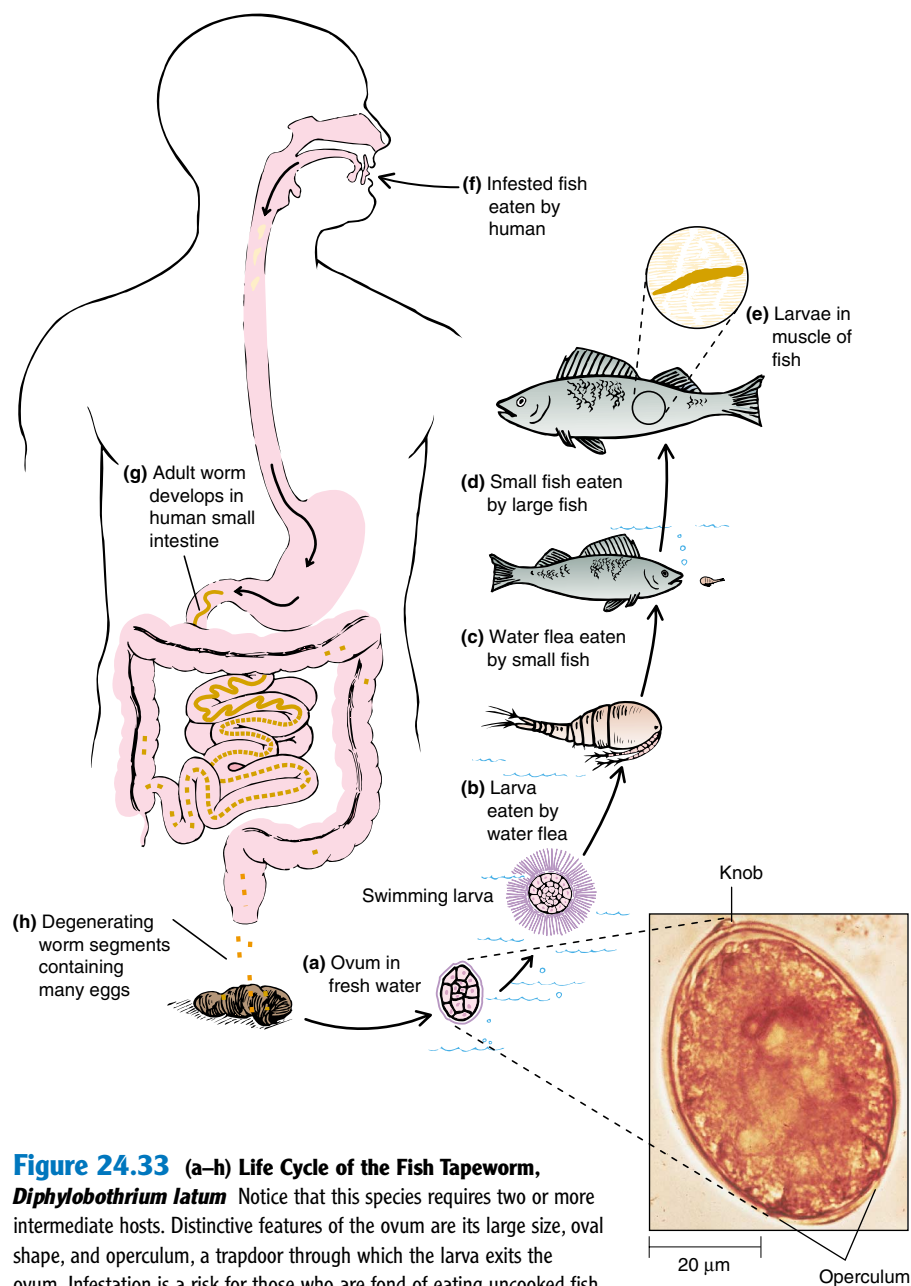


Figure 24.33 (a–h) Life Cycle of the Fish Tapeworm, *Diphyllobothrium latum* Notice that this species requires two or more intermediate hosts. Distinctive features of the ovum are its large size, oval shape, and operculum, a trapdoor through which the larva exits the ovum. Infestation is a risk for those who are fond of eating uncooked fish.

for an intermediate host, the larvae penetrate the intestinal wall by means of tiny hooklets. Then they enter the bloodstream, from which they invade tissues throughout the body, including the eyes, brain, heart, and muscles. In the tissues they develop into cysticerci, 0.5 to 5 or more cm in diameter. The condition resulting from cysticerci in the tissues is called **cysticercosis** and can mimic a brain tumor or cause epilepsy (figure 24.34).

