Electronic Atlas of Parasitology

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1.1 Trypomastigotes of *Trypanosoma brucei rhodesiense*, peripheral blood smear. Note the undulating membrane (U), anterior flagellum (F), and posterior location of the kinetoplast (K) relative to the nucleus (N). These would be indistinguishable from trypomastigotes of *T. b. gambiense*. The long slender form of trypomastigote is the dividing form (arrow), whereas the short, stumpy form (not shown) is infective for the intermediate host. *T. b. rhodesiense* is transmitted by the *tsetse fly*, *Glossina morsitans*, *G. pallidipes*, and *G. tachinoides* in the savannah regions of east Africa. Numerous wild game animals serve as reservoir hosts. This parasite is highly pathogenic for humans, causing 100% mortality unless treated. *T. b. rhodesiense* typically does not cause the symptoms of African sleeping sickness seen with infections of *T. b. gambiense*, simply because death occurs first.

**Life cycle:**

- **trypomastigotes** in blood $\rightarrow$ ingested by tsetse fly $\rightarrow$ dividing **epimastigotes** in fly gut $\rightarrow$ **metacyclic trypomastigotes** in fly saliva $\rightarrow$ fly blood meal $\rightarrow$ **trypomastigotes** in blood
1.2 Trypomastigotes of *Trypanosoma brucei gambiense*, peripheral blood smear. Note the undulating membrane and posterior location of the kinetoplast relative to the nucleus. These would be indistinguishable from trypomastigotes of *T. b. rhodesiense*. The long slender form of trypomastigote is the dividing form (arrow), whereas the short, stumpy form (not shown) is infective for the intermediate host. *T. b. gambiense* is transmitted by the tsetse fly, *Glossina palpalis* and *G. tachinoides*, in riverine regions of west and central Africa. There are no reservoir hosts. This species causes immune-mediated damage to capillaries in the brain (perivascular cuffing), resulting in African sleeping sickness and, if untreated, death.

**Life cycle:**

- **Trypomastigotes** in blood → ingested by tsetse fly → dividing **Epimastigotes**
- in fly gut → **Metacyclic trypomastigotes** in fly saliva
- --fly blood meal--→ **Trypomastigotes** in blood
1.3 African trypanosomiasis in a histological section of brain. Note the accumulation of inflammatory cells around the periphery of the blood vessel (perivascular cuffing), including numerous plasma cells (arrows). This phenomenon may be indicative of a hypersensitivity response against parasite antigens adsorbed onto endothelial cells of blood vessels. The resulting immune-mediated damage to the endothelium results in seepage of fluid from the blood into the brain (cerebral edema), leading to neurological symptoms. No trypomastigotes are visible in this section.

• back to *Trypanosoma b. gambiense*
1.4 *Glossina* sp. (tsetse fly), the vector of African trypanosomiasis due to *Trypanosoma brucei brucei* in animals, and *T. b. gambiense* and *T. b. rhodesiense* in humans. The wings, which are extended outward on this mounted specimen, normally are folded on top of each other when resting. Although most flies are not susceptible to infection, both males and females can serve as vectors.

- back to *Trypanosoma b. rhodesiense*
- back to *Trypanosoma b. gambiense*
1.5 Trypomastigotes of *Trypanosoma cruzi*, peripheral blood smear. Note the posterior location and large size of the kinetoplast (K), and the characteristic “C”-shape of several cells. The trypomastigote of this species is nondividing, and serves instead to disseminate the infection to tissue cells and to the vector. *T. cruzi* is transmitted in South and Central, and rarely North, America by several species of **kissing bugs**. Numerous wild and peridomestic animals (e.g., dogs and cats) serve as reservoir hosts. This parasite causes Chagas’ disease, which has both an acute stage, sometimes fatal in young children, and a chronic stage, which includes a gastrointestinal form (megaesophagus and megacolon, due to destruction of autonomic ganglia) and a **cardiac form** (cardiomegaly, ventricular aneurism, and arrhythmia, due to destruction of heart muscle and conducting cells).

**Life cycle:**

intracellular **amastigotes** (dividing) --burst cell--→ **trypomastigotes** in blood (nondividing) --re-invade cell or ingested by kissing bug--→ dividing **epimastigotes** in bug gut --→ **metacyclic trypomastigotes** in bug feces --rubbed into bite wound or eye--→ intracellular **amastigotes**
1.6 Amastigotes of *Trypanosoma cruzi*, spleen smear. Note the absence of an undulating membrane or emergent flagellum. The kinetoplast (K) is more darkly stained than the nucleus (N), and the parasite’s cytoplasm is unstained. Large purple objects are host spleen cell nuclei (H). Amastigotes of *T. cruzi* would be indistinguishable from those of *Leishmania donovani*.

• back to trypomastigotes of *Trypanosoma cruzi*
1.7 Amastigotes of *Trypanosoma cruzi* in heart muscle cells, histological section. Due to the destruction of myofibers and conducting cells of the heart, this parasite is the leading cause of heart disease in S. America. Note necrosis in upper right corner.

• back to *trypomastigote* of *Trypanosoma cruzi*
1.8 Epimastigotes of *Trypanosoma cruzi*, culture smear. This is the replicating stage found in the gut of the kissing bug. Note the undulating membrane (U) and anterior location of the kinetoplast (K) relative to the nucleus (N). These are indistinguishable from epimastigotes of other trypanosomes.

• back to trypomastigote of *Trypanosoma cruzi*
• back to trypomastigote of *Trypanosoma b. rhodesiense*
• back to trypomastigote of *Trypanosoma b. gambiense*
1.9 Kissing bug, *Triatoma gerstaeckeri* (Family Reduviidae, Subfamily Triatominae), a potential vector of *Trypanosoma cruzi*. 

**a.** Entire bug viewed from above.  
**b.** Side view of head, showing proboscis folded underneath.  
**c.** Bug feeding on a mouse. Note the extended proboscis. In addition to its large size, other features of this vector include a cone-shaped head with prominent eyes, dorsoventrally flattened body with wings folded in a concavity on top of the abdomen, margin of the abdomen with orange stripes, antennae in 4 segments, and a 3-segmented labial tube. Infectious metacyclic trypomastigotes of *T. cruzi* pass out in the bug’s feces, and are rubbed into the bite wound or the eye, usually while the victim is sleeping. This specimen was collected in San Antonio, TX.

- back to [trypomastigote](#) of *Trypanosoma cruzi*
- back to [epimastigote](#) of *Trypanosoma cruzi*
1.10 Amastigotes of *Leishmania donovani*, liver smear. These are indistinguishable from amastigotes of *Trypanosoma cruzi*. Note the minute size, and absence of an emergent flagellum or undulating membrane. The kinetoplast (K) is the dark rod-shaped inclusion near the round nucleus (N). Large purple structures are host liver cell nuclei (H). *L. donovani* is transmitted by *Phlebotomus* spp. sand flies in the old world (Africa, Asia, Middle East) and by *Lutzomyia* spp. in the new world (C and S America). Dogs and rodents are important reservoir hosts. Amastigotes of *L. tropica* or *L. mexicana* from skin lesions and *L. braziliensis* from mucocutaneous lesions would appear identical. Amastigotes of *L. donovani* infect macrophages of internal organs and cause **visceral leishmaniasis** (kala azar), characterized by hepatosplenomegaly, immunosuppression, anemia and death in 2-3 years if untreated.

**Life cycle:**

- **dividing amastigotes** in macrophage → **burst macrophage** → **free amastigotes**
- **re-phagocytosed or ingested by fly** → **dividing promastigotes** in fly gut
- **injected into bite wound, phagocytosed** → **dividing amastigotes** in macrophage
1.11 Visceral leishmaniasis in liver caused by *Leishmania donovani*, histological section. **a.** Low magnification view, showing extensive infection of liver macrophages (Kupffer cells) by amastigotes, apparent as dark, mottled areas. **b.** Higher magnification, showing infected host cells adjacent to uninfected hepatocytes.

• back to amastigote of *Leishmania donovani*
1.12 Promastigotes of *Leishmania donovani*, culture smear. This is the stage found in the gut of the **sand fly**. Note the absence of an undulating membrane, and the anterior location of the kinetoplast (K) relative to the nucleus (N).

• back to **amastigote** of *Leishmania donovani*
1.13 *Lutzomyia diabolica* (sand fly), a potential vector of *Leishmania mexicana* in the New World. In addition to its small size, the sand fly can be recognized by its hairy wings and body, and the 60-degree angle at which the resting wings are held from the body. This insect possesses cutting rather than piercing mouthparts. The specimen pictured here is a nonbiting male.

- back to *amastigote* of *Leishmania donovani*
- back to *promastigote* of *Leishmania donovani*
2. Lumen-Dwelling Flagellates

- Trophozoites of *Chilomastix mesnili*
- Cysts of *Chilomastix mesnili*
- Trophozoites of *Giardia lamblia*
- Cysts of *Giardia lamblia*
- Trophozoites of *Dientamoeba fragilis*
- Trophozoites of *Trichomonas vaginalis*
2.1 Trophozoites of *Chilomastix mesnili*, stool smear. Note the pyriform shape, single nucleus, and presence of cytostomal groove (C), visible when the focus is changed slightly (arrow). There are three anteriorly directed flagella (F), and one flagellum that is recurved into the cytostomal groove. Note also the considerable size variation. Although usually considered harmless, some authorities suspect that it may cause diarrhea. The trophozoite would be found mainly in loose stools.

