

CHAPTER

8

Parasitology

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I. INTRODUCTION

A. Parasitic Disease Risk Factors

1. Unsanitary food handling/preparation (i.e., contaminated meats and vegetables)
2. Contaminated water for drinking or recreational use
3. Immunocompromised conditions resulting from disease states or poor nutrition
4. Blood transfusion and organ transplantation
5. Foreign travel to endemic regions of the world

B. Parasitic Disease Characteristics

1. **Diarrhea** is the most frequent symptom, along with abdominal cramping, seen in gastrointestinal tract infections.
2. **Other symptoms** depend on the parasite and the site of infection.
 - a. Intestinal obstruction, weight loss, and bloating
 - b. Organ involvement with ulcers, lesions, and abscesses
 - c. Blood and tissue parasites can cause anemia, fever, chills, bleeding, encephalitis, and meningitis.

C. Specimen Collection and Processing

1. Diagnosis of parasite infections often depends on observing parasite forms that include protozoa, ova, larva, or adult forms.
2. Specimen types include stools (most common), tissue, urine, sputum, and blood.
 - a. Stool samples should be free of antimicrobial agents or other substances that inhibit parasite growth. Barium (from enemas) can obscure parasites during microscopic examination.
 - 1) At least **3 grams of fecal sample** on three consecutive days are required for most parasite analyses.
 - 2) Because urea and acidic pH inhibit some parasites and distort their morphology, stool should be free of urine.
 - 3) **Liquid stools** are best to detect trophozoites, whereas **formed stools** are best to detect ova and cysts.
 - b. Stool preservatives
 - 1) Stool specimens should **not** be frozen, and **unpreserved** specimens should not be stored at room temperature longer than a couple of hours.
 - 2) **Formalin** (5 or 10%) is an all-purpose preservative to preserve stool specimens for concentration procedures.
 - 3) **Polyvinyl alcohol (PVA)** is a mercury-containing preservative for preparing permanent stained smears.
 - 4) **Sodium acetate formalin (SAF)** is a mercury-free preservative that can be used to preserve stool samples for both concentration and permanent stained smears.

- 5) Less toxic preservatives generally substitute **zinc sulfate** for mercury. Compared to PVA, these preservatives do not provide the quality of preservation of intestinal protozoa.
- c. Optimal detection of parasites often requires concentration of specimen.
 - 1) Gross examination of stool may detect adult forms, particularly helminths (worms).
 - 2) Concentration procedures for feces remove debris that could obscure parasites. Barium is not removed during concentration procedures.
 - 3) Fecal concentration methods
 - a) **Formalin-ethyl acetate sedimentation:** Approximately 3–4 grams of stool are suspended in 5 or 10% formalin. The suspension is filtered through gauze into a 15 mL centrifuge tube. Either 0.85% NaCl or 5 or 10% formalin is added to fill the tube almost completely. The tube is centrifuged at $500 \times g$ for 10 minutes. After centrifugation, the supernatant is discarded. The wash step is usually repeated until the supernatant is clear. After the last wash step, the sediment is resuspended in about 9 mL of formalin. A 4- to 5-mL aliquot of ethyl acetate is added; the tube is shaken vigorously for at least 30 seconds. The cap is loosened slightly to release the pressure in the tube. The tube is centrifuged again, and four layers should be visible (from top to bottom): ethyl acetate, plug of fecal debris, formalin, and fecal sediment. The plug is loosened from the side of the tube with an applicator stick, and the top three layers are poured off. The sediment is resuspended in formalin and used for wet mounts.
 - b) **Zinc sulfate flotation:** Approximately 3–4 grams of stool are suspended in 5 or 10% formalin. The suspension is filtered through gauze into a 15 mL centrifuge tube. The tube is centrifuged at $500 \times g$ for 10 minutes. After centrifugation, the supernatant is discarded. The wash step is usually repeated until the supernatant is clear. After the last wash step, the sediment is resuspended in about 3 mL of 33% aqueous solution of zinc sulfate. The specific gravity of the zinc sulfate should be adjusted to 1.20 in formalin fixed stools or to 1.18 in fresh (nonformalinized) stools. After resuspending the fecal material, the tube is filled to within 3–4 mm of the top. The tube is centrifuged for 2 minutes at $500 \times g$. Two layers will result: a small amount of sediment and a layer of zinc sulfate. One or two drops of the surface film should be removed with a bacteriological loop before removing the tube from the centrifuge. The liquid is examined for parasites.
 - c) **Sheather sugar flotation:** This procedure is similar to the zinc sulfate procedure, except sucrose is used in place of zinc. The sucrose solution has a specific gravity of 1.25–1.27. The Sheather

sugar flotation procedure is generally recommended for *Cryptosporidium* and some ova.

- 4) Blood concentration methods
 - a) The **Knott method** uses low-speed centrifugation to concentrate blood samples suspected of containing minimal numbers of parasites.
 - b) **Buffy coat** slides are used for *Leishmania* or *Trypanosoma* detection.
3. Various stains are used for microscopic detection of stool, tissue, and blood parasites.
 - a. **Saline wet mounts** are quick and easy to perform and will allow trophozoite motility and helminth ova and larvae to be seen.
 - b. **Iodine wet mounts** are useful for the detection of larvae, ova, and protozoan cysts in stool samples.
 - c. Permanent stained smears are used to enhance parasite morphology and to allow for future study. Stained fecal smears are important in the identification of *Entamoeba histolytica*.
 - 1) **Iron hematoxylin stain** of fecal smears is used when enhanced detail is needed; however, it is difficult to obtain consistent staining results.
 - 2) **Trichome stain (Wheatley or Gomori)** is the most commonly used stain for fecal parasite study.
 - 3) **Modified acid-fast stain** is used to detect *Cryptosporidium* and *Isospora*.
 - 4) **Modified trichrome stains** for microsporidia: The microsporidia are not easily stained; therefore, the concentration of the stain and the staining time is increased. Alternatively, a hot stain can be used. In the **Weber green stain**, microsporidia stain pink (oval, 1–3 µm) and the background is green. With the **Ryan blue stain**, the microsporidia also stain pink, but the background is blue.
4. Collection methods
 - a. The **cellophane (Scotch) tape** method is used to collect *Enterobius vermicularis* (pinworm) eggs from the perirectal area.
 - b. The **EnterоТest®** (string test) is used to obtain duodenal contents for parasitic examination.
 - c. Sigmoidoscopy is used to collect colon material.
5. Sample types and associated parasites
 - a. **Feces:** *Giardia*, *Cryptosporidium*, *Entamoeba*, *Ascaris*, *Enterobius*, etc.
 - b. **Blood:** *Plasmodium*, *Leishmania*, *Trypanosoma*, and microfilariae
 - c. **Skin:** *Onchocerca*
 - d. **Vaginal or urethral:** *Trichomonas*
 - e. **Eye scrapings:** *Acanthamoeba*
 - f. **Tissue:** *Naegleria*, *Acanthamoeba*, and *Leishmania*
 - g. **Urine:** *Schistosoma* and *Trichomonas*
 - h. **Sputum:** *Ascaris* and *Strongyloides*

D. Diagnostic Tests

1. Direct fluorescent antibody: Used to identify *Giardia lamblia*, *Cryptosporidium*, *Trichomonas vaginalis*
2. Direct agglutination test: Used to diagnose leishmaniasis and Chagas disease
3. ELISA: Used to identify *Giardia lamblia*, *Cryptosporidium*, *Toxoplasma gondii*
4. DNA probes and polymerase chain reactions are used to diagnose parasite infections.

E. Terminology

1. **Carrier:** An asymptomatic host that harbors a parasite and is capable of transmitting it to others
2. **Cestode:** Tapeworm
3. **Ciliate:** Protozoa motile by means of cilia
4. **Commensalism:** Symbiotic relationship beneficial to one member and harmless to another
5. **Cyst:** Thick-walled stage of protozoa resistant to adverse conditions
6. **Definitive host:** Host supporting the adult or sexual phase of a parasitic life cycle
7. **Ectoparasite:** Parasite found on the surface of a host
8. **Endoparasite:** Parasite found inside a host
9. **Filariae:** Blood or tissue roundworms
10. **Flagellate:** Protozoa motile by means of flagella
11. **Gravid:** Containing ova
12. **Helminths:** Worms that include nematodes (roundworms), cestodes (tapeworms), and trematodes (flukes)
13. **Hermaphroditic:** Organism capable of self-fertilization
14. **Host:** Living organism that harbors another organism
15. **Hydatid cyst:** Larval stage of *Echinococcus granulosus*
16. **Intermediate host:** Host containing the asexual phase of a parasite
17. **Larva:** Juvenile stage of a parasite
18. **Schizont**
 - a. **Immature schizont:** Early stage of asexual sporozoan trophozoite
 - b. **Mature schizont:** Developed stage of asexual sporozoan trophozoite
19. **Mutualism:** Symbiotic relationship beneficial to both species
20. **Nematode:** Roundworm
21. **Oocyst:** Encysted form of an egg
22. **Parasite:** An organism that obtains its nutrients from another organism (the host) while harming the host
23. **Parasitism:** Symbiotic relationship in which one member benefits at the expense of another member (the host)
24. **Symbiosis:** An association between two or more organisms of different species

25. **Trematode:** Fluke or flat worm
26. **Trophozoite:** Developmental stage of protozoa
27. **Zoonosis:** An animal infection or disease that humans accidentally acquire

II. INTESTINAL PROTOZOA

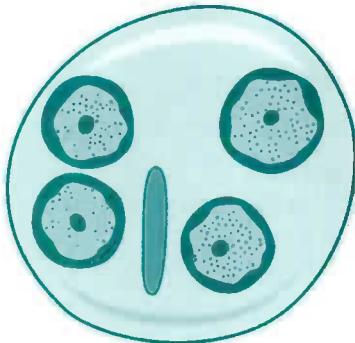
A. General Characteristics

1. **Pseudopods** are extensions of cytoplasm providing motility unique to amebae.
2. **Trophozoite** and **cyst** stages are part of the amebae life cycle.
3. Most amebic infections are spread to humans through contaminated water.
4. Cyst is the **infective stage**, whereas the trophozoite is the active reproduction stage destroyed by stomach acid.
5. **Laboratory identification:** Microscopic identification of cysts (in formed stools) and trophozoites (in liquid stools) based on size, nuclear characteristics, and inclusions
6. Size is one of the most important criteria for identification.
7. Morphologic terms associated with protozoa
 - a. **Karyosome:** Area of chromatin within the nucleus
 - b. **Peripheral chromatin:** Nucleic acid combined with protein found along the nuclear membrane
 - c. **Excystation:** Development of a cyst into a trophozoite
 - d. **Encystation:** Development of a trophozoite into a cyst
 - e. **Chromatoid bar:** Rod-shaped, RNA containing structure found in the cytoplasm

B. Intestinal Amebae

1. *Entamoeba histolytica*
 - a. The only ameba pathogenic for the gastrointestinal tract
 - 1) **Amebic colitis** is characterized by abdominal cramping, anorexia, fatigue, and diarrhea. Amebic colitis can also cause ulcers and amebic dysentery.
 - 2) Extraintestinal amebiasis primarily involves infections of the **liver**, but it is a rare complication.
 - 3) Additional conditions include infections of the spleen, brain, and lungs.
 - b. **Life cycle:** Cysts are infective when ingested. Excystation occurs in the small intestines. Infective cysts are passed in stools and are resistant to environmental stress.
 - c. **Morphology**
 - 1) **Cyst characteristics**
 - a) Cysts range in size from 8 to 22 μm , and they are spherical. See Figure 8-1■.
 - b) *E. histolytica* contains **one to four nuclei**; peripheral chromatin is fine and uniformly distributed.

- c) The **karyosome** is centrally located.
- d) **Cytoplasm** is finely granular with chromatoid bars with round ends.

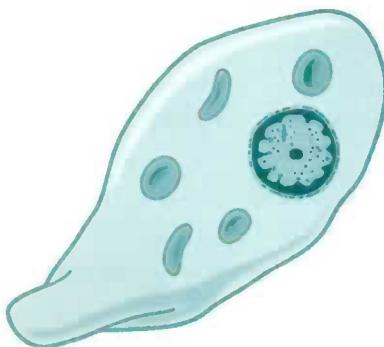


Size Range: 8–22 μm
Average Size: 12–18 μm

FIGURE 8-1 ■ *Entamoeba histolytica* cyst

2) Trophozoite characteristics

- a) Trophozoites range in size from 5 to 70 μm , and they are motile by means of pseudopods. See Figure 8-2■.
- b) *E. histolytica* trophozoites contain one nucleus, and they resemble those found in the cyst.
- c) **Cytoplasm** is finely granular and may contain red blood cell (RBC) inclusions. The presence of intracellular RBCs in intestinal amebae is considered diagnostic of *E. histolytica*.



Size Range: 8–65 μm
Average Size: 12–25 μm

FIGURE 8-2 ■ *Entamoeba histolytica* trophozoite

- 3) Morphologically, *E. histolytica* is identical to the nonpathogen *E. dispar*. These two species can be differentiated by immunologic assays detecting surface antigens.