Epidemiology

Tapeworm disease occurs wherever people eat raw meat or fish. The beef tapeworm is the most common in the United States, reported from eight states in one survey. The fish tapeworm mainly occurs in the north central part of the United States, where formerly outhouses were constructed so as to discharge directly into the lakes. The pork tapeworm is rare in the United States, but it may occur in immigrants from parts of Mexico, India, the Philippines, and other parts of the world where eating raw pork is traditional.

Prevention and Treatment

Control of tapeworms depends on adequate cooking of meat until it is no longer pink in the center. Fish should also be thor-

oughly cooked, or if eaten raw should be deep frozen for a week before eating. Proper disposal of human feces and good hygienic habits are especially important for controlling pork tapeworm disease. Effective medicines are available both for ridding the body of adult worms and for treating cysticercosis.

Giant Intestinal Fluke Disease (Fasciolopsiasis)

Fasciolopsiasis, disease caused by *Fasciolopsis buski*, may be acquired in a number of countries of Southern Asia, including parts of China, India, Myanmar (Burma), Thailand, Laos, Cambodia, Vietnam, Malaysia, Indonesia, and the Philippines. An estimated 10 million people are infested worldwide.

Symptoms

Symptoms of fasciolopsiasis are diarrhea, abdominal pain, generalized weakness, and swelling of the face and other parts of the body.

Causative Agent

Fasciolopsis buski, also known as the giant intestinal fluke, can be as large as 7.5 cm long and 2.0 cm wide. This hermaphroditic helminth lives in the upper and middle small intestine; attachment