**Life cycle:**

- trophozoite in cecum & colon → **cyst** in feces ← ingested ← trophozoite in cecum & colon
2.2 Cysts of *Chilomastix mesnili*, stool smear. Note the lemon shape, single nucleus, and “cap” at one end (C). Axonemes and the cytostomal groove often can be seen within the cyst. This stage normally would be found in solid stools, and is the infective form.

• back to trophozoite of *Chilomastix mesnili*
2.3 Trophozoites of *Giardia lamblia*, stool smear. Note the pyriform shape, two nuclei, and median bodies (M). The trophozoite stage normally would be found in loose stools. Flagella (which number 8) are not visible in these photographs, although axonemes (A) can be seen in the cytoplasm of some cells as dark lines. While many infected people are asymptomatic, this flagellate can cause protracted diarrhea.

**Life cycle:**

*<trophozoite>* in small intestine → *cyst* in stools → ingested → *trophozoite* in small intestine
2.4 Cysts of *Giardia lamblia*, stool smear. Note the oval shape, smooth cyst wall, axonemes (A), and four nuclei, usually not all of which are visible in one focal plane. The cytoplasm often is retracted from the cyst wall in fixed specimens, leaving a clear space. The cyst normally would be found in formed stools, and is the infective stage. Although ingestion of cysts from human feces accounts for most cases of giardiasis, there are numerous reservoir hosts, e.g., beavers, and infections have been acquired by persons who drank what appeared to be pristine stream water or melted snow contaminated with cysts of animal origin.

- back to *trophozoite* of *Giardia lamblia*
2.5 Trophozoites of *Dientamoeba fragilis*, stool smear. Although the trophozoite is ameboid and there are no flagellated stages in the life cycle, this parasite is actually a trichomonad flagellate. Approximately 60% of specimens possess two nuclei (which are still connected by a mitotic spindle). The cytoplasm usually contains endocytosed material, and while not very obvious in these photographs, the nuclear chromatin typically occurs in 3-5 clumps. In contrast to most intestinal protozoa, there is no cyst, and the trophozoite is the infective stage. Infections apparently are acquired by ingesting eggs of the pinworm, *Enterobius vermicularis*, that are hyperparasitized by trophozoites of *D. fragilis*. Usually considered harmless, there is some evidence that *D. fragilis* can cause diarrhea.

**Life cycle:**

- **trophozoite** in large intestine --*infects pinworm?*--\(\rightarrow\) **trophozoite** in pinworm eggs --*egg ingested*--\(\rightarrow\) **trophozoite** in large intestine
2.6 Trophozoites of *Trichomonas vaginalis*, culture smear. Note the presence of a single nucleus (N), undulating membrane (U), four anterior flagella (F), and axostyle (A). As for all trichomonads, there is no cyst stage, and transmission is direct, usually via sexual intercourse but also by sharing washcloths. Symptoms range from none to a painful discharge in females and prostatitis in males.
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<td>Trophozoites of <em>Iodamoeba butschlii</em></td>
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3.1 Trophozoites of *Entamoeba histolytica*, stool smear. A nucleus with a central endosome and a fine peripheral ring of chromatin distinguishes this parasite from *E. coli*. Trophozoites would be found mainly in loose stools. Charcot-Leyden crystals, representing the crystallized contents of granules from eosinophil leukocytes (bottom right frame), may also be found in a fecal smear. Infection occurs when the cyst is ingested in fecally contaminated food or water. This parasite is capable of causing ulcerative colitis, resulting in severe dysentery, as well as extraintestinal amebiasis, including fatal brain infections.

**Life cycle:**

**trophozoite** in large intestine \rightarrow **cyst** in feces \rightarrow ingested \rightarrow **trophozoite** in large intestine
3.2 Cysts of *Entamoeba histolytica*, stool smear. Note the presence of four or fewer nuclei. Although all four nuclei may not be visible in the same plane, they can be counted by carefully adjusting the fine focus control (N1-N4, second row). Chromatoidal bars (C), when present in immature cysts, usually have blunt ends, versus splintered ends in cysts of *E. coli*. Cysts would be found mainly in formed stools, and are the infective stage.

• Back to *trophozoite* of *Entamoeba histolytica*
3.3 Trophozoites of *Entamoeba coli*, stool smear. This species can be distinguished from *E. histolytica* by the usually eccentric location of the endosome and the relatively coarser, larger granules in the ring of peripheral chromatin. Although harmless, accurate identification of this parasite is important, because it is an indicator of fecal-oral contamination, and because it could be confused with the pathogenic species. Infection occurs when the cyst is ingested. Trophozoites would be found mainly in loose stools.

**Life cycle:**

**trophozoite** in large intestine $\rightarrow$ **cyst** in feces $\rightarrow$ ingested $\rightarrow$ **trophozoite** in large intestine
3.4 Cysts of *Entamoeba coli*, stool smear. Note the presence of more than four nuclei (actually, eight are present in mature cysts). Chromatoidal bars (C) in immature cysts have splintered ends, versus blunt ends in cysts of *E. histolytica*. Cysts would be found mainly in formed stools, and are the infective stage.

• Back to *trophozoite* of *Entamoeba coli*
3.5 Trophozoites of *Endolimax nana*, stool smear. Note the small size and prominent endosome. Although harmless, it is important to be able to identify this parasite, because it is an indicator of fecal-oral contamination, and because it could be confused with the pathogenic species. Infection occurs when the cyst is ingested. Trophozoites would be found mainly in loose stools.

**Life cycle:**

*trophozoite* in large intestine → **cyst** in feces → ingested → **trophozoite** in large intestine
3.6 Cysts of *Endolimax nana*, stool smear. Note the small size and presence of up to 4 nuclei with prominent endosomes. Cysts would be found mainly in formed stools, and are the infective stage.

- Back to trophozoite of *Endolimax nana*
3.7 Trophozoites of *Iodamoeba butschlii*, stool smear. Note the prominent endosome and numerous cytoplasmic vacuoles. Although usually considered to be harmless, it is suspected of causing diarrhea. Also, it is important to be able to identify this parasite, because it is an indicator of fecal-oral contamination, and because it could be confused with the pathogenic species. Trophozoites would be found mainly in loose stools. Infection occurs when the cyst is ingested.

**Life cycle:**

**trophozoite** in large intestine $\rightarrow$ **cyst** in feces $\rightarrow$ ingested $\rightarrow$ **trophozoite** in large intestine
3.8 Cysts of *Iodamoeba butschlii*, stool smear. Note the oval shape, prominent endosome, and large, single, glycogen-filled vacuole (called an iodinophilous vacuole, since the glycogen stains with iodine). Cysts would be found mainly in formed stools, and are the infective stage. The cell is retracted from the cyst wall in one specimen (arrow).

• back to trophozoite of *Iodamoeba butschlii*
3.9 Cysts of *Blastocystis hominis*, trichrome stain. Although considered a yeast by some, others classify it as an amoeba. Cysts may contain a central vacuole-like inclusion surrounded by a thin rim of cytoplasm with a variable number of granules. There is some controversy not only over its taxonomic position, but also whether it can cause diarrhea.
3.10 *Acanthamoeba culbertsoni* trophozoite, culture smear. Note the spike-like rhizopods. Certain species of this genus of free-living amoebae have been found as opportunistic parasites of immunosuppressed individuals and in immunocompetent persons suffering trauma to the conjunctiva of the eye or using contaminated contact lens cleaning solutions. In immunosuppressed individuals, it forms slowly spreading granulomas in the visceral organs. Eye infection may require surgical removal of the eye. The cyst is the infective stage, and it can also be found in biopsies of infected tissues.

**Life cycle:**

**trophozoite** in soil ↔ **cyst** in soil ↔ introduced into eye → **trophozoite** in tissues ↔ **cyst** in tissues
3.11 Histological section of mouse brain infected with *Naegleria fowleri*. a. Low magnification view of brain with central necrotic zone (area within dashed line). b. Individual trophozoites within necrotic zone, each with a prominent endosome. c. Trophozoites in a culture smear. Human infections with this opportunistic parasite are contracted by diving into water containing the infective biflagellated form, which adheres to the olfactory epithelium, transforms into the trophozoite, and invades the brain via the olfactory nerve. The resulting primary amoebic meningoencephalitis (PAM) is rapidly fatal. Cysts are not found in the tissues.

**Life cycle:**

- **Cyst** in bottom mud $\leftarrow\rightarrow$ **trophozoite** in bottom mud $\rightarrow\rightarrow$ **biflagellated cell**
  - Inhaled into nasal cavity $\rightarrow\rightarrow$ **trophozoite** in nasal cavity
  - Migrates along olfactory nerve $\rightarrow\rightarrow$ **trophozoite** in brain
3.12 Trophozoites of *Balantidium coli*, stool smear. Note the oval shape, large curved macronucleus (M), cytostome (C), peristomal cilia (P), and food vacuoles (V). The only pathogenic ciliate parasite of humans, *B. coli* can cause intestinal lesions that result in a disease similar to amoebic dysentery, although this is rare. Trophozoites would be found mainly in loose stools. Infections are established when the infective cyst is ingested with fecally-contaminated food or water. Because this parasite also infects pigs, human infections with *B. coli* are especially common in pig-rearing areas.