2. *Entamoeba coli*

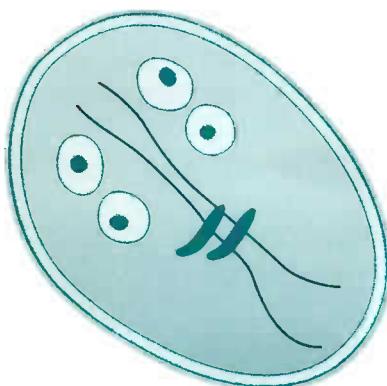
- a. *E. coli* is generally nonpathogenic but may cause intestinal problems in immunosuppressed patients.

- b. If found in a stool specimen, *E. coli* can indicate the presence of pathogenic organisms.
- c. Needs to be differentiated from *E. histolytica* for purposes of treatment
- d. **Morphology**
 - 1) **Cyst characteristics**
 - a) Cysts range in size from 8 to 40 µm, and they are spherical.
 - b) *E. coli* contains one to eight nuclei; the peripheral chromatin is coarse and unevenly distributed. Young cysts may contain a large central glycogen mass pushing two nuclei to the periphery of the cell.
 - c) The **karyosome** is eccentric and large.
 - d) The **cytoplasm** is coarse with thin chromatoid bars with pointed ends.
 - 2) **Trophozoite characteristics**
 - a) Trophozoites range in size from 10 to 60 µm, and they are motile by means of short/blunt pseudopods.
 - b) *E. coli* trophozoites contain a single nucleus with coarse, unevenly distributed chromatin, and they resemble those found in the cyst.
 - c) The **cytoplasm** is coarse and vacuolated, with bacterial inclusions.
- 3. ***Blastocystis hominis***
 - a. *B. hominis* is currently classified as an ameba, but rRNA analysis indicates it is related to algae and water moulds.
 - b. Associated with diarrhea and abdominal pain
 - c. Transmission is through contaminated food and water.
 - d. **Diagnosis:** Microscopic examination of stool sample
 - e. **Morphology:** The **classic form** varies in diameter from 4 to 60 µm and contains a **large central body** that fills about 90% of the cell volume. There is an outer ring of cytoplasm with several nuclei around the central body.
- 4. Other intestinal amebae
 - a. ***Entamoeba gingivalis*:** Causes asymptomatic mouth and genital tract infections
 - b. ***Iodamoeba bütschlii*:** Nonpathogenic intestinal parasite
 - c. ***Endolimax nana*:** Nonpathogenic intestinal parasite
 - d. ***Entamoeba hartmanni*:** Nonpathogenic intestinal parasite

C. Flagellates

1. General characteristics
 - a. Flagellates are a subclass of protozoa that have one or more flagellum that provide motility.
 - b. All flagellates have a trophozoite stage, but several lack the cyst stage.
 - c. Many flagellates live in the small intestines.
 - d. ***Giardia lamblia*** is the only pathogenic flagellate; it causes mild to moderate diarrhea. Severe infections can lead to malabsorption.
 - e. **Diagnosis** is by microscopic examination of stool for trophozoites or cysts.
 - f. Morphologic terms associated with flagellates

- 1) **Axostyle:** Rodlike structure that functions in cellular support
 - 2) **Axoneme:** The intracellular portion of the flagellum
 - 3) **Undulating membrane:** Flagellum finlike structure that generates a wavelike motion
 - 4) **Cytostome:** A rudimentary oral cavity
2. *Giardia lamblia*
- a. **Taxonomy:** *G. duodenalis* and *G. intestinalis* are synonyms.
 - b. *G. lamblia* causes giardiasis (a form of **traveler's diarrhea**) characterized by acute diarrhea, abdominal pain, and weight loss. Self-limiting infections last 10–15 days, following a 10- to 35-day incubation period.
 - c. Infection is due to exposure to contaminated water and food (mostly from wild animal stool). Campers and hunters are prone to infection after drinking untreated water from streams.
 - 1) Cysts are the infective stage.
 - 2) Cysts pass through the stomach and excyst in the duodenum.
 - 3) Trophozoites attach to the duodenum mucosa.
 - 4) **Encystation** occurs in the large intestines, and the cysts will pass in the stool.
 - d. **Diagnosis**
 - 1) Microscopic examination of stool samples for trophozoites and cysts
 - 2) Other diagnostic tests include the EnteroTest® and antigen detection by immunological assays (ELISA, etc.).
 - e. **Morphology**
 - 1) **Cyst characteristics**
 - a) *G. lamblia* cysts are oval shaped, and the average size ranges from 12 µm long to 8 µm wide. See Figure 8-3■.
 - b) Cysts contain **four nuclei** with no peripheral chromatin.
 - c) **Cytoplasm** is retracted from the cyst wall and may contain two to four comma-shaped, median bodies.

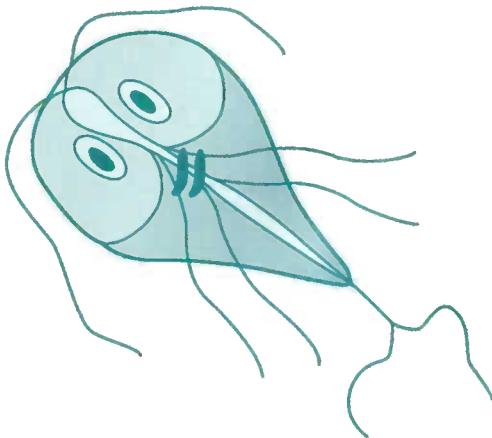


Size Range: 8–17 µm by 6–10 µm
Average Length: 10–12 µm

FIGURE 8-3 ■ *Giardia lamblia* cyst

2) Trophozoite characteristics

- G. lamblia* trophozoites have an average size of 15 μm long to 10 μm wide. They are motile and pear shaped, with bilateral symmetry and two large nuclei on each side of a central **axostyle**. See Figure 8-4 ■.
- Trophozoites contain **two oval-shaped nuclei**, without peripheral chromatin.
- Trophozoites possess four pair of **flagella**.
- Two median bodies, two axonemes, and a sucking disk are present.



Size Range: 8–20 μm by 5–16 μm
Average Length: 10–15 μm

FIGURE 8-4 ■ *Giardia lamblia* trophozoite

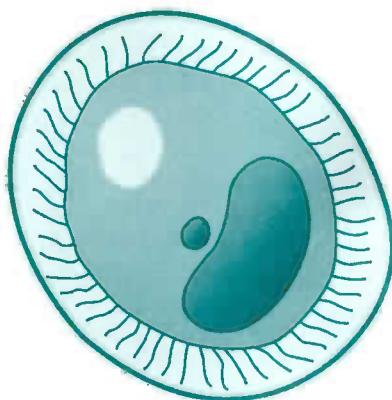
3. *Chilomastix mesnili*

- Generally nonpathogenic but has been associated with disease in immunosuppressed patients
- Infection is acquired from contaminated food or water containing the cyst stage, which is infective.
- Diagnosis is by microscopic examination of stool samples.
- Cyst characteristics**
 - The cyst ranges in size from 5 to 10 μm in length and is oval shaped.
 - C. mesnili* contains a single nucleus without peripheral chromatin.
 - The **karyosome** is large and centrally located.
 - The **cytostome** is well defined.
- Trophozoite characteristics**
 - Size ranges from 5 to 25 μm in length and 5 to 10 μm in width; they are pear shaped and motile.

- 2) Single nucleus without peripheral chromatin
 - 3) **Karyosome:** Eccentric and small
 - 4) **Flagella:** Three anterior and one posterior
 - 5) **Cytostome** is very large, and a spiral groove is present.
4. *Dientamoeba fragilis*
- a. Causes diarrhea, abdominal pain, and anal pruritus (itching)
 - b. Many cases of diarrhea caused by *D. fragilis* occur in individuals living in close quarters, such as inmates, college students, and military recruits.
 - c. *D. fragilis* infects the mucosal lining of the large intestines. There is no cyst stage, and the life cycle is not well defined.
 - d. Diagnosis is made from microscopic examination of trophozoites in the stool. Multiple samples are required. The parasite is very delicate and stains poorly.
 - e. **Trophozoite characteristics**
 - 1) Size ranges from 5 to 19 μm ; they are motile by means of hyaline pseudopods and are round shaped.
 - 2) Most cells contain two nuclei without peripheral chromatin but with clumps of nuclear chromatin.
 - 3) The **cytoplasm** is vacuolated with bacterial inclusions.

D. Ciliates

1. General characteristics
 - a. Motile by cilia
 - b. Trophozoites and cysts are part of the life cycle.
 - c. ***Balantidium coli*** is the only species pathogenic for humans.
2. ***Balantidium coli***
 - a. Causes balantidiasis, characterized by diarrhea to dysentery
 - b. Transmission of the infective cyst is through contaminated (feces) water or food.
 - c. **Diagnosis:** Microscopic examination of stool for cysts or trophozoites
 - d. **Morphology**
 - 1) **Cyst characteristics**
 - a) Ranges in size from 43 to 65 μm and is round in shape (Figure 8-5■)
 - b) *B. coli* contains two nuclei; one, the macronucleus, is kidney-shaped and very large. The micronucleus is round and much smaller; it is rarely seen.
 - c) Has a double cyst cell wall with numerous cilia between the two cell walls

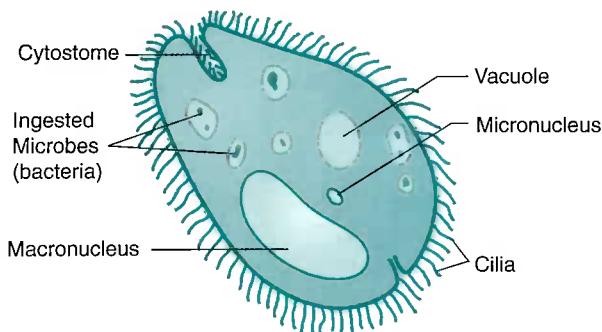


Size Range: 43–66 µm
Average Size: 52–55 µm

FIGURE 8-5 ■ *Balantidium coli* cyst

2) **Trophozoite characteristics**

- Trophozoites range in size up to 100 µm in length and 70 µm in width. See Figure 8-6■.
- Like the cyst, trophozoites contain two nuclei.
- Has one or two contractile vacuoles with cilia around the cell



Size Range: 28–152 µm by 22–123 µm
Average Size: 35–50 µm by 40 µm

FIGURE 8-6 ■ *Balantidium coli* trophozoite

E. Intestinal Sporozoa

1. *Cryptosporidium parvum*

- Causes cryptosporidiosis, which is characterized by moderate to severe diarrhea
- In patients with acquired immunodeficiency syndrome (AIDS), *Cryptosporidium* infections are an important cause of death due to dehydration.
- In the immunosuppressed patient, the parasite causes a wide range of debilitating problems, including malabsorption and stomach, liver, and respiratory disorders.

- d. Transmission of the infected oocyst is through contaminated food or water (rodent, cow, pig, or chicken feces). Human-to-human transmission has been documented in daycare centers.
- e. **Diagnosis:** Microscopic detection of **acid-fast oocysts** in stool or small bowel mucosal epithelial cells
- f. **Oocyst characteristics**
 - 1) The oval oocyst ranges in size from 4 to 6 µm.
 - 2) Oocysts contain four sporozoites enclosed within a thick cell wall.
 - 3) The cytoplasm may contain several dark granules.
- 2. *Cyclospora cayetanensis*
 - a. Humans are the only host for *C. cayetanensis*.
 - b. Nonbloody diarrhea is the most common symptom, although infections can be asymptomatic.
 - c. **Diagnosis** is made by examination of stained fecal smears. The **oocysts** will stain with the **modified Kinyoun's acid-fast stain** and are 8–10 µm in diameter.
- 3. *Isospora belli*
 - a. Causes isosporiasis, which is characterized by mild diarrhea to severe dysentery
 - b. Transmission is by ingestion of the infective oocyst in contaminated food and water.
 - c. Humans are the definitive host; there are no intermediate hosts.
 - d. **Diagnosis:** Microscopic examination of stool for oocysts by wet mounts and/or acid-fast or auromine-rhodamine stains
 - e. **Oocyst characteristics**
 - 1) The oval oocyst ranges in size from 25 to 40 µm in length.
 - 2) The cytoplasm is granular and contains two sporoblasts that contain four sporozoites each.

III. EXTRAINTESTINAL PROTOZOA

A. *Plasmodium*

1. Causative agents of malaria: *P. vivax*, *P. falciparum*, *P. malariae*, and *P. ovale*
2. *Plasmodium* spp. have two life cycle phases.
 - a. **Sporogony:** Sexual phase that occurs within the intestinal tract of the mosquito
 - b. **Schizogony:** Asexual phase that occurs in the human host
3. **Transmission**
 - a. Occurs with the bite of a **female *Anopheles* mosquito** that harbors the infective **sporozoites** in the salivary gland
 - b. Other forms of transmission include contaminated blood products, contaminated needles, and congenital malaria.