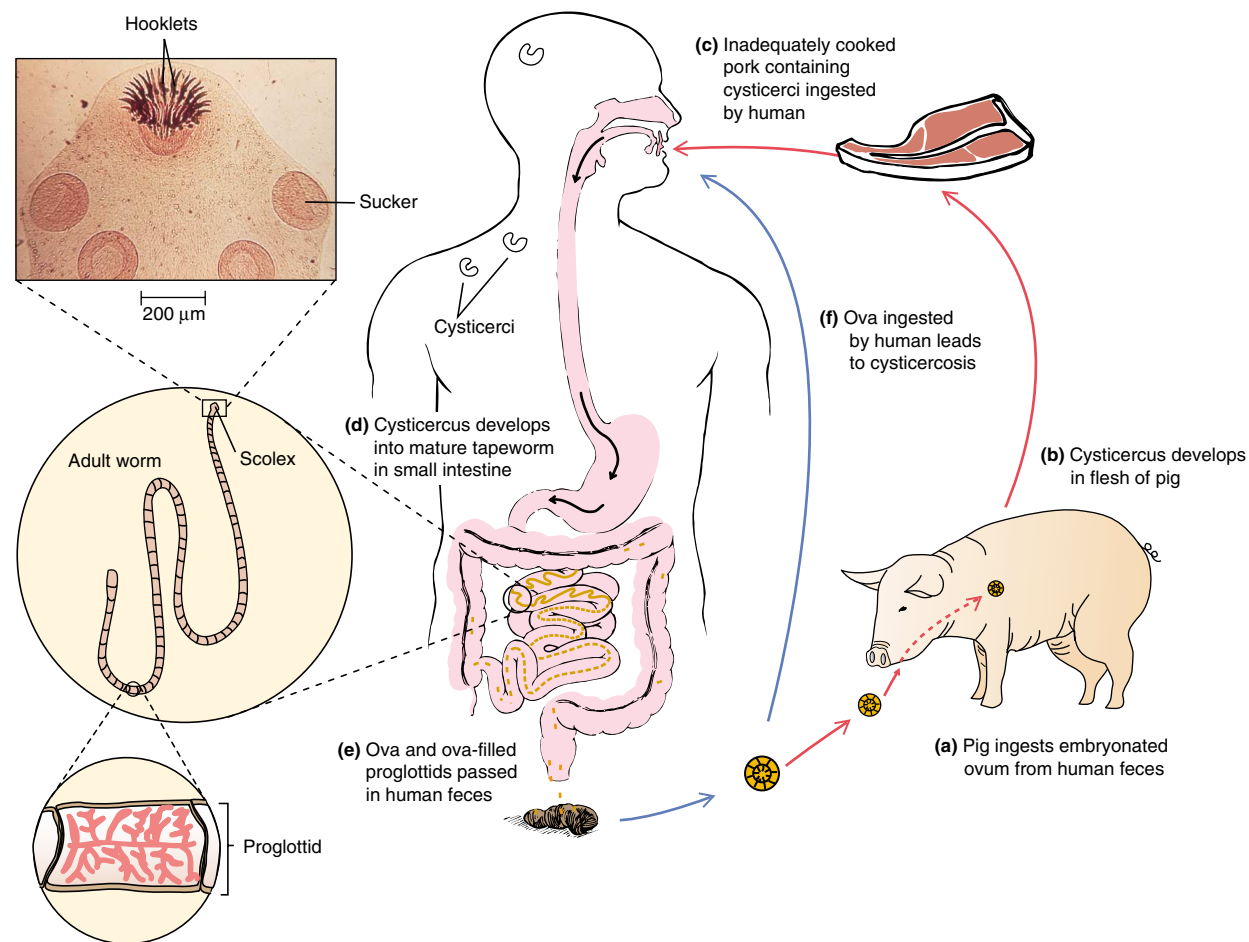


Figure 24.34 (a–e) Life Cycle of the Pork Tapeworm, *Taenia solium*, Acquired by Eating Inadequately Cooked Pork If worm ova hatch in the intestine, larval forms called cysticerci can develop throughout the person's tissues. A cysticercus in the brain can cause epilepsy.

and movement is aided by two suckers. Unlike tapeworms, flukes like *F. buski* have a digestive system. Ova are passed in the feces of the definitive hosts, humans and pigs, and the enclosed embryos mature in warm fresh water in about 6 weeks (**figure 24.35**). The ova then hatch, releasing ciliated larvae, which penetrate the flesh of certain snail species that serve as intermediate hosts. In the snail, the organisms develop and multiply asexually, eventually exiting the snail in the form of motile long-tailed larvae called **cercariae**. These cercariae attach to the outer covering of water plants such as water chestnuts, where they form cysts infectious for pigs and human beings. People generally become infected when they peel off the outer portion of water plants with their teeth in order to eat the edible inner portion of the plant. The worms exit from their cysts in the duodenum, attach, and after several months begin producing ova.

Pathogenesis

Inflammation occurs at the site of attachment of the helminths, followed by ulceration and bleeding. Heavy infestations can interfere with nutrition or even obstruct the intestinal tract. Severe symptoms also arise from toxicity and allergy to substances released by the worms and absorbed by the host's circulation.

Epidemiology

Fasciolopsiasis occurs in warm climates where people raise pigs and eat raw freshwater plants, and where a suitable snail intermediate host exists. Feces from infested humans or pigs most reach the ponds inhabited by the snails and edible water plants. Each adult worm produces more than 20,000 ova per day and lives about 1 year.

Prevention and Treatment

Fasciolopsiasis can be prevented by killing encysted *F. buski* on water plants by dipping them in boiling water for a few seconds before peeling and eating. Rinsing the edible portion thoroughly in clean water after peeling is probably also effective. The disease is effectively treated with praziquantel. **Table 24.17** compares some features of these parasitic helminths.