**Life cycle:**

**trophozoite** in large intestine $\rightarrow$ **cyst** in feces $\rightarrow$ ingested $\rightarrow$ **trophozoite** in large intestine
3.13 Cysts of *Balantidium coli*, stool smear. Note the smooth round shape, large curved macronucleus, and cyst wall (W), which has separated from the cell in some specimens. Cysts would be found mainly in formed stools, and are the infective stage.

• Back to trophozoite of *Balantidium coli*
3.14 Intestinal balantidiasis and amebiasis, histological sections. 

a. Lesion (area under bracket) in colon caused by *Balantidium coli*. MM, muscularis mucosae. In addition to trophozoites in the lesion itself (green arrow), there are also trophozoites in lymphatic vessels in the submucosa (red arrows), demonstrating how the infection may spread to other sites. *B. coli* only rarely causes this pathology in humans.  

b. Higher magnification of trophozoites in lesion. Note the macronucleus in some specimens (arrow).  


d. Trophozoites at base of the lesion, some of which contain darkly stained, phagocytosed red blood cells. Arrow points to the nucleus of a trophozoite.

• back to trophozoite of *Entamoeba histolytica*  
• back to trophozoite of *Balantidium coli*
4. Spore-Forming Tissue Protozoa

- Oocysts of *Cryptosporidium parvum*
- Bovine cryptosporidiosis
- Oocysts of *Cyclospora cayetanensis*
- Oocysts of *Isospora belli*
- Tachyzoites of *Toxoplasma gondii*

- Zoitocysts of *Toxoplasma gondii* in brain
- Enteroepithelial cycle of *Toxoplasma gondii*
- Muscle sarcocysts of *Sarcocystis* sp.
- Microsporidian spores
- *Pneumocystis carinii*, lung smear
4.1 Oocysts of *Cryptosporidium parvum*, stool smear. First row, modified acid fast stain; rows 2-5, wet mount. Cryptosporidiosis is a major cause of diarrheal disease in developing countries, and has increasingly been recognized as a health problem in the United States. Due to its widespread occurrence in animals and resistance of oocysts to chlorination (including household bleach), it is a threat to public water supplies. Symptoms range from severe diarrhea for up to 2 weeks in previously healthy people to life-threatening diarrhea in immunocompromised patients. Oocysts contain 4 sporozoites when passed in the feces, and are immediately infective, with some rupturing in the intestine and reinfecting epithelial cells (autoinfection). A water-borne outbreak in Milwaukee in 1993 sickened over 400,000.

**Life cycle:**

infective oocyst --ingested--➤ sporozoites in intestinal lumen --invade cell--➤ trophozoite in brush border -- mitosis--➤ schizont in brush border --cytokinesis, release from cell--➤ merozoites in lumen --reinvade cell--➤ gametocytes in brush border --differentiation--➤ gametes --fertilization--➤ zygote --cyst wall formation, meiosis, release from cell--➤ infective oocyst in feces
4.2 Bovine cryptosporidiosis: *Cryptosporidium parvum* infection in the intestinal epithelium of a cow. **a.** Heavily infected intestinal villus. Villus atrophy, which may be occurring here, and crypt hyperplasia are the two prominent histopathological features of cryptosporidiosis. Note the numerous parasites in the brush border of the enterocytes. **b.** Higher magnification view of a developing oocyst (arrow). Although the parasites appear to be on the surface of the enterocytes, they are actually enclosed by the plasma membrane of the microvilli, and hence are intracellular.

• back to oocysts of *Cryptosporidium parvum*
4.3 Oocysts of *Cyclospora cayetanensis*, wet mount. This coccidian has been implicated in several outbreaks of diarrhea in the U.S. following the consumption of fresh produce (raspberries from Guatemala, mesclun lettuce, basil). Symptoms range from mild to fever, nausea, and diarrhea, which can be protracted and severe (e.g. 35 stools/day). Therefore, infections in AIDS patients are serious. The oocyst is unsporulated when passed in the feces, producing 2 sporocysts, each with 2 sporozoites, after 7-12 days, depending on the temperature. Because the oocyst, like that of *Isospora belli*, is autofluorescent, diagnosis can be made by scanning wet mounts with a fluorescence microscope equipped with a 340-380 nm filter (right photos).

**Life cycle:**

infective oocyst -- ingested --► sporozoites in intestinal lumen --► invade cell --►

trophozoite -- mitosis --► schizont --► cytokinesis, release from cell --►

merozoites in lumen --► reinvade cell --► gametocytes --► differentiation --►

gametes --► fertilization --► zygote --► cyst wall formation --►

oocyst in feces --► sporulation (7-12 days) --► infective oocyst
4.4 Oocysts of *Isospora belli*, wet mount, bright field and Nomarski interference optics. Oocysts are passed out in the feces unsporulated, containing one cell (sporont) or two cells (sporoblasts). Each sporoblast develops outside the host into a sporocyst with 4 sporozoites (8 sporozoites/oocyst). As with *Cyclospora cayetanensis*, oocysts of *I. belli* fluoresce when viewed with ultraviolet light between 340 and 380 nm (top right photographs). Human infections with *I. belli* occur mainly in the tropics, and can cause fever and severe diarrhea, which may be fatal in AIDS patients.

**Life cycle:**

infective oocyst → ingested → ♣ sporozoites in intestinal lumen → invade cell → ♣ trophozoite → mitosis → ♣ schizont → cytokinesis, release from cell → ♣ merozoites in lumen → reinvade cell → ♣ gametocytes → differentiation → ♣ gametes → fertilization → ♣ zygote → cyst wall formation → ♣ oocyst in feces → sporulation → ♣ infective oocyst
4.5 Extraintestinal cycle of *Toxoplasma gondii* in the mouse. When an intermediate host, which could be almost any mammal or bird, ingests **oocysts** (containing sporozoites) from cat feces or **zoitocysts** (containing bradyzoites) in the tissues of another intermediate host, repeated, rapid cycles of schizogony occur, releasing **merozoites** (tachyzoites), which infect cells in a wide variety of tissues.  

**a.** Histological section of liver, showing an infected cell in the center (arrow) and a necrotic area above. **b.** Smear of peritoneal fluid, showing tachyzoites. This stage of the infection usually produces mild, if any, symptoms in healthy persons, but can be lethal in immunocompromised individuals, (acquired toxoplasmosis), and can cause severe damage to the fetus if transmitted **transplacentally** (congenital toxoplasmosis).
4.6 Histological sections of zoitocysts of *Toxoplasma gondii* in the brain of a mouse. The proliferation of tachyzoites elicits an immune response that slows down schizogony, resulting in accumulations of slowly-dividing merozoites, called bradyzoites, within an infected cell. These intracellular accumulations, known as zoitocysts, may persist for years in nervous tissue. Ingestion of zoitocysts will initiate the **enteroepithelial cycle** in cats, and the **extraintestinal cycle** in birds and mammals.

**Extraintestinal life cycle:**

infective **oocyst** or **zoitocyst** --ingested--➤ **sporozoites** or **merozoites** in intestinal lumen --invade cells--➤ intracellular **trophozoite** --mitosis--➤ **schizont** --cytokinesis, release from cell--➤ **tachyzoites** --reinvade cell--➤ intracellular **trophozoite** --mitosis--➤ **schizont** --host immune response--➤ **zoitocyst** containing **bradyzoites**
4.7 Enteroepithelial cycle of *Toxoplasma gondii* in the epithelial lining of the cat intestine, histological section. **a.** Intestinal epithelial cells infected with oocysts (O) and schizonts (S) containing merozoites. **b.** Oocysts in infected epithelial cells and free in lumen. Ingestion of oocysts (containing sporozoites) or intermediate hosts infected with *tachyzoites* or *zoitocysts* (containing bradyzoites) results in schizogony and sexual reproduction, leading to the production of oocysts. This sexual cycle occurs only in the cat, whereas in intermediate hosts, only asexual schizogony occurs.

**Enteroepithelial life cycle:**

infective oocyst or zoitocyst $\rightarrow$ ingested $\rightarrow$ sporozoites or merozoites in intestinal lumen $\rightarrow$ invade cell $\rightarrow$ intracellular trophozoite $\rightarrow$ mitosis $\rightarrow$ schizont $\rightarrow$ cytokinesis, release from cell $\rightarrow$ merozoite in lumen $\rightarrow$ rein invade cell $\rightarrow$ gametocytes $\rightarrow$ differentiation $\rightarrow$ gametes $\rightarrow$ fertilization, cyst wall formation, release from cell $\rightarrow$ oocyst in feces $\rightarrow$ sporulation (2 to 3 days) $\rightarrow$ infective oocyst
4.8 Histological sections of muscle cysts (sarcocysts) of *Sarcocystis* spp. from cattle. Members of this genus undergo an obligately heteroxenous life cycle, with sexual reproduction occurring in a carnivore, and several cycles of schizogony occurring in a herbivore. Because the oocyst easily ruptures in the digestive tract of the definitive host, usually only sporocysts (packets of sporozoites) are released in the feces. Humans can serve as definitive host for some species and intermediate host for others. **a.** Sarcocyst in skeletal muscle packed with bradyzoites and compartmentalized by internal septa. **b, c.** Cardiac muscle cysts.