4. Diagnosis is made by clinical symptoms and **microscopic examination of blood smears.**
 - a. Because of the rapid progression of *P. falciparum* infections, examination of blood smears for malaria should be considered a **STAT procedure.**
 - b. Ideally, blood should be collected by finger stick and blood smears made immediately. Alternatively, **EDTA** (ethylenediaminetetraacetic acid) can be used as an anticoagulant in a venipuncture. Heparin can cause distortion of the parasites.
 - c. **Thick smears:** A large drop of blood is placed on a slide and allowed to air dry. The RBCs are lysed in distilled water, and the material is stained with Giemsa stain.
 - d. **Thin smears:** A drop of blood is placed on a glass microscope slide, and the blood is spread out on the slide using another slide. The smear is fixed in methanol to prevent RBC lysis and then stained.
 - e. Both thick and thin smears are thoroughly examined microscopically. The thick smear allows examination of about 20 times more blood volume than the thin smear, so it is much more **sensitive.** However, because the RBCs are intact, it is easier to identify the parasites in thin smears, which makes them more **specific.**
5. ***Plasmodium* morphology**
 - a. **Trophozoites or ring forms**
 - 1) Erythrocytic intracellular ringlike appearance
 - 2) Giemsa or Wright's stain will show a blue cytoplasmic ring connected to a red **chromatin dot.**
 - 3) Mature trophozoites will lose the ring appearance but will contain remnants of the cytoplasmic ring and chromatin dot.
 - b. **Schizonts**
 - 1) Active chromatin activity causes the parasite to increase in size.
 - 2) Pigmented granules are numerous and reddish-brown in color.
 - 3) Schizonts contain **merozoites;** the number and arrangement depend on the species.
 - c. **Gametocytes**
 - 1) Characterized by a chromatin mass staining pink to purple.
 - 2) The gametocytes of most species are round to oval in shape. *P. falciparum* gametocytes are "banana shaped."
 - 3) Pigmentation varies by species.
6. Diagnosis is primarily made by microscopic examination of Giemsa (stain of choice) or Wright's stained smears.
7. **Life cycle**
 - a. The **sporozoite** is the infective stage transmitted to humans by *Anopheles* mosquitoes.
 - b. The sporozoites infect hepatic cells and begin the **exoerythrocyte cycle.** *Plasmodium* spp. undergo **schizogony**, an asexual form of reproduction.

- c. Following schizogony, **merozoites** are produced that invade erythrocytes.
- d. A dormant form of *P. vivax* and *P. ovale*, called **hypnozoites**, can remain in the liver. Reactivation of the hypnozoites results in a **recurrence** (true relapse).
- e. Merozoites infect RBCs and initiate the **erythrocyte cycle**. Merozoites develop into ring forms and reproduce by schizogony.
- f. Instead of undergoing schizogony, some merozoites develop into **microgametocytes** or **macrogametocytes**. These stages are transmitted to the mosquito during human blood meal for completion of the life cycle (sexual phase).
- g. The RBC form of the parasites can be nearly eliminated by treatment or an immune response, and the patient may become asymptomatic. After several weeks, the parasites can increase in number and the symptoms will return; this is referred to as **recrudescence**. All four *Plasmodium* spp. can cause a recrudescence.

8. *Plasmodium vivax*

- a. Infected erythrocytes appear enlarged and pale with prominent **Schüffner's dots**. Only reticulocytes are infected, thus limiting the parasitemia to 2–5%. Table 8-1 ■ compares the important characteristics of the *Plasmodium* spp.

TABLE 8-1 CHARACTERISTICS OF HUMAN *PLASMODIUM* spp.

Characteristic	<i>P. vivax</i>	<i>P. falciparum</i>	<i>P. malariae</i>	<i>P. ovale</i>
Persistence of exo-erythrocytic cycle	Yes	No	No	Yes
Length of replication cycle (hours)	44–48	36–48	72	48
Shüffner's dots	Usually present in all infected RBCs except with early ring forms	Absent	Absent	Usually present in all infected RBCs
Number of merozoites in mature schizont	16 (12–24)	Schizonts not seen in peripheral blood	8 (6–12)	8 (8–12)
Important criteria for identification	Infected RBCs enlarged, trophozoites irregular shaped, Schüffner's dots	Multiple ring forms seen in single RBC, crescent shaped gametes and ring shaped young trophozoites are only forms seen	Infected RBCs normal size and color, trophozoites compact and band forms may be seen	Infected RBCs enlarged and often oval shaped with fimbriated edges, trophozoites irregular shaped, Schüffner's dots

- b. **Trophozoite:** Ring stage is one-third the size of an RBC; mature trophozoites fill the entire RBC.
 - c. **Schizont** contains 12 to 24 merozoites.
 - d. **Gametocyte:** Round to oval with a large chromatin mass that almost fills the RBC
 - e. **Fever cycle** lasts 48 hours.
 - f. *P. vivax* causes benign tertian malaria following a 10- to 17-day incubation period. It is the most common cause of malaria.
9. ***Plasmodium falciparum***
- a. Infected erythrocytes appear normal in size, and all ages of RBCs can be infected, which can result in a large number of infected cells.
 - b. **Trophozoite:** Ring stage is one-fifth the size of the RBC, and multiple rings are found in a single RBC. Some trophozoites will have two chromatin dots in one ring form.
 - c. **Schizonts** are rarely seen in peripheral blood smears.
 - d. Crescent- or banana-shaped **gametocytes** are diagnostic of *P. falciparum*.
 - e. Miscellaneous characteristics: The interval between **paroxysms** (intense fever and chills) is 24 hours. Patients have a high ratio of infected RBCs to uninfected RBCs compared to other *Plasmodium* spp.
 - f. *P. falciparum* causes malignant tertian malaria (**blackwater fever**) following a 7- to 10-day incubation period.
10. ***Plasmodium malariae***
- a. Infected erythrocytes appear normal in size without dots; *P. malariae* prefers to infect older RBCs.
 - b. **Trophozoites** appear similar to *P. vivax* but stain a more intense blue. Mature trophozoites can produce **band forms**, which spread across the diameter of the RBC.
 - c. **Schizonts** average 8 to 12 merozoites arranged in rosettes.
 - d. **Gametocytes** resemble *P. vivax*.
 - e. Fever cycle is 72 hours.
 - f. *P. malariae* causes quartan or malarial malaria following an 18- to 40-day incubation period.
11. ***Plasmodium ovale***
- a. Infected RBCs appear enlarged with thicker ring forms and contain Schüffner's dots. Infected RBCs resemble those infected with *P. vivax*; however, *P. ovale*-infected RBCs are often oval shaped and have irregularly shaped membranes with projections. Like *P. vivax*, only reticulocytes are infected.
 - b. **Trophozoites** maintain their ring appearance as they develop.
 - c. **Schizont:** Averages 4 to 8 merozoites arranged in rosettes
 - d. **Gametocyte** resembles *P. vivax* but slightly smaller.
 - e. *P. ovale* causes benign tertian or ovale malaria following a 10- to 20-day incubation period.

B. *Babesia microti*

1. ***B. microti*** causes babesiosis, which can affect the spleen, liver, and kidneys. *B. microti* is an **erythrocytic intracellular parasite**, like *Plasmodium* spp., that can also cause hemolytic anemia.
2. Babesiosis is a self-limiting infection; death is a rare outcome.
3. The infective sporozoite is transmitted to humans by a tick bite (*Ixodes scapularis*).
4. Diagnosis is made by blood smear examination and serologic testing. It is difficult to differentiate *Babesia* spp. from *Plasmodium* spp.
5. **Ring form characteristics**
 - a. Size ranges from 3 to 5 μm .
 - b. Cytoplasm: Minimal with two or more chromatin dots
 - c. Two to four rings per RBC are often seen, sometimes appearing like a "Maltese cross."

C. *Toxoplasma gondii*

1. **Toxoplasmosis** is characterized by a broad spectrum of symptoms depending on the individual's state of health. *T. gondii* has a predilection for **central nervous system (CNS)** infections.
 - a. In healthy individuals, toxoplasmosis often resembles infectious mononucleosis and produces fatigue, swollen lymph glands, fever, and myalgia. The disease can become chronic and affect the heart and liver.
 - b. **Congenital toxoplasmosis** occurs in premature or antibody-deficient infants, where symptoms include splenomegaly, jaundice, and fever. CNS infections can lead to developmental complications, including vision and hearing problems, hydrocephalus, and mental retardation.
 - c. In patients with immunosuppression, such as AIDS, the parasite becomes localized in the CNS with symptoms of encephalitis and brain lesions, often resulting in death.
2. **Transmission to humans**
 - a. The sexual stage of reproduction occurs in the intestinal tract of **house cats**. The infective form (**oocysts**) of the parasite is passed in the stool, and the **ingestion of cat feces**—contaminated food and water can produce infection.
 - b. **Ingestion** of undercooked meat (**lamb and pork**) containing viable tissue cysts
 - c. **Transplacental** transmission from the infected mother to the fetus
3. **Diagnosis:** Serologic testing for *Toxoplasma* antibody
4. Because **tachyzoites** and **bradyzoites** are small and no single organ is typically involved, it is difficult to diagnose infection by microscopic examination of tissue samples.
5. Tachyzoites (trophozoites) range in size from 1 to 3 μm and are crescent to round in shape.
6. Cysts contain many bradyzoites.

D. *Naegleri fowleri*

1. Causes amebic meningoencephalitis, which is often fatal within 3–6 days
2. *N. fowleri* is found in lakes, ponds, and swimming pools where the water is warm.
3. **Life cycle:** Trophozoites are the infective stage. *N. fowleri* does not need a host to survive and can be free living, spending its entire life cycle in the external environment.
4. The amebae are contracted from contaminated water, where trophozoites enter the body through the nasal mucosa and migrate along the olfactory nerve to the brain.
5. Diagnosis is made by finding the organism (ameba) in cerebrospinal fluid (CSF) or brain biopsies.
6. **Morphology**
 - a. **Cyst characteristics**
 - 1) The round cyst ranges in size from 10 to 13 μm .
 - 2) *N. fowleri* cysts contain a single nucleus, without peripheral chromatin.
 - 3) The **karyosome** is centrally located and large.
 - b. **Trophozoite characteristics**
 - 1) Size ranges from 10 to 23 μm , and they are motile by means of blunt pseudopods.
 - 2) Trophozoites contain a single nucleus, without peripheral chromatin.
 - 3) The **cytoplasm** is granular and vacuolated.
 - c. **Flagellate characteristics**
 - 1) Flagellates range in size from 7 to 15 μm and are pear shaped. They are motile by means of two flagella.
 - 2) The single nucleus is indented.
 - 3) **Karyosome** is centrally located and large.
 - 4) The **cytoplasm** is granular and vacuolated.

E. *Acanthamoeba*

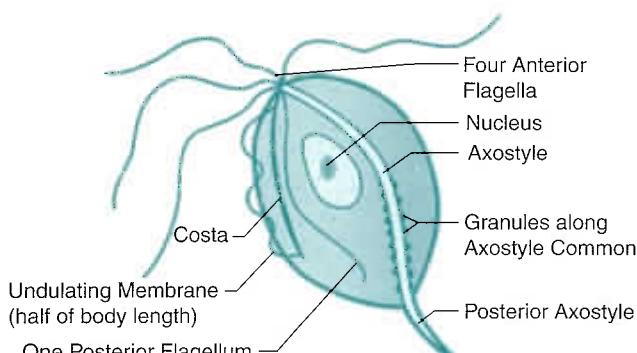
1. Causes amebic encephalitis and amebic keratitis (cornea infection)
2. The life cycle is not well characterized.
 - a. The eye is directly invaded by trophozoites, producing keratitis.
 - b. Skin, respiratory tract, and CNS infections are caused by the cyst or trophozoite stage (unknown entry route).
3. **Diagnosis** is made by finding the cyst or trophozoite stages in CSF.
4. **Morphology**
 - a. **Cyst characteristics**
 - 1) Size ranges from 8 to 25 μm with a jagged edge and a round shape.
 - 2) Single nucleus without peripheral chromatin
 - 3) The **karyosome** is centrally located and large.
 - 4) The **cytoplasm** is granular and vacuolated.

b. Trophozoite characteristics

- 1) Size ranges from 15 to 45 μm ; motility is by spinelike pseudopods.
- 2) Contains a single nucleus without peripheral chromatin
- 3) The **karyosome** is centrally located and large.
- 4) The **cytoplasm** is granular and vacuolated.