MICROCHECK

Tapeworms are ribbonlike creatures, consisting largely of a string of hermaphroditic egg-producing segments. The pork tapeworm, *Taenia solium*, is the most dangerous because its ova can hatch in the human intestine, the larvae entering brain and other tissues,

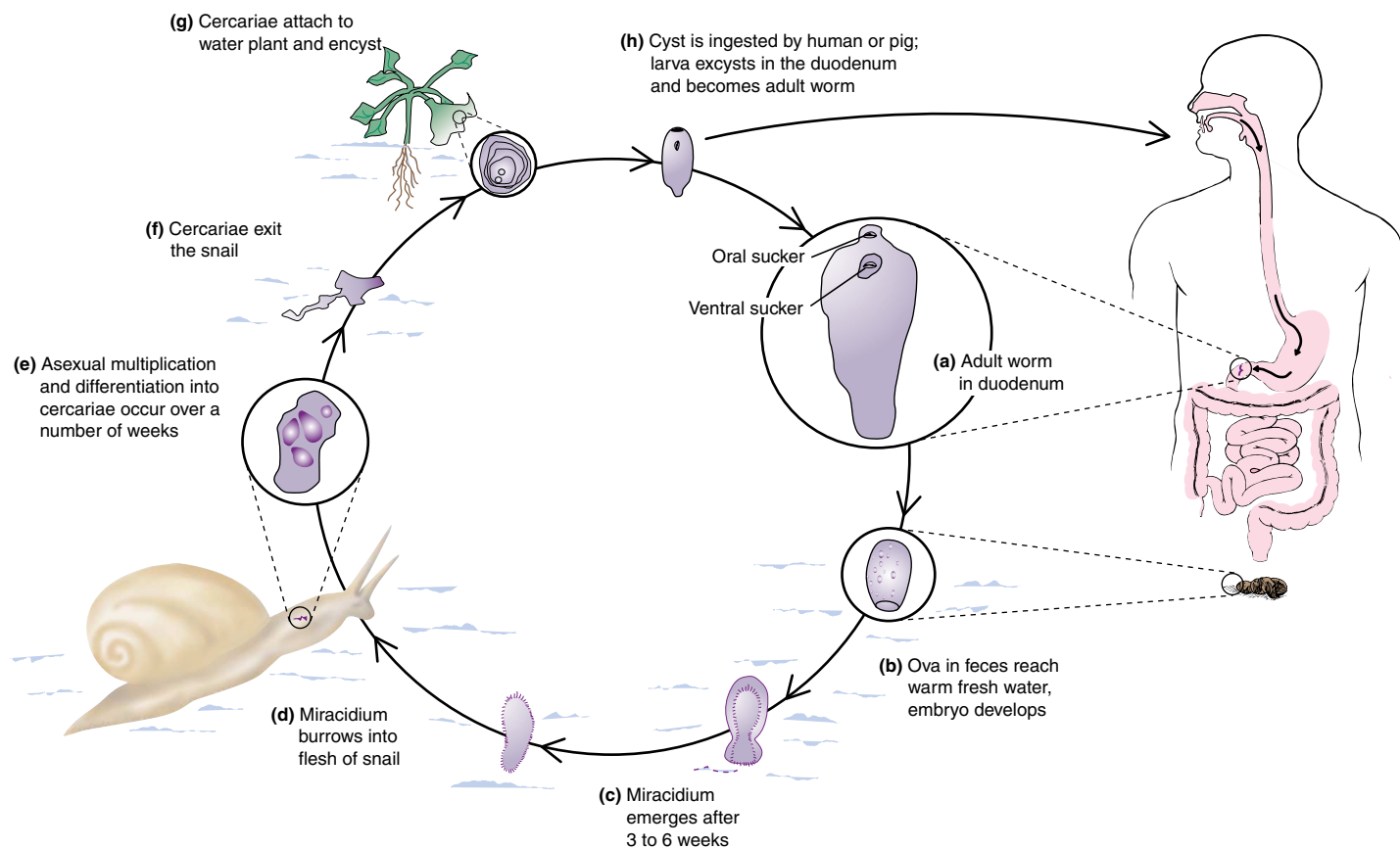


Figure 24.35 (a–h) Life Cycle of the “Giant Intestinal Fluke,” *Fasciolopsis buski* The infectious larva of this worm encysts on certain edible water plants, including a kind of water chestnut. People become infested when they peel the edible portion with their teeth.