**Life cycle:**

- **sporocyst** or **oocyst** → ingested by intermediate host → **sporozoites** in intestinal lumen → invade tissues, penetrate endothelial cells → **trophozoite** → schizogony → **merozoites** → rein invade muscle cells, undergo schizogony → **sarcocyst** with bradyzoites → ingested by definitive host → **merozoites** in intestinal lumen → invade lamina propria, differentiate → **gametes** → invasion of epithelial cell, fertilization → **zygote** → cyst wall formation, meiosis → **oocyst** → released from cell, ruptures → **sporocyst** in feces
4.9 Spores of a microsporidian, *Pleistophora husseyi*, in a smear of tissue from an infected snail (*Physa virgata*). Parasites of everything from other protozoa to mammals, microsporidia can inflict economic losses on the silkworm and honeybee industries, and several species can cause serious disease in AIDS patients. These organisms are unrelated to the apicomplexan sporozoans in Figures 4.1 - 4.8, but as intracellular protozoa that form spores, they are most conveniently included here. Top right photograph shows a snail tissue section stained with the fluorescent dye Uvitex 2-B, which binds to chitin in the spore wall, and viewed with a fluorescence microscope.
4.10 *Pneumocystis carinii* in a smear of infected rat lung. *P. carinii* is now considered to be fungus, rather than a protozoan. Life threatening pneumonia develops in immunocompromised individuals infected with this organism. The life cycle is not fully known, but precysts (green arrow), cysts, with 8 intracystic bodies (red arrow), and amoeboid trophozoites (yellow arrow) have been described.
5. Blood Sporozoans

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<td>Oocysts of <em>Plasmodium</em> sp. on midgut</td>
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<td>Sporozoites of <em>Plasmodium vivax</em></td>
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<td>Exoerythrocytic schizont of <em>Plasmodium</em></td>
<td>Erythrocytic schizonts of</td>
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<td>Trophozoites of <em>Plasmodium vivax</em></td>
<td>Trophozoites of <em>Plasmodium</em></td>
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<td>Erythrocytic schizonts of <em>Plasmodium</em></td>
<td>Erythrocytic schizonts of</td>
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<td>Young trophozoites of <em>Plasmodium falciparum</em></td>
<td>Trophozoites of <em>Babesia canis</em></td>
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<td>Cerebral malaria</td>
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5.1 Mouthparts of *Anopheles* sp. mosquitoes. *Plasmodium* spp. infections are transmitted to humans by the bite of the female *Anopheles* mosquito (top). Males (bottom) are physiologically capable of supporting parasite development, but since they do not feed on blood, they cannot transmit infection. Males are easily recognized by the plumose hairs on their antennae. This genus of mosquito can be identified by its palps, which are almost as long as the proboscis, and the 45-degree angle at which it sits when resting or feeding.

• back to oocysts of *Plasmodium*

• back to sporozoites of *Plasmodium*
5.2 Oocysts of *Plasmodium* sp. on the surface of an *Anopheles* sp. mosquito midgut. **Gametocytes** taken up in a blood meal develop into gametes in the midgut, fertilization occurs, and the zygote (ookinete) penetrates the midgut wall to develop into an oocyst, which produces **sporozoites**. The sporozoites then migrate to the salivary gland.

**Life Cycle (mosquito stages in orange):**

- **sporozoite** in mosquito salivary glands → injected during feeding → **sporozoite** in blood → invades hepatocyte → **trophozoite** in hepatocyte → mitotic division →
- **schizont** in hepatocyte → hepatocyte bursts → **merozoites** in blood → invade RBC →
- **trophozoite** in RBC → mitotic division → **schizont** in RBC → RBC bursts →
- **merozoites** in blood → reinvade RBC → **schizont** or **gametocyte** in RBC →
  - gametocytes ingested by mosquito → **gametes** in midgut → fertilization → **zygote** → elongation → **ookinete** → penetrates midgut epithelium, meiotic and mitotic division →
- **oocyst** containing **sporozoites** → sporozoite migration in hemolymph →
- **sporozoites** in salivary glands
5.3 Sporozoites of *Plasmodium vivax* in a squash of an oocyst from an infected *Anopheles* mosquito. Sporozoites develop in oocysts on the wall of the stomach, and then migrate in the hemolymph to the salivary glands. Several thousand may be injected into the host by one mosquito during feeding. Upon reaching the liver, each will penetrate into an hepatocyte and develop into an exoerythrocytic schizont.

*back to* gametocytes of *Plasmodium falciparum*
5.4 Exoerythrocytic schizonts of *Plasmodium* sp. in liver cells. Once introduced into the bloodstream, **sporozoites** of *Plasmodium* penetrate hepatocytes within 30 minutes. Each undergoes schizogony, to produce an exoerythrocytic (EE) schizont, which is a single multinucleate cell. Cytokinesis occurs, and thousands of merozoites burst from the hepatocyte within 1-2 weeks post infection, depending upon the species (e.g., 40,000 merozoites in 5-7 days in the case of *P. falciparum*). These merozoites then infect erythrocytes. During infections with *P. vivax* and *P. ovale*, some EE schizonts develop into dormant hypnozoites, and upon becoming active may cause a relapse of the disease years after a supposed cure.

• back to **Babesia canis**
5.5 Trophozoites of *Plasmodium vivax*. These can be identified as *P. vivax* by the following features: enlarged, decolorized infected erythrocytes; prominent Schüffner’s dots; and the ameboid shape of the trophozoite. Decolorization is not apparent here. Hemozoin granules may be relatively difficult to identify in this species. Malaria caused by *P. vivax* usually is not life-threatening.

• back to trophozoites of *Plasmodium malariae*

• back to trophozoites of *Plasmodium ovale*
5.6 Erythrocytic schizonts of *Plasmodium vivax*. When merozoites invade host erythrocytes, most undergo schizogony to produce 12 to 24 merozoites (average of 16) within approximately 48 hours. These burst out of the cell and immediately infect new cells. Because the infection becomes synchronous in the host, large numbers of infected erythrocytes burst more or less simultaneously, causing a rapid rise in body temperature at 48-hour intervals.
5.7 Young signet ring stage trophozoites of *Plasmodium falciparum*. This organism kills more people annually than all other parasites combined. Because of its pathogenicity, a failure to recognize *P. falciparum* infection in a smear like the one shown here may have fatal consequences. Diagnostic features are: high parasitemia; presence of only signet ring trophozoites; appliqué forms, double chromatin dots, and multiple infections in some cells; and absence of Schüffner’s dots. Soon after this stage, infected cells disappear from the circulation by adhering to endothelial cells of blood vessels in the tissues, making diagnosis difficult and potentially leading to cerebral malaria. Schizogony results in new infected erythrocytes, which reappear in the peripheral blood at 48-hour intervals. Some individuals who are apparently “cured” of infection may develop symptoms years later due to resurgence of previously low, nondetectable levels of parasitemia (a phenomenon called recrudescence, not to be confused with relapse).
5.8 Erythrocytic schizonts of *Plasmodium falciparum*. This stage usually is not observed in peripheral blood, except in very heavy infections. Each schizont produces from 6 to 32 merozoites, with an average of 20 to 24, every 48 hours. Hemozoin pigment is clumped in the center of the infected RBC. Note that the merozoites are very small, and that the schizont usually does not fill up the RBC.
5.9 Gametocytes of *Plasmodium falciparum*. Some merozoites penetrate erythrocytes and differentiate into gametocytes instead of undergoing schizogony. Although the gametocytes of all four human-infecting species can be distinguished, those of *P. falciparum* have a unique appearance, and therefore are valuable in diagnosis. Macrogametocytes of this species are elongate, and have a nucleus less than one-half the length of the cell. Microgametocytes may be shorter and more blunt-ended, have a lighter blue cytoplasm, and have a nucleus that is greater than one-half the length of the cell. Gametocytes do not produce gametes until they reach the midgut of a mosquito. The gametes fuse to produce a zygote that elongates into an ookinete. The ookinete penetrates the midgut wall and develops into an oocyst, in which sporozoites are produced.
5.10 Trophozoites of *Plasmodium malariae*. Occasionally trophozoites form a band shape, stretching across the red blood cell, as shown in these photographs. The cytoplasm of the parasite stains more darkly than in *P. vivax*, and there are no Schüffner’s dots. Hemozoin granules are much more conspicuous in this species than in the other three. Unlike the case with *P. vivax*, infected erythrocytes are not enlarged.
5.11 Erythrocytic schizonts of *Plasmodium malariae*. From 6 to 12 merozoites (average of 8) form in each infected cell at 72-hour intervals. The merozoites are often, but not always, arranged in a rosette around the periphery, with the hemozoin granules at the center.
5.12  Growing trophozoites of *Plasmodium ovale*. This species has the lowest prevalence among malarial parasites, occurring mainly in tropical Africa. Although sometimes difficult to distinguish from *P. vivax*, up to 20-60% of infected cells show oval distortion (versus around 5% in *P. vivax*), as depicted in this plate. Schüffner’s dots and hemozoin granules are prominent, as is the large chromatin mass. Also, infected cells are enlarged (although usually not as enlarged as with *P. vivax*), and some of the infected cells have fimbriated (ragged) edges.
5.13 Erythrocytic schizonts of *Plasmodium ovale*. This stage shares many diagnostic features with the trophozoite stage: enlarged, ovaly-distorted host cells, and prominent Schüffner’s dots. From 6 to 14 merozoites (average = 8) are produced by each schizont in 48 hr. The schizonts shown in these photographs are at a relatively early stage of development.
Trophozoites of *Babesia canis* from dog blood. Trophozoites are pear shaped and often occur in pairs or fours, joined at the tip, a result of binary schizogony. A related species in rodent reservoirs, *B. microti*, has caused numerous human infections on the northeast coast of the U.S. The resulting malaria-like disease can be treated with anti-trypanosome drugs, but usually self cures without complication except in splenectomized patients, for whom it may be fatal. There is no *exoerythrocytic schizogony* in the life cycle, and the vector is a tick. In some species of *Babesia*, transovarial transmission may occur from one tick generation to the next, allowing the parasite to persist in ticks that feed on only a single host. Patient history (no travel to a malarious area) and the absence of hemozoin may allow one to distinguish this parasite from *Plasmodium* spp.
5.15 Histological section of brain from a case of cerebral malaria. In *Plasmodium falciparum* infections, the surfaces of infected red blood cells express parasite proteins that cause them to adhere to the endothelial lining of blood vessels in the organs. Note the brown (hemozoin)-tinted blood vessels in the low magnification view on the left, which at higher magnification on right are seen to be clogged with infected red blood cells, visible by their black deposits of hemozoin pigment in the parasite cytoplasm. Cerebral malaria can be rapidly lethal, especially in small children and nonimmune adults, and is a major reason that *P. falciparum* is one of the greatest killers of humans.