F. *Trichomonas vaginalis*

1. Causes **vaginitis** in women, whereas men are generally asymptomatic carriers
2. *T. vaginalis* is a sexually transmitted disease and can infect neonates (aspiration pneumonia) during delivery.
3. Trophozoites are the infective stage and infect the epithelial or mucosal lining of the vagina, urethra, and prostate gland. *T. vaginalis* does not have a cyst stage.
4. **Diagnosis:** Trophozoites are usually detected during a microscopic urinalysis.
5. **Trophozoite characteristics**
 - a. Trophozoites average about 30 μm in length. They are motile, with an **undulating membrane**, and are pear shaped. See Figure 8-7 ■.
 - b. Single prominent nucleus
 - c. **Flagella:** Three to five anterior and one posterior
 - d. Large axostyle with cytoplasmic granules



Size Range: up to 30 μm long
Average Length: 8–15 μm

FIGURE 8-7 ■ *Trichomonas vaginalis* trophozoite

G. Hemoflagellates

1. General characteristics
 - a. Hemoflagellates inhabit the blood and tissues of humans.
 - b. Four stages of development: amastigote, promastigote, epimastigote, and trypomastigote
 - 1) **Amastigote:** Nonflagellated oval form, found in tissue
 - 2) **Promastigote:** Flagellated stage found in the vector, rarely seen in the blood

- 3) **Epimastigote:** Long, slender flagellated form found in arthropod vectors
- 4) **Trypomastigote:** Has an undulating membrane running the length of the body; found both in the vector and bloodstream of humans. See Figure 8-8■.
- c. Transmission to humans is by arthropod bites.

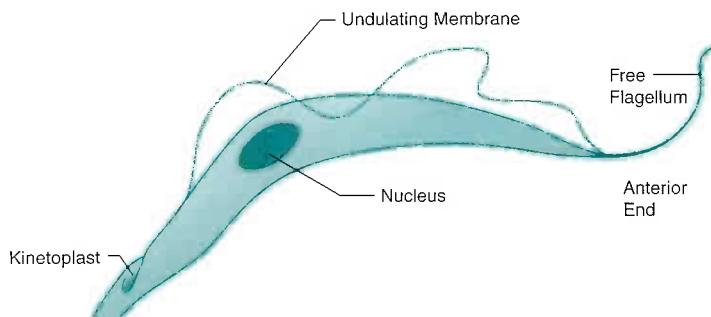


FIGURE 8-8 ■ *Trypanosoma* trypomastigote

- 2. **Trypanosoma**
 - a. Diagnosis is made by microscopic examination of blood and CSF and serologic testing.
 - b. Trypanosomiasis occurs mainly in Africa and South America.
 - c. Pathogenic species
 - 1) **Trypanosoma brucei**
 - a) *T. brucei* causes **African trypanosomiasis** or **sleeping sickness**, and infection affects the lymphatic system and CNS. Swollen lymph nodes at the posterior base of the neck (Winterbottom's sign) are sometimes present.
 - b) Subspecies ***gambiense*** and ***rhodesiense*** are named according to their geographic location.
 - 2) **Trypanosoma cruzi**
 - a) Causes **Chagas disease** or **American trypanosomiasis**, which is characterized by lesion formation (**chagoma**), conjunctivitis, edema of the face and legs, and heart muscle involvement leading to myocarditis.
 - b) Mostly found in South America
 - 3. **Leishmania**
 - a. Human leishmaniasis
 - 1) **Cutaneous leishmaniasis** is characterized by skin and mucous membrane ulcers.
 - 2) **Disseminated leishmaniasis:** Liver, spleen, and reticuloendothelial involvement
 - b. **Diagnosis:** Finding the amastigote in the blood or tissue and serologic testing
 - c. Mainly a disease of Africa, Eastern Europe, and South/Central America

IV. TREMATODES

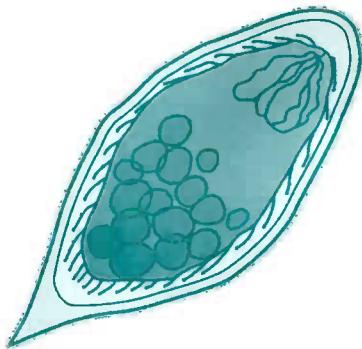
A. General Characteristics

1. Trematodes (**flukes**) are a class of helminths pathogenic to humans.
2. Trematodes are flat, hermaphroditic (except the schistosomes), and have at least two suckers: One opens into the digestive tract and one is for attachment.
3. Morphologic terms associated with trematodes
 - a. **Cercaria:** Final stage of development occurring in snails; motile by means of a tail
 - b. **Metacercaria:** Encysted form occurring in the second intermediate host (fish or crayfish)
 - c. **Miracidium:** First larval stage that emerges from the egg in fresh water
 - d. **Sporocyst:** Emerges from the miracidium as a saclike structure containing the larva
 - e. **Redia:** Intermediate larval stage occurring in the sporocyst
 - f. **Schistosomulum:** Resulting form when the cercaria penetrates human skin and loses its tail
4. Life cycle
 - a. **Eggs** are usually passed with feces into the water, where they hatch.
 - b. Free-swimming **miracidia** are released, which are then ingested by snails (the intermediate host).
 - c. **Sporocytes** (schistosomes) or **redia** (trematodes) develop in the snail, resulting in the replication of hundreds of cercariae.
 - d. **Cercariae** are infective to humans, in whom they are acquired by swimming in infested water.
 - e. **Diagnosis:** Examination of feces for adult forms or ova or, in the case of schistosomes, feces and urine examination for ova
 - f. Trematodes can infect many organs, especially the intestines, liver, and lungs.

B. *Schistosoma*

1. Species pathogenic for humans include *S. mansoni*, *S. haematobium*, *S. japonicum*, and less frequently *S. mekongi* and *S. intercalatum*.
2. *Schistosoma* spp. cause schistosomiasis, which is characterized by abdominal pain, bloody diarrhea, and hepatosplenomegaly. They can also cause intestinal lesions and blockage. *S. haematobium* adults reside in the blood vessels around the **bladder**. The eggs penetrate the bladder and are passed in the urine. Patients often present with **hematuria**.
3. Prevalent in Africa but also seen in Puerto Rico and South America
4. Humans acquire the infective cercariae from contaminated water when the parasite penetrates the skin.
5. **Diagnosis** is made by microscopic examination of feces or urine for eggs. Adult forms are rarely seen in human blood samples.

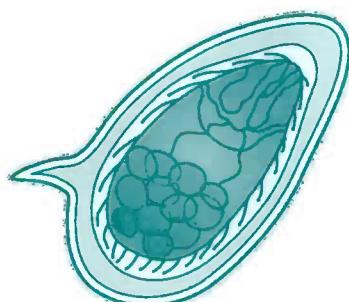
6. **Morphology:** Eggs of different species are diagnostic.
- S. haematobium:* Large terminal spine (Figure 8-9■)



Size Range: 110–170 μm by 38–70 μm

FIGURE 8-9 ■ *Schistosoma haematobium* egg

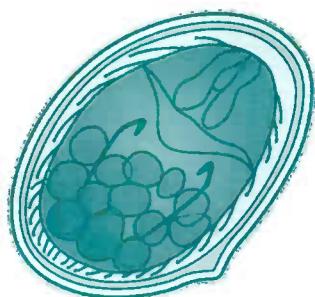
- S. mansoni:* Large lateral spine (Figure 8-10■)



Size Range: 112–182 μm by 40–75 μm

FIGURE 8-10 ■ *Schistosoma mansoni* egg

- S. japonicum:* Small inconspicuous lateral spine (Figure 8-11■)

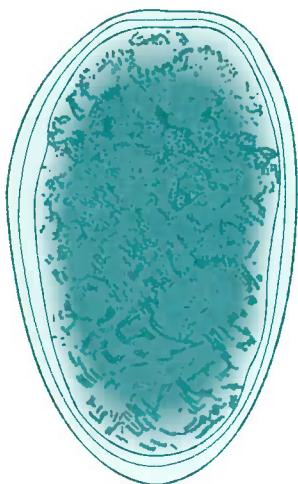


Size Range: 50–85 μm by 38–60 μm

FIGURE 8-11 ■ *Schistosoma japonicum* egg

C. *Paragonimus westermani* (lung fluke)

1. *P. westermani* causes pulmonary infections characterized by chest pain, cough, bronchitis, and sputum with blood.
2. Humans acquire infection by ingesting metacercariae in undercooked crabs and crayfish. Adult forms develop in human lung tissue.
3. Most infections occur in Africa, India, and South America.
4. **Diagnosis:** Microscopic examination of feces for eggs
5. **Morphology:** Eggs range in size from 72 to 130 μm in length with a prominent operculum. See Figure 8-12■.

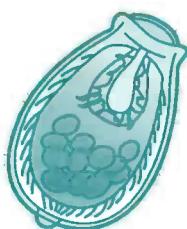


Size Range: 72–130 μm by 48–60 μm

FIGURE 8-12 ■ *Paragonimus westermani* egg

D. *Clonorchis sinensis* (Chinese or oriental liver fluke)

1. Causes liver problems characterized by fever, abdominal pain, and diarrhea
2. Found mainly in China and the Far East
3. Humans acquire the disease by eating undercooked fish containing encysted metacercariae.
4. **Diagnosis:** Egg detection in stool sample
5. **Morphology:** Egg contains miracidium with small knob opposite the operculum. See Figure 8-13■.



Average Size: 30 μm by 15 μm

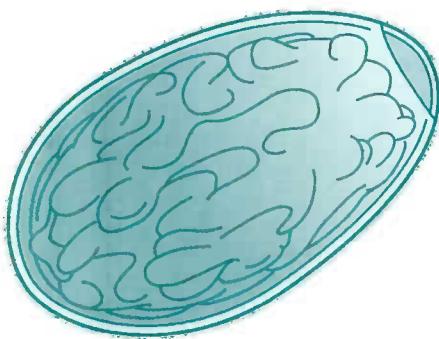
FIGURE 8-13 *Clonorchis sinensis* egg

E. *Fasciolopsis buski* (intestinal flukes)

1. Causes intestinal problems, including diarrhea and ulceration of the intestines and possibly the stomach
2. Found in China and the Far East
3. Humans acquire infections by ingesting metacercariae on water plants (e.g., water chestnuts and bamboo).
4. **Diagnosis:** Egg detection in stool sample
5. **Morphology:** Eggs are large, oblong (130–140 µm by 80–85 µm) and contain an operculum. See Figure 8-14 ■.

F. *Fasciola hepatica* (liver fluke)

1. Primarily a zoonosis of sheep affecting the liver
2. Found in South America and the Mediterranean area
3. Humans acquire infections by ingesting metacercariae on water plants (e.g., watercress).
4. **Diagnosis:** Egg detection in stool sample
5. **Morphology:** Eggs are large, oblong (130–150 µm by 63–90 µm), and contain an operculum. See Figure 8-14 ■.



Fasciolopsis Size Range: 128–140 µm by 78–85 µm
Fasciola Size Range: 128–150 µm by 60–90 µm

FIGURE 8-14 *Fasciola hepatica* egg

V. CESTODES

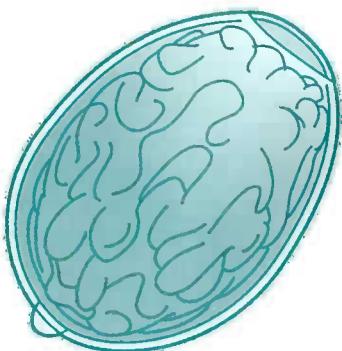
A. General Characteristics

1. Cestodes are a subclass of helminths comprising true **tapeworms**.
2. **Morphology**
 - a. The **scolex** is the anterior portion of the body containing suckers and sometimes hooklets responsible for attachment to the host. The “crown” of the scolex is called the **rostellum**.
 - b. **Proglottids** make up the major portion of the tapeworm; they contain male and female reproductive structures.

- c. The **neck region** is located directly behind the scolex and is the site of new proglottid production.
- d. **Strobila** is the entire length of the tapeworm except for the scolex and neck.
3. Cestodes have three **life cycle stages**: egg, larval stage(s), and the adult worm.
4. Cestodes have several intermediate hosts.
5. **Diagnosis:** Microscopic examination of stool samples for eggs or proglottids
6. **Transmission** of infective eggs occurs with contaminated food and water. Contamination can come from the feces of cows, pigs, fish, and humans.

B. Cestodes Pathogenic for Humans

1. ***Taenia saginata* and *T. solium***
 - a. *T. saginata* and *T. solium* cause infections that are typically mild and characterized by abdominal pain and mild diarrhea.
 - b. Infection is by the ingestion of undercooked **beef** (*T. saginata*) or **pork** (*T. solium*) that contains the **cysticercus larvae**.
 - c. In rare cases, humans are the **intermediate host** following the ingestion of *T. solium* ova. This causes a larval form of extraintestinal disease called **cysticercosis**, which causes lesions in the cerebral cortex and other body sites that can be fatal.
 - d. **Diagnosis** is made by microscopic examination of stool specimens for ova. The eggs of the two species are identical. Species identification relies on proglottid or scolex analysis.
 - e. **Egg morphology**
 - 1) Range in size from 30 to 40 µm
 - 2) Three pairs of hooklets
 - 3) Have radial striations
2. ***Diphyllobothrium latum* (fish tapeworm)**
 - a. Infection is acquired by eating raw or undercooked fish containing the **pleurocercoïd**)
 - b. *D. latum* infection causes intestinal pain, diarrhea, and sometimes vitamin B₁₂ deficiency. Individuals with pernicious anemia are predisposed to more severe symptoms.
 - c. Infections occur in populations that eat raw fish, such as northern Europe and Japan.
 - d. **Diagnosis:** Egg detected in stool samples
 - e. **Egg morphology**
 - 1) Range in size from 50 to 80 µm in length and are oblong in shape (Figure 8-15■)
 - 2) The shell is smooth and color is yellow to brown.
 - 3) Terminal knob is located at one end opposite of the operculum.