TABLE 24.17 Notable Helminthic Diseases of Human Beings

Disease and Causative Agent	How Acquired	Disease Characteristics	Prevention and Control
Enterobiasis (pinworm), <i>Enterobius vermicularis</i>	Hand to mouth; inhalation	Itching of anal region, restlessness, nervousness, irritability, poor sleep	Handwashing, daily change of underclothing and bed sheets
Trichuriasis, (whipworm) <i>Trichuris trichiura</i>	Ingestion of eggs of parasite along with contaminated food or water	Abdominal pain, bloody stools, diarrhea, and weight loss	Sanitary disposal of human feces; frequent handwashing
Ascariasis, <i>Ascaris lumbricoides</i>	Ingestion of eggs of parasite or water along with contaminated food	Abdominal pain, live worms vomited or passed in stool	Sanitary disposal of human feces
Hookworm disease, <i>Necator americanus</i> and <i>Ancylostoma duodenale</i>	Larvae penetrate bare feet	Anemia, weakness, fatigue, physical and mental retardation in children	Sanitary disposal of human feces; wearing shoes
Strongyloidiasis, <i>Strongyloides stercoralis</i>	Larvae penetrate bare feet	Skin rash at site of penetration, cough, abdominal pains, weight loss	Sanitary disposal of human feces; wearing shoes
Trichinosis, <i>Trichinella spiralis</i>	Eating raw or undercooked meat, usually pork	Fever, swelling of upper eyelids, muscle soreness	Adequate cooking of meat
Tapeworm disease, <i>Taenia solium</i> , <i>T. saginata</i> , <i>Diphyllobothrium latum</i>	Eating raw or undercooked meat or fish	Abdominal pain, anemia, cysticercosis	Thorough cooking or deep freezing of meat and fish
Fasciolopsiasis, <i>Fasciolopsis buski</i>	Eating raw water plants with encysted larvae	Diarrhea, abdominal pain, weakness, body swelling	Brief treatment of plants in boiling water

resulting in cysticercosis. Tapeworm disease is usually acquired by eating inadequately cooked beef, pork, or fish. Fasciolopsiasis is caused by the giant intestinal fluke, a relatively short, nonsegmented hermaphroditic flatworm usually acquired when a person uses their teeth to peel certain edible aquatic plants having encysted fluke larvae on their surface.

- Describe the anatomy of a tapeworm.
- How might you explain the development of epilepsy in a Mexican man fond of eating traditional dishes made from raw pork?

FUTURE CHALLENGES

Defeating Diarrhea

Development of better preventive and treatment techniques for alimentary tract diseases has an urgency arising from massive food and beverage production and distribution methods. For example, in 1994, an estimated 224,000 people became ill because a tanker truck used to transport ice cream mix had previously carried liquid eggs. One day's production from a ground beef factory can yield hundreds of thousands of pounds of hamburgers, which are soon sent to many parts of this or other countries. The challenge is to better educate the producers and transporters, to develop guidelines to help them avoid contamination, and to utilize newly approved methods such as meat irradiation.

Other challenges include the following:

- Exploit the power of molecular biology techniques to produce effective vaccines against rotavirus, hepatitis C virus, and bacterial pathogens. There is special need for bacterial vaccines that can be administered by mouth and evoke long-lasting mucosal immunity.
- Find better ways of preventing and reversing resistance to antibacterial medications. In the early 1980s, 0.6% of *Salmonella Typhimurium* isolates were resistant to ampicillin, chloramphenicol, tetracycline, streptomycin, and sulfa drugs. Now, in some areas, over 30% of isolates of this common salmonellosis cause are resistant to all these medications.
- Explore further the influence of global warming on alimentary tract diseases. A study of Peruvian children by Johns Hopkins University scientists found an 8% increase in clinic visits for diarrhea with each 1°C increase in temperature from the normal.
- Explore new prevention and treatment options. Scientists at the University of Florida have developed a genetically engineered *Streptococcus mutans* that does not produce lactic acid but readily displaces wild strains of the dental decay causing bacterium. Researchers at the University of Alberta have custom-designed a molecule that binds circulating Shiga toxin, potentially preventing hemolytic uremic syndrome. Others work on finding an effective therapy for cryptosporidiosis.