• back to **young trophozoites** of *Plasmodium falciparum*
6. Trematodes (Flukes)

- Echinostoma revolutum
- Heterophyes heterophyes
- Fasciolopsis buski
- Fasciola hepatica
- Clonorchis sinensis
- Dicrocoelium dendriticum
- Paragonimus westermani
- Schistosoma mansoni

Eggs of:
- Clonorchis sinensis
- Fasciola hepatica
- Paragonimus westermani
- Schistosoma mansoni
- Schistosoma haematobium
- Schistosoma japonicum
- Schistosoma mansoni
- Echinostoma paraensei

- Metacercariae
- Life cycle of Schistosoma mansoni
- Schistosome-transmitting snails
- Clonorchis sinensis in bile duct
- Schistosoma mansoni eggs in liver
- Schistosoma mansoni in small intestine
- Eggs of Schistosoma haematobium in bladder
6.1 *Echinostoma revolutum.*  

**a.** Adult worm. Echinostomes are intestinal parasites with a worldwide distribution. Infection results from ingesting metacercariae, usually in uncooked molluscs. Mammals and birds serve as reservoir hosts. Heavy infections may cause diarrhea. Structures visible are two tandem testes (T), faintly-stained ootype (O), ovary (OV), uterus (U) filled with eggs, acetabulum (A), and seminal vesicle (S). Extensive vitelline glands (V) occupy lateral margins.  

**b.** Newly formed eggs in the uterus, which are passed out unembryonated in the feces of the definitive host.  

**c.** Collar of spines surrounding mouth, the feature that gives echinostomes their name.  

**Life cycle:**

- **adult** in small intestine of definitive host  
  --→ **egg** in feces  
  --→ **2 wk**  
  --→ **miracidium**  
  --→ penetrates snail (1st intermediate host)  
  --→ **sporocyst**  
  --→ produces many  
  --→ **mother rediae**  
  --→ each produces many  
  --→ **daughter rediae**  
  --→ each produces many  
  --→ **cercariae**  
  --→ penetrate 2nd intermediate host (mollusc)  
  --→ **metacercaria**  
  --→ ingested by definitive host  
  --→ **adult**
Life cycle:

**adult** in small intestine of definitive host ——> **eggs** in feces ——> eaten by snail 1st intermediate host ——> **miracidium** ——> penetrates gut ——> **sporocyst** ——> each produces many ——> **mother rediae** ——> each produces many ——> **daughter rediae** ——> each produces many ——> **cercariae** ——> penetrate fish 2nd intermediate host ——> **metacercaria** ——> ingested by definitive host ——> **adult**
6.3 *Fasciolopsis buski*. a. Adult worm. This giant (up to 75 mm) fascioloid intestinal fluke is contracted in Asia by eating uncooked aquatic plants on which metacercariae have encysted. Dogs and pigs serve as reservoir hosts. Heavy infections can cause diarrhea, intestinal obstruction, and systemic toxicity, which may be fatal. Tandem, dendritic testes are faintly visible posteriorly. Unlike the related *Fasciola hepatica*, *F. buski* possesses unbranched intestinal ceca (not visible here), and does not possess “shoulders” at the anterior end. Extensive vitelline glands occupy the lateral margins, and the gravid uterus is visible at the anterior end. b. Eggs in uterus. c. Tegument, showing absence of spines.

**Life cycle:**

adult in small intestine of definitive host → **eggs** in feces → 7 wk → **miracidium** → penetrates *Segmentina* snail (1st intermediate host) → **sporocyst** → produces many → **mother rediae** → each produces many → **daughter rediae** → each produces many → **cercariae** → encyst on vegetation → **metacercaria** → ingested by definitive host → **adult**
6.4 *Fasciola hepatica*. **a.** Adult worm. This large (up to 30 mm) liver fluke has a worldwide distribution. Infections are contracted by eating uncooked aquatic plants on which metacercariae have encysted. Sheep and cattle are reservoir hosts. Juvenile worms cause anemia, damage to the liver parenchyma, and may lodge in ectopic locations, e.g., the brain or eye, whereas adults damage the bile ducts. This species can be recognized easily by its cephalic cone and “shoulders,” as well as the highly branched intestinal ceca, clearly visible at the posterior end. Two darkly stained, tandem, dendritic testes occur in the middle of the body. **b.** Eggs in uterus, similar to those of *Fasciolopsis buski*. **c.** Tegument, showing spines.

**Life cycle:**

adult in bile ducts of definitive host --► **eggs** in feces --9-10 days--► **miracidium** --penetrates lymnaeid snail (1st intermediate host)--► **sporocyst** --produces many--► **mother rediae** --each produces many--► **daughter rediae** --each produces many--► **cercariae** --encyst on vegetation--► **metacercaria** --ingested by definitive host--► **juvenile** --penetrates through intestine into coelom, then into liver--2 months in parenchyma--► **adult** in bile ducts
6.5 *Clonorchis sinensis*.  

**a.** Adult worm. Infections with this liver fluke are contracted in Asia by eating uncooked freshwater fish in which metacercariae have encysted. Piscivorous mammals can serve as reservoir hosts. Although the liver parenchyma is not invaded, heavy infections may cause such **damage to the bile ducts** that jaundice, hepatomegaly, ascites, and death occur. Note the posterior, tandem, dendritic testes, the relatively large seminal receptacle anterior to the testes, the gravid uterus, and vitelline glands, confined to the middle of the body.  

**b.** Eggs in uterus.  

**c.** Tegument, showing absence of spines.  

- back to **adult** of *Dicrocoelium dendriticum*

**Life cycle:**

- adult in bile ducts of definitive host  ➔ **eggs** in feces  ➔ eaten by *Parafossarulus* snail (1st intermediate host)  ➔ **miracidium**  ➔ penetrates gut  ➔ **sporocyst**  ➔ produces many  ➔ **rediae**  ➔ each produces many  ➔ **cercariae**  ➔ penetrate 2nd intermediate host (freshwater fish)  ➔ **metacercaria**  ➔ ingested by definitive host  ➔ **juvenile**  ➔ migrates up bile duct  ➔ **adult**
6.6 *Dicrocoelium dendriticum*. a. Adult worm. This liver fluke occurs in Europe, Asia, and N. America. It has an unusual terrestrial life cycle, and infections are contracted by eating ants infected with metacercariae. Infected ants display negative geotaxis during cool times of the day, causing them to crawl up blades of grass where they may be eaten by sheep and cattle. Thus, human infections are rare, but can mimic biliary disorders seen with other liver flukes. Note pointed ends of body, and extensive posterior uterus (unlike that of *Clonorchis sinensis*, with which it may be confused). b. Eggs in uterus. c. Tegument, showing absence of spines.

**Life cycle:**

- **adult** in bile ducts of definitive host $\rightarrow$ **eggs** in feces $\rightarrow$ eaten by *Cionella* land snail (1st intermediate host) $\rightarrow$ **miracidium** $\rightarrow$ penetrates gut $\rightarrow$ **mother sporocyst** $\rightarrow$ produces many $\rightarrow$ **daughter sporocysts** $\rightarrow$ each produces many $\rightarrow$ **cercariae** in snail mucus $\rightarrow$ ingested by ant (2nd intermediate host) $\rightarrow$ **metacercaria** in ant hemocoel $\rightarrow$ ingested by definitive host $\rightarrow$ **juvenile** migrates up bile duct $\rightarrow$ **adult** in bile ducts
Life cycle:

**adult** in lungs of definitive host --**eggs** in sputum or feces --2 wks--**miracidium**
--penetrates thiarid snail (1st intermediate host)--**sporocyst** --produces many--**mother rediae**
--each produces many--**daughter rediae** --each produces many--**cercariae**
--penetrate freshwater crab (2nd intermediate host)--**metacercaria**
--ingested by definitive host--**juvenile** --penetrates through intestine into coelom, then through diaphragm into lung--**adult**

6.7 *Paragonimus westermani*. **a.** Adult worm. Infections with this lung fluke are contracted in Asia, the S. Pacific, and S. America by eating uncooked freshwater crabs that are infected with metacercariae. Numerous mammals, especially cats, serve as reservoir hosts. The lung lesions containing worm pairs result in hemoptysis, chronic cough, and frequent bacterial superinfection. Also, the juvenile worms may travel to ectopic locations, e.g., the brain, causing seizures. Note the coffee-bean shape, long, wavy ceca, adjacent, branched testes, and off-centered, lobate ovary. **b.** Eggs in uterus, collapsed during specimen processing. **c.** Tegument, showing spines.
6.8 *Schistosoma mansoni*.  