Size Range: 55–75 μm by 40–55 μm
Average Size: 65 μm by 48 μm

FIGURE 8-15 *Diphyllobothrium latum* egg

3. *Hymenolepis nana* (dwarf tapeworm)
 - a. Causes abdominal pain and diarrhea
 - b. Humans usually acquire the infection by ingestion of **ova** found in mice or human **feces**.
 - c. Most common tapeworm in the U.S.
 - d. **Diagnosis:** Egg detection in stool samples
 - e. **Egg morphology**
 - 1) The average size is 40 μm , and ova are round.
 - 2) Contains three pairs of hooklets
 - 3) Polar thickening of the shell is common.
4. *Hymenolepis diminuta* (mouse and rat tapeworm)
 - a. Causes abdominal pain and diarrhea
 - b. Humans acquire the infection from the ingestion of **insects** containing the **cysticercoids**.
 - c. **Diagnosis:** Egg detection in stool samples
 - d. **Egg morphology**
 - 1) Average size of the round egg is 40 μm .
 - 2) Contains three pairs of hooklets
5. *Echinococcus granulosus* (dog tapeworm)
 - a. Human infection results in the development of a **hydatid cyst** in many body sites (hydatid disease). As the cyst grows, surrounding tissue is destroyed. Depending on cyst location, death can occur. The release of hydatid cyst fluid may cause anaphylactic shock.
 - b. Infections are most common where **sheep** (intermediate host) are raised, including England, South America, and Australia. Some cases have been reported in Alaska.
 - c. Humans acquire the infection by ingesting ova in dog feces. The dog acquires the parasite by consuming infected sheep meat. Humans are intermediate hosts.

- d. **Diagnosis:** Analysis of hydatid cyst fluid containing cysts and other parasite components, and serologic testing
- e. The cyst contains fluid, daughter cysts, brood capsules, and hydatid sand.

VI. NEMATODES

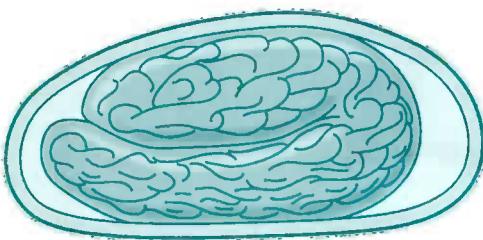
A. General Characteristics

- 1. Nematodes (roundworms) are a class of helminths.
- 2. Adult nematodes have a tapered, cylindric body with an esophagus and longitudinal muscles.
- 3. **Diagnosis** is based on adult, larvae, or egg morphology.
- 4. Nematode life cycles vary as to species and can be quite complex.
 - a. Most species require an intermediate host to develop into an infective form.
 - b. Some nematodes are transmitted through the ingestion of eggs.
 - c. Other nematode infections are transmitted by larvae, which must gain entry through the skin on their way to the intestines.
- 5. Nematodes cause diseases associated with the intestines and the skin, including diarrhea, vomiting, and skin lesions.
- 6. Nematodes are placed into one of two groups: the **intestinal nematodes** and the **intestinal-tissue nematodes**.
 - a. Intestinal nematodes
 - 1) *Enterobius vermicularis*
 - 2) *Trichuris trichiura*
 - 3) *Ascaris lumbricoides*
 - 4) *Strongyloides stercoralis*
 - 5) *Necator americanus*
 - 6) *Ancylostoma duodenale*
 - b. Intestinal-tissue nematodes
 - 1) *Trichinella spiralis*
 - 2) *Dracunculus medinensis*

B. *Enterobius vermicularis*

- 1. *E. vermicularis*, **pinworm**, causes infections (**enterobiasis**) that are usually self-limiting and characterized by itching and inflammation of the anus. Enterobiasis can be asymptomatic.
- 2. Pinworm infections are common in the U.S., especially in school-age children.
- 3. **Life cycle**
 - a. Infective eggs are ingested, and larvae are released in the **small intestines**.
 - b. Larvae develop into adult worms in the colon.
 - c. Gravid females migrate to the **perianal region**, where eggs are laid.
 - d. The eggs are infective following a 6-hour incubation period.

- e. Itching results from the irritation caused by the deposition of eggs. Eggs are spread from the perianal region by scratching.
 - f. The eggs will be infective for several weeks and can be found in dust, clothing, etc.
4. **Diagnosis**
- a. Based on the identification of ova from a tape preparation in which the sticky side of tape is pressed to the perianal skin
 - b. Because the gravid female deposits eggs in the perianal folds during the late evening hours, yield is best in children if the specimen is collected in the morning.
5. **Egg morphology**
- a. Eggs range in size from 50 to 60 μm in length and 30 μm in width. They are oval in shape, and one side is flat. See Figure 8-16 ■.
 - b. The shell is thick and double walled.
 - c. The ovum contains a developing embryo.



Size Range: 48–60 μm long by 20–35 μm wide

FIGURE 8-16 ■ *Enterobius vermicularis* egg

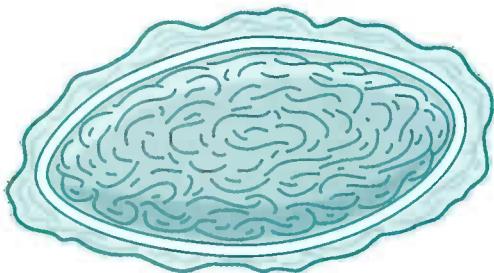
C. *Trichuris trichiura*

1. *T. trichiura* (**whipworm**) causes infection that in children, presents as colitis and dysentery. In adults symptoms include abdominal pain and bloody diarrhea.
2. Most infections occur in Africa and South America, but infections also occur in the deep south of the U.S.
3. Eggs from human feces are infective. After ingestion of the ova, the larvae develop into adults in the intestines.
4. **Diagnosis:** Detection of eggs in stool samples
5. **Egg morphology**
 - a. The eggs range in size from 50 to 60 μm in length and 25 μm in width and are football shaped with clear plugs at each end.
 - b. The shell is smooth and yellow to brown.
 - c. The egg contains a developing embryo.
6. **Adult morphology**
 - a. The female adult measures 35–50 mm long, and the male is 30–45 mm long. Adults are rarely found in the stool.

- b. The anterior end resembles a whip handle.
- c. The posterior end resembles a whip and is gray in color.

D. *Ascaris lumbricoides*

1. *A. lumbricoides* is known as the giant intestinal roundworm and causes ascariasis, resulting in intestinal tissue destruction and bowel obstruction that can be fatal. The worms can also migrate to the lungs, where they cause pulmonary disorders, and to other body sites.
2. Worldwide, *A. lumbricoides* affects over 1 billion people per year; however, infection is rare in the U.S.
3. Eggs (the infective stage) are passed in human feces.
4. **Diagnosis:** Examination of stool for eggs and adult forms



Size Range: 85–95 µm by 38–45 µm

FIGURE 8-17 *Ascaris lumbricoides* infertile egg

5. **Egg morphology**
 - a. Infertile ova are oval and measure up to 90 µm in length. See Figure 8-17 ■.
 - b. Fertile eggs are round and range in size up to 75 µm in length and 50 µm in width. The shell is thick and contains a developing embryo. See Figure 8-18 ■.

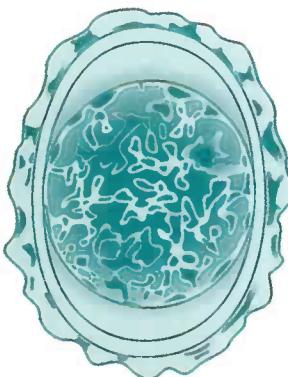


FIGURE 8-18 *Ascaris lumbricoides* fertile egg

6. **Adult morphology**
 - a. Females are 20–30 cm long.
 - b. Males are 15–31 cm long with a curved posterior end.

E. *Strongyloides stercoralis*

1. Causes threadworm infections, characterized by diarrhea and abdominal pain
2. Most infections occur in the tropics.
3. Skin contact with contaminated soil (**filariform larvae**) is the transmission route for humans. After penetration, larvae migrate through the skin, and repeated exposure to larvae can produce an allergic reaction commonly referred to as **larva migrans**.
4. **Diagnosis:** Stool examination for rhabditiform larvae
5. **Morphology of rhabditiform larvae**
 - a. Larvae range in size up to 700 µm in length.
 - b. The tail is notched.

F. *Necator americanus* and *Ancylostoma duodenale*

1. *N. americanus* (New World hookworm) and *A. duodenale* (Old World hookworm) cause human hookworm infections. Depending on the infected body site, symptoms can include coughing (lung infection) and headaches.
2. Hookworms are common worldwide, including in North America.
3. Humans acquire the **filariform larvae** through skin penetration. The larvae migrate to the lungs and then to the intestines.
4. **Diagnosis:** Identification of larvae in sputum or ova from stool specimens
5. **Egg morphology**
 - a. Eggs of the two species are identical.
 - b. The eggs are oval and measure 56–75 µm long by 36–40 µm wide.
 - c. Eggs are thin shelled, and a developing embryo can sometimes be seen inside.
6. **Morphology of adult worms**
 - a. Adult worms firmly attach to the intestinal mucosa and are rarely seen.
 - b. Adults range in size from 7 to 11 mm in length; *Anclyostoma* worms tend to be slightly larger than *Necator* worms.
 - c. The buccal cavity of *N. americanus* contains a pair of cutting plates, whereas *A. duodenale* has teeth.

G. *Trichinella spiralis*

1. *T. spiralis* causes trichinosis with symptoms including diarrhea, blurred vision, muscle edema (mostly **striated muscle**), and coughing. Infections can be fatal.
2. The parasite is found worldwide; **pigs** are important reservoirs.
3. Humans acquire the infection by eating contaminated **undercooked pork**.
4. **Diagnosis** can be made by examining muscle tissue for encysted larvae. Laboratory tests reveal eosinophilia, leukocytosis, and increased creatine kinase and lactate dehydrogenase.

5. Morphology

- a. Larvae range in size up to 125 µm in length and 7 µm in width. Many encysted forms are found in striated muscle tissue.
- b. Adults range up to 1 mm in length and reside in the intestinal tract.

H. *Dracunculus medinensis*

1. Causes guinea worm infection; symptoms include allergic reactions and painful ulcers
2. Most infections occur in Africa, India, and Asia.
3. Humans acquire the infection by the ingestion of infected **copepods** (water fleas) carrying the larvae.
4. **Diagnosis:** Observing worms emerging from ulcerated areas of the body
5. **Morphology of adults**
 - a. Adult females range in size up to 1 m in length and 2 mm in width.
 - b. Males are about 2 cm in length.

VII. FILARIAE

A. General Characteristics of the Filarial Parasites

1. Filarial parasites are an order of nematodes consisting of adult threadlike worms.
2. Filariae inhabit the circulatory and lymphatic system and are also found in muscle, connective tissue, and serous cavities.
3. Four primary species cause disease in humans: *Wuchereria bancrofti*, *Brugia malayi*, *Loa loa*, and *Onchocerca volvulus*.
4. **Transmission** of the filariae parasites occurs after the bite of mosquitoes or other arthropods.
5. **Diagnosis** is by microscopic examination of blood or tissue for microfilariae. Some species migrate in the daytime, whereas others migrate at night (nocturnal periodicity). It is therefore important to draw blood in the morning (between 10 A.M. and noon) and in the evening (between 10 P.M. and midnight).
6. Most filarial disease occurs in Africa and South America.

B. Filariae Pathogenic for Humans

1. *Loa loa*
 - a. Causes subcutaneous tissue infections and infections of the conjunctival lining of the eye
 - b. Most infections occur in Africa.
 - c. Transmission of the parasite is through the bite of the *Chrysops* (deer) fly.
 - d. **Diagnosis:** Blood smear examination for microfilariae
 - e. **Microfilariae characteristics**
 - 1) Size ranges from 250 to 300 µm in length.
 - 2) Contains a row of **nuclei** that extends to the tail of the parasite
 - 3) A **sheath** is present.

2. *Brugia malayi*

- a. *B. malayi* causes Malayan filariasis, a condition that produces lesions in the lymphatics, and **elephantiasis** may result.
- b. Most infections occur in the Far East, Japan, and China.
- c. *W. bancrofti* is transmitted by the *Anopheles* or *Aedes* mosquito.
- d. **Diagnosis** is by microscopic examination of blood smears for microfilariae. Samples collected at night offer the largest yield.
- e. **Microfilariae characteristics**
 - 1) Size ranges from 200 to 300 µm in length.
 - 2) Two **nuclei** are located in the tail.
 - 3) A **sheath** is present.