**a.** Adult worms. Infections with this blood fluke are acquired in Africa, S. America, and parts of the Caribbean when cercariae from *Biomphalaria* spp. snails penetrate through the skin. Thus, no metacercarial stage is involved. Eggs deposited by the female in mesenteric veins are swept into the liver and elicit an **inflammatory response**, resulting in fibrosis, which may cause portal hypertension and hemorrhage of collateral vessels. **Intestinal lesions** may also occur. Note that the worms have separate sexes, and that the female is wrapped within the gynecophoral canal of the male.  

**b.** Single egg within uterus.  

**c.** Male tegument, showing papillae. The tegument of *S. haematobium* (which occurs in Africa) has fewer papillae, and that of *S. japonicum* (in Asia) is smooth.

**Life cycle:**

- **adult** in mesenteric veins of definitive host → **eggs** in feces → **miracidium**
- penetrates *Biomphalaria* snail (1st intermediate host) → **mother sporocyst**
- produces many → **daughter sporocysts** → each produces many → **cercariae**
- penetrate skin of definitive host → **schistosomulum**
- migrates to liver, mates, migrates to mesenteric veins → **adult**
6.9 Eggs of *Clonorchis sinensis*. Top row photographed at the same magnification as eggs of other species in following figures. The small size of this egg is a key diagnostic feature. Second and third rows photographed at a higher magnification, to show the operculum sitting in a rim, and a fully formed miracidium, which does not hatch from the egg until ingested by a snail. A small abopercular knob is visible on some eggs.

*back to adult of *Clonorchis sinensis*

*back to adult of *Heterophyes heterophyes*
6.10 Eggs of *Fasciola hepatica*. Note the unembryonated condition, smooth oval shape, and relatively small (compared to eggs of *Paragonimus westermani*) operculum, which is most easily seen at the bottom right, where it has partially opened due to the pressure of the coverslip. Usually, yolk granules completely fill the immature egg.

- back to **adult** of *Fasciola hepatica*
- back to **eggs** of *Echinostoma paraensei*
6.11 Eggs of *Paragonimus westermani*. This egg would be found in human sputum, but also occurs in feces when swallowed. Note the thick abopercular wall, unembryonated condition, and relatively wide (compared to eggs of *Fasciola hepatica*) operculum, which sits in a rim.

• back to adult of *Paragonimus westermani*
6.12 Eggs of *Schistosoma haematobium*. These would be found mainly in urine, because the adult worms inhabit veins surrounding the bladder, but eggs also are found in feces. They are easily identified by the terminal spine and fully formed miracidium, which hatches immediately in fresh water through a tear in the egg shell (upper right photo). *S. haematobium* occurs in Africa and the Middle East, and is transmitted by *Bulinus* snails. In addition to hematuria and fibrosis of the bladder and ureters, infections are associated with bladder cancer.
6.13 Eggs of *Schistosoma japonicum*. Note the fully formed miracidium, which hatches immediately in fresh water through a tear in the shell (bottom row), and the minute lateral spine, which is not apparent in several photographs because it is not viewed in profile. This species, which occurs in Asia, is the most pathogenic of the human-infecting schistosomes due to the high egg production by females and the tendency of the small eggs to pass through the liver and enter the systemic circulation, causing pathology in other organs, especially the central nervous system. *S. japonicum* is transmitted by operculate snails in the genus *Oncomelania*. 
6.14 Eggs of *Schistosoma mansoni*. Note the fully formed miracidium, which hatches immediately in fresh water through a tear in the shell (lower right photo), and the large lateral spine, which may be inconspicuous if pointing straight up (top right photo). This species is transmitted in Africa, the Caribbean, and Brazil by snails in the genus *Biomphalaria*.

• back to adult of *Schistosoma mansoni*
6.15 Eggs of *Echinostoma paraensei*. Unembryonated when first deposited in the feces, a miracidium develops within two weeks and hatches through a small operculum (bottom right two photos). Compare with eggs of *Fasciola hepatica*.

• back to adult of *Echinostoma revolutum*
6.16 Metacercariae. These encysted stages occur in the life cycle of nearly all trematodes except for the schistosomes.  

a. Histological section of *Clinostomum*, a parasite of bird definitive hosts, in fish muscle.  
b. *Fasciola hepatica*, metacercariae of which would be found on the surface of aquatic plants, e.g., watercress.  
c. *Paragonimus westermani*, from the muscle of infected crab.  
d. *Echinostoma paraensei*, from the pericardial cavity of a snail. Note the thick tunic of snail hemocytes surrounding each echinostome metacercaria.

- back to **adult** of *Echinostoma revolutum*
- back to **adult** of *Fasciola hepatica*
- back to **adult** of *Paragonimus westermani*
6.17 Life cycle of *Schistosoma mansoni*. **a.** Adult worms *in copula*. **b.** Egg in feces. Eggs hatch immediately upon reaching fresh water, releasing a miracidium.  **c.** Miracidium, which must penetrate into a susceptible snail within several hours.  **d.** Miracidia penetrating head foot of *Biomphalaria glabrata*. Each miracidium transforms into a single mother sporocyst at the site of penetration.  **e.** Mother sporocyst in tentacle of *B. glabrata* several weeks after penetration of the miracidium.  **f.** Squash of tentacle infected with mother sporocyst, showing released daughter sporocysts.  **g.** Higher magnification of daughter sporocyst, showing typical elongation and enlargement of anterior end. These migrate posteriorly to the digestive gland.  **h.** Digestive gland of infected snail (green), largely replaced by daughter sporocysts (yellow). These give rise to cercariae.  **i.** Cercaria, with characteristic forked tail. These attach to human skin, drop their tail, penetrate, and are then called schistosomula.  **j.** Schistosomulum, which pairs with a worm of the opposite sex in the liver, develops to adulthood, and migrates to the mesenteric veins.

- back to adult of *Schistosoma mansoni*
6.18 Snail vectors of schistosomiasis. **a. Biomphalaria glabrata**, intermediate host of *Schistosoma mansoni* in the New World. Note the planospiral shell and the red tissue coloration, due to free hemoglobin in the hemolymph, a characteristic of planorbid snails (i.e., in the family Planorbidae). These snails can grow to well over 20 mm in diameter. Since they are hermaphroditic and can self-fertilize, and because they can survive desiccation by entering a state of dormancy, they are difficult to control with molluscicides. **b. Bulinus truncatus** from Egypt, the intermediate host of *S. haematobium*. Note the more conical, globose shell. This snail is also a planorbid. **c. Oncomelania hupensis**, the intermediate host of *S. japonicum*. This snail is much smaller than the other two (only several mm long), and unlike them lacks hemoglobin, has separate sexes, possesses a gill, and has an operculum on its head foot that it uses to seal the aperture of its shell. Due to its operculum and because it is amphibious rather than aquatic, it too is difficult to control with molluscicides.

- back to eggs of *S. haematobium*, *S. japonicum* or to eggs / adults of *S. mansoni*
6.19 Histological section of bile duct infected with adults of *Clonorchis sinensis*. These worms feed upon, and damage, the epithelium of the duct, which is eroded in some areas of this section. Note the inflammatory response in the lamina propria of the duct, possibly caused by bacterial infection, which results in further tissue damage. Routine ingestion of uncooked freshwater fish harboring metacercariae can lead to infections with thousands of adults, resulting in biliary dysfunction, jaundice, ascites, and sometimes death.

*back to adult of *Clonorchis sinensis*
6.20 Histological section of liver from mouse infected with *Schistosoma mansoni*.  

**a.** Low magnification view, showing three granulomas in the parenchyma.

**b.** Higher magnification view of single granuloma surrounding an egg, which has a clearly visible lateral spine. These granulomas protect the surrounding hepatocytes from lytic enzymes released by the egg, but unfortunately occlude the sinusoids and presinusoidal capillaries through which blood must flow. As a result, pressure is elevated in the hepatic portal vein carrying blood from the intestine to the liver ( portal hypertension), causing seepage of fluid into the abdominal cavity (ascites fluid). More importantly, thin-walled collateral vessels form to carry the blood around the liver blockage and back to the heart. If a large vessel bursts, especially in the wall of the esophagus (rupture of esophageal varices), fatal hemorrhage may result. Liver disease occurs in about 8% of cases of infection with *S. mansoni* and *S. japonicum*.