3. *Wuchereria bancrofti*

- a. *W. bancrofti* causes Bancroftian filariasis, a condition that produces lesions in the lymphatics. **Elephantiasis** may result.
- b. Disease occurs in the tropics and subtropics.
- c. Vectors for the disease are the *Culex*, *Aedes*, and *Anopheles* mosquitoes.
- d. **Diagnosis:** Examination of blood smears for microfilariae
- e. **Microfilariae characteristics**
 - 1) Ranges in size from 250 to 300 µm in length
 - 2) **No nuclei** are found in the tail.
 - 3) A **sheath** is present.

4. *Onchocerca volvulus*

- a. *O. volvulus* causes **river blindness**; eye infections may lead to blindness.
- b. Most infections occur in Africa, South America, and Mexico.
- c. Transmission of the infective microfilariae is by the bite of the *Simulium* (blackfly).
- d. **Diagnosis:** Tissue or ophthalmologic analysis for microfilariae
- e. **Microfilariae characteristics**
 - 1) Size ranges from 150 to 360 µm in length.
 - 2) **No nuclei** are located in the tail.
 - 3) A **sheath** is present.



review questions

INSTRUCTIONS

Each of the questions or incomplete statements that follows is comprised of four suggested responses. Select the *best* answer or completion statement in each case.

1. *Enterobius vermicularis* infection is usually diagnosed by finding
 - A. Eggs in perianal specimens
 - B. Larvae in perianal specimens
 - C. Larvae in feces
 - D. Eggs in the feces
2. The best direct diagnosis of *Echinococcus granulosus* infection in humans is made by identification of
 - A. Adult worms in the intestine
 - B. Adult worms in tissues
 - C. Eggs in feces
 - D. Hydatid cysts in tissues
3. Which statement is correct for specimen collection and processing?
 - A. Stool samples can contain urine.
 - B. Stools can be frozen without affecting parasitic structure.
 - C. Liquid stools are best for detecting ameba and flagellate trophozoites.
 - D. Unpreserved stools can remain at room temperature for up to 72 hours.
4. Cysts are the infective stage of this intestinal flagellate.
 - A. *Balantidium coli*
 - B. *Dientamoeba fragilis*
 - C. *Entamoeba coli*
 - D. *Giardia lamblia*
5. Eggs or larvae recovered in the stool are *not* routinely used to diagnose infections caused by which one of the following helminths?
 - A. *Trichinella spiralis*
 - B. *Strongyloides stercoralis*
 - C. *Necator americanus*
 - D. *Ascaris lumbricoides*
6. Many parasites have different stages of growth within different hosts. The host where the sexual reproductive stage of the parasites exists is called the
 - A. Commensal
 - B. Definitive host
 - C. Intermediate host
 - D. Vector

7. Species identification of an immature amebic cyst can be very difficult. The presence of a large glycogen mass is sometimes seen in
 - A. *Dientamoeba fragilis*
 - B. *Endolimax nana*
 - C. *Entamoeba coli*
 - D. *Entamoeba histolytica*
8. Which of the following is typical in cysts of *Iodamoeba bütschlii*?
 - A. A glycogen mass
 - B. Blunt chromatoidal bars
 - C. Four nuclei with large karyosomes
 - D. Many ingested bacteria
9. Which of the following is the most important feature in differentiating cysts of *Entamoeba histolytica* from *E. dispar*?
 - A. Number of nuclei
 - B. Size of the cyst
 - C. Shape of the karyosome
 - D. Distinguishing surface antigens by immunologic assays
10. Which of the following findings in a peripheral blood smear is especially associated with tissue-invading helminths but may also be found in a variety of allergic conditions and other diseases?
 - A. Eosinophilia
 - B. Leukopenia
 - C. Lymphocytosis
 - D. Neutropenia
11. A 48-year-old man from Texas developed fever and weakness 16 days after a hunting trip in northwest Tanzania. Several days after the onset of fever, he noticed a raised, tender, erythematous nodule (6–8 cm in diameter) on the posterior aspect of his right arm. He was hospitalized in Africa and treated for 5 days with a cephalosporin for presumed cellulitis. After little improvement, he returned to Texas. On arrival, the patient had a temperature of 38.9°C (102°F), a morbilliform rash of the trunk, and right-sided, anterior cervical lymphadenopathy. Cerebrospinal fluid contained 12 red cells and 18 mononuclear cells/ μ L and a normal protein level (32 mg/dL). Laboratory tests of peripheral blood revealed a hemoglobin level of 107 g/L, a white cell count of 2.4×10^9 /L, and a platelet count of 75×10^9 /L. The diagnosis was made by finding the extracellular flagellate parasite in a peripheral blood smear. Which of the following is the most probable etiologic agent of this infection?
 - A. *Leishmania donovani*
 - B. *Trypanosoma brucei*
 - C. *Trypanosoma cruzi*
 - D. *Toxoplasma gondii*
12. Which species of malaria parasite usually has ameboid trophozoites and produces small reddish dots in the red blood cell cytoplasm?
 - A. *Plasmodium knowlesi*
 - B. *Plasmodium falciparum*
 - C. *Plasmodium malariae*
 - D. *Plasmodium vivax*

13. With a fecal specimen, which one of the following is the most dependable procedure for the accurate, specific diagnosis of an intestinal amebic infection?
- Direct saline wet mount
 - Direct iodine wet mount
 - Permanently stained smear
 - Formalin-ethyl acetate sedimentation technique
14. In an examination of stained blood films, *Babesia* spp. are likely to resemble
- Leishmania donovani*
 - Plasmodium falciparum*
 - Toxoplasma gondii*
 - Trypanosoma cruzi*
15. Which of the following is a mercury-containing fixative used to preserve parasites in stool specimens?
- Formalin
 - Sodium acetate
 - Buffered glycerol
 - Polyvinyl alcohol
16. Examination of a fecal smear following acid-fast stain reveals round acid-fast positive structures 8–10 µm in diameter. You should suspect
- Cryptosporidium*
 - Cyclospora*
 - Isospora*
 - Microsporidia
17. A 22-year-old male presents to his family physician complaining of fatigue, muscle pain, periorbital edema, and fever. He denies travel outside the U.S. The physician suspects infectious mononucleosis; however, serologic tests for infectious mononucleosis are negative. The complete blood count revealed a slightly elevated white blood count, and there were 10% eosinophils on the differential. Which of the following should be considered part of the differential diagnosis?
- Ascaris lumbricoides*
 - Taenia solium*
 - Trichinella spiralis*
 - Trypanosoma cruzi*
18. Which *Schistosoma* species has a large terminal spine?
- S. haematobium*
 - S. japonicum*
 - S. mansoni*
 - S. mekongi*
19. Elephantiasis is a complication associated with which of the following?
- Cysticercosis
 - Guinea worm
 - Hydatid cyst disease
 - Filariae
20. A patient with history of human immunodeficiency virus infection presents with a 5-day history of diarrhea and weight loss. A series of stool specimens is collected and examined for the presence of ova and parasites. An acid-fast stain on direct smear reveals pink-stained round structures approximately 4 µm in diameter. The most likely pathogen is
- Blastocystis hominis*
 - Cryptosporidium* sp.
 - Isospora* sp.
 - Microsporidium*

21. A 55-year-old female presents to her physician complaining of a fever that “comes and goes” and fatigue. A complete blood count reveals decreased red blood cell count and hemoglobin. History reveals the patient recently traveled through Europe and Africa. You should suspect
- Cutaneous larval migrans
 - Filariasis
 - Malaria
 - Trichinella
22. The disease most commonly associated with *Acanthamoeba* sp. is
- Diarrhea
 - Keratitis
 - Liver abscess
 - Meningoencephalitis
23. A modified trichrome stain of a fecal smear can be used to detect microsporidia. Which of the following would describe the appearance of this parasite in this stain?
- Purple circles, 10–15 µm in diameter
 - Pink ovals, 1–3 µm in diameter
 - Blue ovals, 4–6 µm in diameter
 - Fluorescent circles, 8–12 µm in diameter
24. Hydatid cysts in humans are due to ingestion of a tapeworm stage normally found in canines. This stage is the
- Cercaria
 - Cercocystis
 - Cysticercus
 - Embryonated egg
25. Oocysts, the infective stage of *Toxoplasma gondii*, is found in
- Cat feces
 - Human feces
 - Undercooked pork
 - Undercooked beef
26. A 15-µm pear-shaped flagellate with a visible parabasal body and “falling leaf” motility in a direct saline mount of a diarrheal stool specimen is most probably
- Balantidium coli*
 - Chilomastix mesnili*
 - Giardia lamblia*
 - Trichomonas hominis*
27. This parasitic infection may result in vitamin B₁₂ deficiency, and individuals with pernicious anemia are predisposed to more severe symptoms.
- Diphyllobothrium latum*
 - Echinococcus granulosus*
 - Hymenolepis diminuta*
 - Taenia saginata*
28. Knowledge of nocturnal periodicity is especially important in the diagnosis of certain infections caused by
- Babesia*
 - Plasmodium*
 - Microfilariae
 - Trypanosoma*
29. For which of the following diseases is close contact with an infected human host the most important mechanism of transmission?
- Schistosomiasis
 - Toxoplasmosis
 - Trichinosis
 - Trichomoniasis
30. Which of the following helminths produces an elongate, barrel-shaped egg (50 × 22 µm) with a colorless polar plug at each end?
- Ascaris lumbricoides*
 - Hymenolepis nana*
 - Necator americanus*
 - Trichuris trichiura*

31. Which species of *Plasmodium* may readily be identified when crescent-shaped gametocytes are found in stained blood films?
- P. falciparum*
 - P. malariae*
 - P. ovale*
 - P. vivax*
32. Cysts of *Giardia lamblia*
- Contain four nuclei
 - Are motile by flagella
 - Have an undulating membrane
 - Are rarely found in stool specimens
33. Migration of larva through the skin can sometimes produce allergic reactions called larva migrans; this is associated with
- Strongyloides stercoralis*
 - Dracunculus medinensis*
 - Onchocerca volvulus*
 - Loa loa*
34. A free-living ameba that causes primary amebic meningoencephalitis is
- Dientamoeba fragilis*
 - Entamoeba coli*
 - Entamoeba histolytica*
 - Naegleria fowleri*
35. Decontamination of drinking water, fruits, and vegetables before consumption is necessary in countries without well-developed public sanitation. Which of the following diseases would probably be least affected by that kind of precaution?
- Amebiasis
 - Ascariasis
 - Filariasis
 - Giardiasis
36. Which stage of *Taenia saginata* is usually infective for humans?
- Cysticercus larva
 - Embryonated egg
 - Filariform larva
 - Rhabditiform larva
37. This amebic cyst has an average size of 6–8 μm and is usually spherical. When mature, it has four nuclei, but immature cysts with one or two nuclei are often seen. The nuclei have fine uniform granules of peripheral chromatin and small, discrete, usually central karyosomes. Chromatoidal bars with bluntly rounded ends are sometimes present. Name the species.
- Endolimax nana*
 - Entamoeba coli*
 - Entamoeba hartmanni*
 - Entamoeba histolytica*
38. Which stage of *Trichuris trichiura* is infective for humans?
- Proglottid
 - Filariform larva
 - Rhabditiform larva
 - Embryonated ovum
39. An intestinal parasite is seen in an iodine-stained fecal wet mount that is described as being 25 μm in diameter with a homogenously stained central body surrounded by a thin ring of cytoplasm containing a number of nuclei. This best describes
- Blastocystis hominis*
 - Endolimax nana*
 - Entamoeba dispar*
 - Iodamoeba bütschlii*

40. Sanitary disposal of human feces is the most important factor in decreasing the incidence of most infections caused by intestinal parasites. Which of the following diseases would *not* be affected by that kind of sanitation?
- Ascariasis
 - Taeniasis
 - Trichinosis
 - Hookworm infection
41. Which species of *Plasmodium* is characterized by the presence of Schüffner's dots in the infected erythrocytes?
- Plasmodium falciparum*
 - Plasmodium knowlesi*
 - Plasmodium malariae*
 - Plasmodium ovale*
42. Which of the following is the largest intestinal protozoa infecting humans?
- Balantidium coli*
 - Dientamoeba fragilis*
 - Entamoeba histolytica*
 - Giardia lamblia*
43. The rhabditiform larvae of *Strongyloides stercoralis*
- Mate and produce ova
 - Are infective for humans
 - Are the diagnostic form found in feces
 - Are found in the blood of infected humans
44. Which species of *Plasmodium* can have exoerythrocytic stages capable of causing relapses months or years after initial infection?
- P. falciparum*
 - P. ovale*
 - P. malariae*
 - P. cynomolgi*
45. A Giemsa-stained thick blood film showed many ring forms with no older stages, and a number of the rings had double chromatin dots. These findings are characteristic of
- Plasmodium falciparum*
 - Plasmodium vivax*
 - Plasmodium malariae*
 - Plasmodium ovale*
46. Which of the following nematode parasites is acquired from eating inadequately cooked, infected pork?
- Strongyloides stercoralis*
 - Taenia saginata*
 - Taenia solium*
 - Trichinella spiralis*
47. Which of the following pairs of helminths *cannot* be reliably differentiated by the appearance of their eggs?
- Ascaris lumbricoides* and *Necator americanus*
 - Hymenolepis nana* and *H. diminuta*
 - Necator americanus* and *Ancylostoma duodenale*
 - Diphyllobothrium latum* and *Fasciola hepatica*
48. Which of the following forms of *Toxoplasma gondii* are produced in infected humans?
- Bradyzoites
 - Macrogametes
 - Sporoblasts
 - Oocysts
49. Hematuria is a typical sign of human infection caused by
- Trypanosoma cruzi*
 - Trichinella spiralis*
 - Trichomonas vaginalis*
 - Schistosoma haematobium*

50. Which of the following is the vector for *Babesia*?
A. Fleas
B. Lice
C. Ticks
D. Mosquitoes
51. Chagas disease (American trypanosomiasis) is caused by
A. *Trypanosoma brucei*
B. *Trypanosoma cruzi*
C. *Leishmania braziliensis*
D. *Dracunculus medinensis*
52. Which of the following is the preferred anticoagulant for preparing blood smears for diagnosing malaria?
A. EDTA
B. Heparin
C. Sodium citrate
D. Sodium fluoride
53. Refer to Color Plate 38■. This is a photomicrograph of a trichrome stain of a fecal smear, magnification $400\times$. The parasite measures $65 \times 45\text{ }\mu\text{m}$. What is the identification of this parasite?
A. *Balantidium coli*
B. *Diphyllobothrium latum*
C. *Giardia lamblia*
D. *Schistosoma japonicum*
54. Refer to Color Plate 39■. This is a photomicrograph of an iodine wet prep made from a stool sample; magnification is $400\times$. The ovum is about $70 \times 50\text{ }\mu\text{m}$. What is the identification of the parasite?
A. Hookworm
B. *Enterobius vermicularis*
C. *Trichuris trichiura*
D. *Ascaris lumbricoides*
55. Refer to Color Plate 40■. This is a photomicrograph of an iron hematoxylin stain from a fecal smear. The magnification is $1000\times$. The parasite is approximately $20\text{ }\mu\text{m}$ long and $15\text{ }\mu\text{m}$ wide. What is the identification of this parasite?
A. *Chilomastix mesnili* trophozoite
B. *Giardia lamblia* trophozoite
C. *Trichomonas hominis* trophozoite
D. *Trichomonas tenax* trophozoite
56. Refer to Color Plate 41■. This is a photomicrograph of an iron hematoxylin stain from a fecal smear. The magnification is $1000\times$. The parasite is approximately $12\text{ }\mu\text{m}$ in diameter. What is the identification of this parasite?
A. *Entamoeba histolytica* trophozoite
B. *Entamoeba hartmanni* trophozoite
C. *Dientamoeba fragilis* trophozoite
D. *Entamoeba coli* trophozoite
57. Refer to Color Plate 42■. This is a photomicrograph of an iodine wet-mount from a fecal sample. The magnification is $1000\times$. The parasite is approximately $25\text{ }\mu\text{m}$ in diameter. What is the identification of this parasite?
A. *Entamoeba histolytica* cyst
B. *Entamoeba histolytica* trophozoite
C. *Entamoeba coli* cyst
D. *Entamoeba coli* trophozoite
58. Refer to Color Plate 43■. This is a photomicrograph of an iodine wet mount from a fecal sample. The magnification is $400\times$. The ovum is approximately $70 \times 38\text{ }\mu\text{m}$. What is the identification of this parasite?
A. Hookworm
B. *Ascaris lumbricoides*
C. *Diphyllobothrium latum*
D. *Taenia solium*

59. Refer to Color Plate 44 ■. This is a photomicrograph of a trichrome stain from a fecal smear. The magnification is $1000\times$. The parasite is approximately $15\text{ }\mu\text{m}$ in diameter. What is the identification of this parasite?
- A. *Entamoeba hartmanni*
 - B. *Dientamoeba fragilis*
 - C. *Iodamoeba bütschlii*
 - D. *Blastocystis hominis*
60. Refer to Color Plate 45 ■. This is a photomicrograph of a blood smear stained with Wright's stain. Identify the parasite.
- A. *Babesia* sp.
 - B. *Plasmodium malariae*
 - C. *Plasmodium falciparum*
 - D. *Trypanosoma cruzi*



Answers & rationales

1.

- A. Because the eggs of *E. vermicularis* are usually deposited on the perianal area, cellulose tape slides are recommended for collecting the eggs. Recovery is best if specimens are collected late in the evening or before bathing or defecating in the morning. The gravid female worms usually migrate at night to the perianal region to deposit eggs. Because their migration is sporadic, several consecutive collections may be necessary to detect the infection.

2.

- D. When *E. granulosus* eggs are ingested by an intermediate herbivorous host, including humans, they usually develop into hydatid cysts in which invaginated larval scolices are produced. These cysts are most often in the liver or lung. Although clinical findings can provide a presumptive diagnosis, this is best confirmed by the finding, at surgery, of encysted larval scolices. Each scolex is capable of developing into an adult worm after ingestion by a dog or related animal, the definitive host.

3.

- C. Fresh liquid stools are more likely to contain motile protozoan trophozoites that can be detected

in saline wet mounts. Urine in stool specimens can damage parasite morphology, as does freezing. Unpreserved stool specimens should only be left at room temperature up to a couple of hours before examining or placing into a preservative.

4.

- D. Cysts are the infective stage of most intestinal parasites. *D. fragilis* is currently classified as a flagellate, even though it does not produce a flagellum. However, *D. fragilis* does not have a cyst stage. *G. lamblia* is the only flagellate in the list of protozoa with a cyst stage. *B. coli* is a ciliate and *E. coli* is an ameba.

5.

- A. Although *T. spiralis* adults live in the intestinal mucosa, they are rarely seen. The female deposits living larvae into the mucosa or lymphatic vessels, from which they normally enter the bloodstream and are disseminated throughout the body. They then burrow into muscle fibers. Although larvae may occasionally be liberated into the intestinal lumen, the definitive diagnostic procedure is the demonstration of larvae in skeletal muscle, not in feces.

6.

- B.** In parasites with a sexual and asexual stage of development, the definitive host is the host in which the sexual stage of the parasite occurs. The intermediate host is the host in which the asexual stage of the parasite is found. Vectors are arthropods, like mosquitoes and ticks that transmit infectious agents. A commensal is an organism that benefits from an existence with a host but does not damage the host.
-

7.

- C.** Young cysts of *E. coli* can have a large glycogen mass that pushes two nuclei to the outer edge of the cell. No cyst stage is known for *D. fragilis*. The cysts of *E. nana* and *E. histolytica* do not contain glycogen.
-

8.

- A.** Mature cysts of *I. bütschlii* are usually ovoid, with a single nucleus with a large eccentric karyosome. The cytoplasm contains a compact mass of glycogen, which appears as a clear area in unstained or permanently stained preparations but stains dark brown with iodine. Chromatoid bodies are not present.
-

9.

- D.** *E. histolytica* and *E. dispar* cannot be morphologically differentiated. The cyst stage of both organisms has four nuclei with a centrally located karyosome. *E. histolytica* is a well-recognized intestinal parasite, whereas *E. dispar* is considered nonpathogenic. Immunologic assays to detect antigens or molecular biology assays are necessary to differentiate these two species.
-

10.

- A.** Although the condition may vary from patient to patient, eosinophilia is often found in association with infections with tissue-invading nematodes. Eosinophilia of 40–80% is not unusual in

trichinosis and in visceral larva migrans. It may also be present in strongyloidiasis, early in *Ascaris* and hookworm infections, and in filariasis, which may also cause pulmonary eosinophilia.

11.

- B.** The symptoms and history for this patient are compatible with trypanosomiasis (African sleeping sickness) caused by *T. brucei*. The trypanastigote form of the parasite was found in peripheral blood smears from this patient. Another key clinical sign is the presence of swollen lymph nodes at the posterior base of the neck; this is called Winterbottom's sign.
-

12.

- D.** The trophozoites of *P. vivax* often develop fine pseudopodia and large vacuoles and are described as ameboid; infected red blood cells (RBCs) contain clumps of malarial pigment called Schüffner's dots. *P. malariae* cytoplasm is much more compact, and infected RBCs lack Schüffner's dots. *P. ovale* resembles *P. vivax*. Schüffner's dots are generally found in *P. vivax* and *P. ovale*-infected RBCs; however, *P. ovale*-infected RBCs have fimbriated edges. Growing trophozoites of *P. falciparum* seen in the peripheral blood remain in the ring form, and infected RBCs lack malarial pigment. *P. knowlesi* is rarely a human pathogen.
-

13.

- C.** The permanently stained smear is especially recommended for identification of trophozoites, for confirmation of species, and for keeping a permanent record of the organisms found. Species identification of amebic trophozoites can rarely be made from a single feature; permanent stains enable one to observe the cytoplasm and cytoplasmic inclusions and the nuclear morphologic features of many cells. Iron hematoxylin and trichrome are commonly used stains.

14.

B. *Babesia* spp. are sporozoan parasites of RBCs that have been recognized as causing febrile illness in humans. *B. microti* has caused a number of tick-borne infections in the U.S. The parasites often appear as small rings within infected RBCs, resembling *P. falciparum* trophozoites. The pathognomonic form of *Babesia* is the “Maltese cross,” four ring forms inside a single RBC.

15.

D. Polyvinyl alcohol (PVA) is a commonly used fixative for stool specimens. This preservative contains mercury and is used to fix fecal samples for making permanently stained smears. Formalin is commonly used to preserve stool samples in preparation for concentration procedures. Sodium acetate is used with formalin to preserve fecal specimens, but it does not contain mercury and is, therefore, less toxic. Buffered glycerol is sometimes used as a transport medium for stool samples when performing a bacterial culture.

16.

B. Although all the organisms listed have some degree of acid-fast positivity, only *Cyclospora* forms oocysts in the size range of 8–10 µm. The oocysts of *Cryptosporidium* are generally 4–6 µm in diameter and are generally strongly acid-fast positive. Oocysts of *Isospora* are much larger, approximately 25 × 18 µm. Microsporidia are acid-fast variable, and this stain is not recommended for detecting microsporidia. The spores of microsporidia are generally 1–3 µm in diameter.

17.

C. The early symptoms of trichinosis can resemble infectious mononucleosis. The presence of periorbital edema (swelling around the eyes) in this patient and hemorrhaging in the nail beds is suggestive of trichinosis. Eosinophilia also indicates a parasitic infection.

18.

A. The ova of *Schistosoma* contain a spine. *S. haematobium* ova have a large prominent spine on one end. *S. mansoni* has a prominent lateral spine, whereas the spine of *S. japonicum* is small and inconspicuous. *S. mekongi* is a rare human pathogen.

19.

D. Adult filarial helminths typically inhabit the lymph vessels. They produce inflammation and swelling of the lymph vessels, often in the legs and sometimes the scrotum. This condition is referred to as elephantiasis. The larvae are highly motile and migrate through the body.

20.

B. Although all these organisms are potential pathogens of immunocompromised patients, only *Cryptosporidium* produces acid-fast positive oocysts about 4–6 µm in diameter. The oocysts of *Isospora* measure approximately 25 × 18 µm. The spores of microsporidia are generally 1–3 µm in diameter. *B. hominis* is generally considered to be pathogenic in high numbers. The diagnostic form of this intestinal parasite measures 6–40 µm in diameter and is not acid-fast positive.

21.

C. One of the classic signs of malaria is a fever that occurs in cycles. As the infection is developing, all the parasites are in approximately the same stage of development. The fever spikes correspond to the release of the merozoites from infected RBCs. *Plasmodium* is an obligate intracellular parasite of RBCs; therefore, infections can result in decreased RBC counts and hemoglobin.

22.

B. *Acanthamoeba* is a free-living ameba rarely causing human infections. This organism has been associated with granulomatous infections of the skin and lung, as well as meningoencephalitis. However, the most common presentation is keratitis, infection of the cornea. Most keratitis cases have been associated with contact lenses.

23.

B. The small size and variable staining of the microsporidia make their detection difficult. Tissue examination by electron microscopy is the most specific diagnostic method. In the modified trichrome stain, one of the stains (chromotrope 2R) is used at 10 times the normal concentration. In addition, the staining time is increased to 90 minutes. Alternatively, 15 minutes in heated stain can be used. Under these staining conditions, the spores of microsporidia stain as pinkish ovals, 1–3 μm .

24.

D. *Echinococcus granulosus* is a tapeworm that lives as an adult in the small intestines of carnivores, primarily dogs, wolves, and other canines. When the embryonated egg from the feces of a carnivore is ingested by the intermediate host, usually an herbivore but sometimes a human, the liberated embryo can develop into a hydatid cyst. These cysts are most often hepatic or pulmonary, and the resulting symptoms are comparable to those of a slowly growing tumor.