• back to adult of *Schistosoma mansoni*. 
6.21 Histological section of small intestine from mouse infected with *Schistosoma mansoni*. **a.** Several eggs in mucosa, surrounded by a diffuse cellular infiltrate. **b.** Higher magnification of an egg, showing lateral spine (arrow). In humans, the most severe lesions in the case of *S. mansoni* infections occur in the colon. Symptomatic intestinal schistosomiasis is most common with *S. japonicum*.

• back to adult of *Schistosoma mansoni*. 
6.22 Eggs of *Schistosoma haematobium* in the wall of the urinary bladder.  

**a.** Large numbers of calcified eggs in the muscularis. Note the thickened epithelium.  

**b.** Higher magnification of eggs. The terminal spines of the eggs are not visible in this section. Damage to the bladder wall can lead to hematuria, bacterial infections, as well as metaplasia and possibly cancer of the bladder epithelium.

• back to eggs of *Schistosoma haematobium*
7. Cestodes (Tapeworms)

- *Diphyllobothrium latum*
- Scolex of *Taenia pisiformis*
- Proglottids of *Taenia pisiformis*
- *Taenia saginata* vs. *Taenia solium*
- Cysticercus of *Taenia solium*
- *Echinococcus granulosus*
- Unilocular vs. multilocular hydatid cyst

- *Hymenolepis nana*
- *Dipylidium caninum*
- Eggs of *Diphyllobothrium latum*
- Eggs of *Hymenolepis nana*
- Eggs of *Hymenolepis diminuta*
- Taeniid eggs
- Eggs of *Dipylidium caninum*
7.1 Adult of *Diphyllobothrium latum*. **a.** Scolex, showing groove-like bothrium (arrow) used to grasp the host mucosa. **b.** Mature proglottid. 

**c.** Higher magnification of mature proglottid, showing bilobed ovary, uterus with eggs, and follicular vitelline glands. The pink background is due to numerous follicular testes, situated between the dorsal and ventral layers of vitelline follicles. In this species, eggs are released through the uterine pore, located anterior to the uterus. **d.** Higher magnification of eggs in uterus. Infection results from eating second intermediate or paratenic hosts infected with plerocercoids. Symptoms range from none to fatigue, to diarrhea; however, approximately 2% of infected individuals develop megaloblastic anemia, due to the worm’s unique affinity for vitamin $\text{B}_{12}$. Ingestion of first intermediate hosts (or of intermediate or paratenic hosts of non human-infecting pseudophyllideans, e.g., *Spirometra mansonoides*) leads to development of plerocercoids in the tissues (sparganosis).

**Life cycle:**

**adult** in intestine of definitive host (piscivorous mammals) $\rightarrow$ **eggs** in feces $\rightarrow$ 1-several weeks$\rightarrow$

coracidium hatches from egg $\rightarrow$ **procercoid** in hemocoel $\rightarrow$ eaten by fish/frog (2nd intermediate host)$\rightarrow$

plerocercoid in muscles $\rightarrow$ eaten by fish/snake/swine (paratenic hosts)$\rightarrow$

plerocercoid in muscles $\rightarrow$ eaten by definitive host$\rightarrow$ **adult**
7.2 Scolex of *Taenia pisiformis*, a tapeworm of dogs, that shows typical cyclophyllidean anatomy. **a.** Scolex and neck (where immature proglottids are formed), showing armed rostellum and 4 acetabula (suckers). The scolex of *T. solium* would appear similar, whereas that of *T. saginata* lacks hooks. **b.** Higher magnification of rostellum, showing circle of hooks. **c.** Higher magnification of individual hook.
7.3 Strobila (body) of *Taenia pisiformis*. a. Immature proglottids being formed from neck region. b. Immature proglottids containing developing reproductive organs. c. Mature proglottid, showing a bilobed ovary, follicular testes, lateral genital pore, and posterior vitelline mass. Ventral canals of the excretory system are visible laterally.
7.4 *Taenia saginata* vs. *T. solium*. 

**a.** Proglottid of *T. saginata*. 
**b.** Scolex of *T. saginata*. Note the absence of hooks. 
**c.** Proglottid of *T. solium*. 
**d.** Scolex of *T. solium*. Note the rostellum, armed with hooks.

The two species can be distinguished both on the basis of their scolex, and by counting the number of side branches of the gravid uterus, numbering >14 in *T. saginata* and <14 in *T. solium*. Human infections with the adult worm are acquired by eating undercooked beef (*T. saginata*) or pork (*T. solium*) infected with cysticerci. Infections with adults usually cause mild or no symptoms. However, *T. solium* is quite hazardous, because its eggs (unlike those of *T. saginata*) if ingested by humans release an oncosphere that develops into a bladder-like cysticercus larva, which can cause severe disease in the brain or eye. Also, gravid proglottids may rupture in the intestinal lumen, resulting in overwhelming cysticercosis.

- back to scolex of *Taenia pisiformis*

**Life cycle:**

**adult in small intestine** → **gravid proglottid** in feces

→ ruptures → embryonated **eggs** → ingested by cow (*T. saginata*), pig (*T. solium*), human (*T. solium*) → **oncosphere** hatches from egg → penetrates gut, enters - **cysticercus** in internal organs → ingested by human → **adult**
7.5 Cysticercus of *Taenia solium*. a. Histological section of infected pork, showing 4 cysticerci, each consisting of a fluid-filled bladder containing an invaginated, introverted (inside-out) scolex. Cysticercosis results from ingestion of *T. solium* eggs from human feces, and occurs in both pigs and humans. Also, humans harboring the adult tapeworm may develop heavy burdens of cysticerci when gravid proglottids are retained in the intestine and then rupture, releasing thousands of infective eggs. Cysticerci can lodge in any organ, and may be visible as surface swellings if occurring subcutaneously. Depending on numbers and location, cysticerci in the brain may cause symptoms of epilepsy. Note the absence of inflammation around viable cysticerci. However, dead cysticerci elicit a strong inflammatory response, which can be fatal if occurring in the brain. b. Whole mount of cysticercus, showing bladder and introverted, invaginated scolex (hooks not visible at this magnification).

• back to adult of *T. solium* and *T. saginata*
7.6 Adult of *Echinococcus granulosus*. a. Adult worm, consisting of a scolex and 3 proglottids. b. Eggs in uterus. These are indistinguishable from eggs of other taeniids that are found in dog feces. c. Higher magnification of the scolex, which bears 4 suckers and an armed rostellum. When eggs of this parasite are ingested by intermediate hosts, including humans, the oncosphere develops in internal organs into a large fluid-filled hydatid cyst, in which infectious protoscolices are produced asexually. These cysts grow slowly, sometimes filling with up to 2 liters of fluid, eventually compressing surrounding tissues. Disease may result from pressure effects or from rupture of large cysts, causing anaphylactic shock. This parasite is more common in sheep-rearing areas, where sheep, rabbits, and other mammals eaten by dogs become infected by ingesting eggs from dog feces. Dogs develop heavy infections, because a single cyst contains many protoscolices, each of which develops into an adult.

**Life cycle:**

adult in dog intestine $\rightarrow$ **eggs** in feces $\rightarrow$ ingested by intermediate host $\rightarrow$

oncosphere hatches from egg $\rightarrow$ penetrates gut, enters blood vessel $\rightarrow$

**hydatid cyst** in internal organs $\rightarrow$ **protoscolices** (hydatid sand) $\rightarrow$

ingested by dog $\rightarrow$ adult
7.7 Hydatid cysts. These develop in the internal organs of intermediate hosts, including humans, that ingest eggs from feces of infected canids. **a.** Histological section of the wall of a unilocular cyst of *Echinococcus granulosus*. Hanging into the fluid filled cavity is a brood chamber, composed of germinal membrane and containing protoscolices. The inner germinal layer of the cyst (endocyst, EN) is surrounded by an acellular, laminated ectocyst (EC). A thick fibrous tissue host response (HR) surrounds the ectocyst. **b.** Histological section of a multilocular cyst of *E. multilocularis*. Because the cyst of this species lacks a restraining laminated ectocyst, the germinal membrane can grow outward into surrounding tissues or break off and metastasize to other sites. Therefore, prognosis is grave unless the infection is diagnosed early and the cyst surgically removed. *E. multilocularis* is mainly a parasite of wild canids, especially foxes, and consequently fur trappers are at risk of infection.

*back to adult of *Echinococcus granulosus*
7.8 *Hymenolepis nana*. a. Cysticercoid (possibly of either *H. nana* or *H. diminuta*). b. Adult. c. Scolex and neck. The rostellum is retractable into a sac and is armed with hooks, not visible at this magnification. d. Mature proglottids. This species is unique among tapeworms in not requiring an intermediate host to complete its life cycle (a direct or homoxenous life cycle). However, an indirect life cycle, utilizing an insect intermediate host, also can occur. Humans become infected by ingesting eggs from rodent or human feces, or by ingesting intermediate hosts infected with cysticerci. Light infections are asymptomatic. However, because eggs may hatch in the intestine of the definitive host, autoinfection can produce heavy parasite burdens (thousands of worms) leading in humans to diarrhea and symptoms of toxicity.

**Life cycle (direct):**

- **adult** in intestine → **proglottid detaches, disintegrates** → **eggs** in feces
  → ingested by definitive host → **oncosphere** hatches from egg
  → **cysticercoid** in lamina propria
  → leaves villus (5-6 days) → **adult** in intestine
7.9 *Dipylidium caninum*.  