25.

A. *T. gondii* is a protozoan parasite of humans and a variety of lower animals. Human infections can be congenital or can result from ingestion of material containing oocysts from cat feces or from eating undercooked beef, lamb, or pork containing toxoplasma cysts. The life cycle of this parasite includes asexual multiplication

in a number of hosts and sexual multiplication only in domestic cats and some closely related species, which then excrete potentially infectious oocysts. Pregnant women should take precautions to avoid infection.

26.

C. All the flagellates listed are pear shaped, but only *C. mesnili* and *G. lamblia* are usually as large as 15 μm . *B. coli* is a ciliate. The typical motion of *G. lamblia* is described as “falling leaf”; *C. mesnili* has a stiff rotary motion. *G. lamblia* is known to cause diarrheal disease and malabsorption, and the trophozoites may be found in diarrheal feces.

27.

A. *D. latum* is a tapeworm that has been linked to vitamin B₁₂ deficiencies in individuals of Scandinavian descent. *T. saginata* and *H. diminuta* are tapeworms that infect the gastrointestinal tract of humans but have not been linked to vitamin B₁₂ deficiencies. *E. granulosus* is a dog tapeworm that causes hydatid disease in the tissue of humans.

28.

C. Transmission of filariasis depends on the presence of microfilariae in the bloodstream at the time the vector bites, and the periodicity of microfilariae in the peripheral blood varies with the species and sometimes with the geographic area. Nocturnal periodicity is marked in *W. bancrofti* in Africa, Asia, and the western hemisphere, and thick blood films for detection of these microfilariae should be made between 10 P.M. and midnight. The other choices do not exhibit nocturnal periodicity.

29.

D. Sexual intercourse with infected men is thought to be the most important mode of transmission of *Trichomonas vaginalis* to women. Other routes of infection are direct contact with infected females or contact with infected toilet articles or toilet seats; these are considered rare modes of transmission. Infants may become infected while passing through the birth canal. Toxoplasmosis occurs as a congenital infection, but it is more commonly acquired by the ingestion of infected, undercooked meat or by swallowing oocysts excreted by infected cats. Schistosomiasis and trichinosis are not passed from person to person.

30.

D. Typical eggs of *T. trichiura* are yellow to brown, with colorless polar plugs. They are shaped like a football or a barrel, and they are in the cell, or unsegmented stage, when passed in the feces. The usual egg range is $49\text{--}65 \times 35\text{--}45 \mu\text{m}$.

31.

A. The gametocytes of *P. vivax*, *P. malariae*, and *P. ovale* are round and somewhat similar in appearance. Those of *P. falciparum* have a typical crescent shape. The gametocytes of *P. falciparum* may remain in the peripheral blood a month or more and are often found with the ring stages.

32.

A. The cysts of *G. lamblia* contain four nuclei and are passed in the stool of infected animals. The trophozoites are motile by flagella. *G. lamblia* does not possess an undulating membrane.

33.

A. The life cycle of a number of human nematodes includes migration through the skin and peripheral bloodstream. In individuals who have

suffered several infections, allergic reactions can produce inflammation in the skin. *S. stercoralis* produces symptoms in the skin sometimes called larva migrans.

34.

D. *Naegleria fowleri* is found in freshwater ponds and lakes, especially those with disturbed or suspended soil. It has caused a number of cases of meningoencephalitis in people who have swum in these bodies of water. Essentially, all these infections have been fulminating and fatal, and they are often not diagnosed until autopsy.

35.

C. Infectious cysts of amebae and *Giardia lamblia* and eggs of *Ascaris lumbricoides* may all be ingested in fecally contaminated water and/or on fecally contaminated plants. These infections are most prevalent in areas lacking good public sanitation; that is, sanitary disposal of human waste and adequately treated and protected drinking water. Filariasis is transmitted by blood-feeding insects (vectors).

36.

A. Humans are infected with *T. saginata* by eating beef containing live cysticerci, the infectious larval stage of this parasite. Cattle become infected by ingesting viable eggs from human feces. Unlike *Taenia solium*, if humans ingest *T. saginata* ova, infection does not develop.

37.

C. Cysts of *E. hartmanni* are differentiated from cysts of *E. histolytica* by their small size; they are otherwise morphologically identical. *E. hartmanni*, which was formerly called “small race ameba,” is considered to be nonpathogenic. The size range for *E. hartmanni* cysts is $5\text{--}10 \mu\text{m}$, and for *E. histolytica*, the range is $10\text{--}20 \mu\text{m}$.

38.

- D. The fertilized ova of *T. trichiura* are unsegmented when released, and embryonic development occurs outside of the host. In moist, warm, shaded soil, the first-stage larva develops within the egg in about 2 weeks. This fully embryonated egg is infective when ingested by a susceptible host, and it hatches in the small intestine. During development from larva to adult, the worm usually passes to the cecum, where it embeds its slender anterior portion in the intestinal mucosa.

39.

- A. The most common form of *B. hominis* seen in human feces is called the “classic form.” This form contains a central body that was previously thought to be a vacuole. The central body can take up to 90% of the volume of the cell, displacing the nuclei to the outer edge of the cell.

40.

- C. Excretion in human feces of the eggs of the hookworms, *Taenia solium*, *T. saginata*, and *Ascaris lumbricoides*, is an essential or important factor in perpetuating the cycle of infection with these parasites. Trichinosis is caused by ingestion of the live larvae of *Trichinella spiralis* encysted in the muscles of a flesh-eating host. The adults live in the host’s intestine, and the viviparous females, after fertilization, produce larvae that migrate into the host’s muscle tissue.

41.

- D. Typically, RBCs infected with *P. ovale* are larger than uninfected cells, pale and often misshapen, and frequently contain Schüffner’s dots or stippling in any stage from young ring forms onward. RBCs infected with *P. vivax* are also larger than normal, oval, and contain Schüffner’s dots. Ovale malaria, however, is a comparatively rare disease.

42.

- A. *Balantidium coli* is the largest intestinal protozoan infecting humans. Cysts range in size from 43 to 65 µm, and the trophozoites are typically 50–100 µm in length and 40–70 µm in width. Pigs seem to be the most important reservoir for *B. coli*.

43.

- C. The rhabditiform larvae of *S. stercoralis* are the diagnostic stage typically passed in the feces of infected persons. The larvae measure up to 380 µm long × 20 µm wide. They have a short buccal cavity and a prominent, ovoid, genital primordium midway along the ventral wall of the body. The infective stage is the filariform larva, which differs from the hookworm filariform larva by having a notched tail tip and a long esophagus.

44.

- B. A malaria relapse is parasitemia developing from exoerythrocytic stages in the liver. These persistent stages are found in *P. ovale* and *P. vivax* infections, and they may cause relapses up to 4 or 5 years after the primary infection. For infections caused by these species, treatment with primaquine is used to prevent relapses (recurrences) after clinical cure with chloroquine or an alternate drug.

45.

- A. *P. falciparum* infections tend to produce a large number of rings that frequently have double chromatin, which is only occasionally found in other species. *P. falciparum* differs from other plasmodia of humans in that only early trophozoites (ring forms) and gametocytes are found in peripheral blood except in severe cases. Sex differentiation of the gametes, when present, is difficult.

46.

D. *T. spiralis* is a nematode parasite whose infectious larvae may be found encysted in the muscles of flesh-eating mammals. Humans are infected most often by eating infected, undercooked pork. *Taenia* spp. are cestodes (tapeworms). *S. stercoralis* and *N. americanus* are roundworms whose infectious larvae usually develop in the environment and infect by penetration of human skin, although internal autoinfection may also occur.

47.

C. *N. americanus* and *A. duodenale* are two species of hookworms infecting humans. Their eggs are so similar when found in stool specimens that they are reported as “hookworm ova.” The two hookworms can be differentiated by the morphologic characteristics of the adult worms, which are intestinal parasites.

48.

A. The life cycle of *T. gondii* includes five forms or stages, but only bradyzoites and tachyzoites appear in the tissue phase during human infections. The crescent-shaped tachyzoites are characteristic of acute infection. The slowly multiplying bradyzoites develop within cysts and are typical of chronic infections. Oocysts, merozoites, and gametes have been found only in the cat, where the sexual cycle of *T. gondii* occurs.

49.

D. A common sign of *S. haematobium* infection is the presence of blood in the urine. This is due to the damage caused when the eggs break out of the blood vessels of the vesicular plexus into the bladder. Falciparum malaria may also cause severe hematuria or “blackwater fever.”

50.

C. *B. microti* is a sporozoan parasite commonly found in voles and field mice. The vector is the tick *Ixodes*, normally a parasite of deer. Humans are accidental hosts when bitten by an infected tick. Many *B. microti* infections within the U.S. occur in the Northeast. It is important to differentiate this parasite from *Plasmodium* in a stained blood film. Antimalarial drugs are not effective in babesiosis.

51.

B. Chagas disease is found throughout the American continents. The infectious agent, *T. cruzi*, is transmitted to humans by reduviid bugs, primarily the triatomids. Chagas disease can be acute or chronic.

52.

A. Collection of blood by finger stick is preferred for preparing blood smears for the detection of malaria. When a venipuncture is performed, the preferred anticoagulant for malarial blood smears is EDTA (ethylenediaminetetraacetic acid). Heparin can be used, but it may cause distortion of some parasite forms.

53.

A. *B. coli* is the only ciliate that is pathogenic for humans. It is relatively easy to detect in stool samples because of its large size. The trophozoite, seen in Color Plate 38■, is generally oval and measures 50–100 × 40–70 µm. A cytosome is present on the anterior end.

54.

D. Color Plate 39■ demonstrates a fertilized egg of *A. lumbricoides*. Eggs measure 45–75 × 35–50 µm. Unfertilized *Ascaris* eggs typically do not float in the zinc sulfate concentration technique.

55.

B. Color Plate 40■ demonstrates a *G. lamblia* trophozoite; notice the two prominent nuclei. Trophozoites of *C. mesnili* are approximately 6–24 µm in length but have a single nucleus, whereas *G. lamblia* trophozoites have two nuclei. Trophozoites of *Trichomonas* are about the same size as *G. lamblia*, but they are more round than the pear-shaped trophozoites of *G. lamblia* and *C. mesnili*. *Trichomonas* spp. have a single nucleus, and *T. tenax* is found in the oral cavity.

56.

C. Color Plate 41■ demonstrates a *D. fragilis* trophozoite. Although this organism lacks a flagellum and morphologically resembles the ameba, based on its ultrastructure and molecular biology studies, it is classified as a flagellate. Like the trichomonads, *D. fragilis* does not have a cyst stage. Most trophozoites of *D. fragilis* have two nuclei, like the one in this image.

57.

C. Color Plate 42■ demonstrates an *E. coli* cyst. These cysts most closely resemble *E. histolytica* and *E. dispar*. The key distinguishing feature is that *E. coli* cysts contain up to eight nuclei, whereas *E. histolytica* and *E. dispar* have up to four nuclei. It is often necessary to use the fine adjustment to see all the nuclei. In this image, six nuclei can be seen. Trophozoites of all three species only contain one nucleus.

58.

A. Color Plate 43■ demonstrates a hookworm ovum. In addition to size, key characteristics are the thin ovum shell and nearly symmetrical shape. *Enterobius vermicularis*, pinworm, ova appear similar, except that they have a flattened side and thicker shell. In addition, the ova are slightly smaller. Ova of *D. latum* are unembryonated, operculated, and slightly larger than hookworm ova.

59.

D. Color Plate 44■ demonstrates the “classic form” of *B. hominis*. After years of taxonomic uncertainty, this organism is currently classified as an ameba; however, rRNA studies indicate it is related to algae and water moulds. The classic form usually seen in human feces varies in size from 6 to 40 µm in diameter. It contains a large central body, resembling a vacuole that pushes several nuclei to the periphery of the cell.

60.

B. Color Plate 45■ demonstrates a *P. malariae* trophozoite. A trophozoite stretching across the infected RBC, called a band form, is a key characteristic of *P. malariae*. Other important characteristics include a lack of malarial pigment, and infected RBCs are about the same size as uninfected RBCs. During *Babesia* infections, only ring forms are seen.

REFERENCES

- Forbes, B. A., Sahm, D. F., and Weissfeld, A. S. (2007). *Bailey and Scott's Diagnostic Microbiology*, 12th ed. Philadelphia: Mosby.
- Garcia, L. S. (2006). *Diagnostic Medical Parasitology*, 5th ed. Washington, DC: American Society for Microbiology Press.
- Mahon, C. R., Lehman, D. C., and Manuselis, G. (2008). *Textbook of Diagnostic Microbiology*, 3rd ed. St. Louis: Saunders Elsevier.
- Murray, P. R., Baron, E. J., Jorgensen, J. H., Landry, M. L., and Pfaffer, M. A. (2007). *Manual of Clinical Microbiology*, 9th ed. Washington, DC: American Society for Microbiology Press.