**a.** Scolex, consisting of 4 suckers and an armed rostellum, retracted into a sac in this photograph.  

**b.** Immature proglottid.  

**c.** Mature proglottid. Note the two lateral genital pores, diagnostic for this species.  

**d.** Gravid proglottid, in which the uterus has broken up into egg capsules, each containing 5-20 eggs. Gravid proglottids are quite motile for a short time after being passed out in the feces.  

**e.** Two egg capsules in the uterus. This relatively harmless tapeworm is a cosmopolitan parasite of dogs and cats, and rarely humans, most often children. Infections are acquired by ingesting a flea intermediate host infected with the cysticercoid stage.  

**Life cycle:**  

- **adult** in small intestine --⇒ **gravid proglottid** in feces --disintegrates--⇒  
- **egg capsule** --ingested by flea--⇒ **oncosphere** hatches from egg --penetrates gut--⇒  
- **cysticercoid** in hemocoel --ingested by definitive host--⇒ **adult**
7.10 Eggs of *Diphyllobothrium latum*. Because of the large size of the adult, a million eggs/day may be shed in the feces from each worm. The eggs are operculate, symmetrically oval, and sometimes have an abopercular knob (arrow). Structurally they are similar to a trematode egg. The embryo is undeveloped when the egg is released from the uterus, and must complete its development to the coracidium stage (a ciliated oncosphere) in fresh water.

• back to adult of *Diphyllobothrium latum*
7.11 Eggs of *Hymenolepis nana*. Top left photograph shows a higher magnification. Note the oncosphere with hooks (thin arrow), surrounded by an embryophore that has polar filaments at either end (thick arrows). The outermost capsule is separated from the embryophore by a gelatinous granular layer. These eggs are infective not only for an insect intermediate host, but also for the rodent or human definitive host.

• back to adult of *Hymenolepis nana*
• back to egg of *Hymenolepis diminuta*
7.12 Eggs of *Hymenolepis diminuta*. As with eggs of *H. nana*, the oncosphere is surrounded by an embryophore, gelatinous layer, and capsule. However, eggs of *H. diminuta* are larger, and the embryophore lacks polar filaments. Note clearly visible hooks in some specimens. These eggs are infective solely for the insect intermediate host, usually a grain or flour beetle. Human infections result from ingestion of insects harboring the infective cysticercoid, and therefore are rare and usually light.

**Life cycle:**

**adult** in intestine → proglottid detaches, disintegrates → **eggs** in feces
→ ingested by insect intermediate host → **oncosphere** hatches from egg
→ penetrates gut → **cysticercoid** in hemocoel → ingested by definitive host →

**adult** in intestine
7.13 Taeniid eggs. The oncosphere is surrounded by a 2-layered embryophore, and the thicker outer layer has prominent radial striations, a diagnostic feature. The surrounding gelatinous layer and capsule (arrow, top left photograph) are flimsy and often detach from the striated embryophore, which then becomes the outermost layer. Eggs of various taeniids (e.g., *Echinococcus*, *Multiceps*, and *Taenia* spp.) are indistinguishable from one another. Taeniid eggs in human feces would indicate infection with either the relatively harmless *Taenia saginata* or the quite pathogenic *T. solium*, and therefore further diagnostic tests would be advisable, e.g., examination of scoleces and gravid proglottids recovered from feces. Taeniid eggs on the ground may remain infective for over 5 months.
7.14 Egg capsules of *Dipylidium caninum*. These are released from disintegrating gravid proglottids, which are quite active after being passed in the feces until they desiccate. The capsules are formed from compartments of the uterus.

•back to **adult** of *Dipylidium caninum*
8. Nematodes & Acanthocephalans

- *Trichuris trichiura*
- *Capillaria hepatica*
- *Trichinella spiralis*
- Hookworms
- Rhabditiform vs. filariform larvae
- *Ascaris lumbricoides*
- Larvae of *Ascaris lumbricoides* in lung
- *Enterobius vermicularis*
- *Dirofilaria immitis*
- Microfilariae of *Brugia malayi* and *Wucheraria bancrofti*
- *Onchocerca volvulus*
- *Gongylonema ingluvicola*
- Eggs of *Trichuris trichiura*
- Hookworm eggs
- Eggs of *Trichostrongylus* sp.
- Eggs of *Ascaris lumbricoides*
- Eggs of *Toxocara canis*
- Eggs of *Enterobius vermicularis*
- Acanthocephalans
8.1 *Trichuris trichiura*.  

**a.** Adult male. Note curved posterior end.  

**b.** Adult female.  

**c.** Portion of esophagus, surrounded by unicellular glands called stichocytes. These cosmopolitan intestinal parasites have an easily recognizable whip-like shape, hence the common name whipworm. The long, thin anterior end lies buried in the mucosa of the ileocecal region. Because of the mechanical and possibly immune-mediated damage to the mucosa, heavy infections can result in dysentery, anemia, and rectal prolapse. Heavy infections in children, common in some tropical countries, can retard physical development and cognition.

**Life cycle:**

- **adult** in ileocecal region $\rightarrow$ unembryonated **eggs** in feces $\rightarrow$ 2 wk $\rightarrow$ **J₁** in egg
- **J₁** ingested, hatches $\rightarrow$ **J₁** in intestinal crypts $\rightarrow$ 4 molts $\rightarrow$ **adult** in ileocecal region
8.2 *Capillaria hepatica*.  

**a.** Histological section of liver, showing adult female. Note disruption of parenchyma in the area surrounding the worm and in the migration path (arrow).  

**b.** Histological section of liver showing large masses of eggs displacing parenchyma.  

**c.** Higher magnification of eggs, which resemble those of *Trichuris* spp., but have thicker, striated shells.  

**d.** Eggs in smear of infected liver tissue. Normally a parasite of rats, its eggs escape to the outside only with the death of the host. The eggs, which do not develop at body temperature, require several weeks to embryonate on the ground, and are then infective for rats (or humans) that ingest them. Note that fecal contamination is not involved in the transmission (unless from a predator that has consumed the rat). Depending on the volume of liver that has been replaced by eggs, infected individuals may be asymptomatic or may display various liver disorders, usually with accompanying eosinophilia.

**Life cycle:**

**adult** in liver $\rightarrow$ **eggs** in liver $\rightarrow$ host dies $\rightarrow$ unembryonated **eggs** on ground $\rightarrow$ 2 wk $\rightarrow$ $J_1$ in egg $\rightarrow$ ingested, hatches, migrates to liver, molts 4x $\rightarrow$ **adult**
8.3 *Trichinella spiralis*.  

**a.** Portion of adult female, showing uterus packed with J₁ larvae. Each female releases approximately 1,500 J₁s in the intestine of the definitive host. 

**b.** Several juveniles encysted in pork skeletal muscle. 

**c.** Higher magnification of juvenile in nurse cell. This nematode is unusual in that it is an intracellular parasite, and the definitive host also serves as intermediate host. Infection occurs when infective encysted larvae are eaten in uncooked meat, usually pork (although an outbreak occurred in France due to ingestion of infected horse meat). Humans are compatible hosts, but they are a “dead end” for the parasite in the sense that their muscles usually are not eaten by another animal. This parasite is quite pathogenic, damaging not only skeletal muscles but also intestinal mucosa, lungs, heart myofibers, and the brain. A single bite of heavily infected, undercooked pork, often in the form of sausage, can be fatal.

**Life cycle:**

- **adult** in intestinal mucosa $\rightarrow$ **J₁** in lymphatics, blood (some pass out in feces) $\rightarrow$ penetrate skeletal myofibers $\rightarrow$ **J₁** in nurse cell $\rightarrow$ ingested by definitive host, molts 4x $\rightarrow$ **adult** in intestinal mucosa
8.4 Hookworms.  a. Female *Necator americanus*.  b. Male *N. americanus*.  Note posterior copulatory bursa.  Both specimens show dorsal curvature of the anterior end, hence the name “hookworm.”

c. Buccal capsule of *Ancylostoma duodenale*, showing the large ventral teeth.  
d. Copulatory bursa of male *A. duodenale*.  
e. Dorsal ray of the bursa of *A. duodenale*, showing 3 branches at the end of each fork.  
f. Buccal capsule of *N. americanus*, showing cutting plate (arrow).  
g. Copulatory bursa of male *N. americanus*.  
h. Dorsal ray of the bursa of *N. americanus*, showing 2 branches at the end of each fork.

Besides structural differences, *N. americanus* is more prevalent everywhere except southern Europe, and its life cycle differs slightly from that of *A. duodenale* (i.e., no developmental arrest in immune hosts; a requirement for migration through the lung).  Heavy infection with these blood-feeding worms causes anemia and symptoms of protein malnourishment, which can be fatal.

**Life cycle:**

**adult** in small intestine $\rightarrow$ unembryonated **egg** in feces $\rightarrow$ 24 hr $\rightarrow$

rhabditiform $J_1$ in soil $\rightarrow$ 2 molts $\rightarrow$ filariform $J_3$ in soil $\rightarrow$ penetrates skin, travels in blood to lungs, breaks through alveolus, coughed up, swallowed, molts 2x $\rightarrow$

**adult** in small intestine
8.5 Rhabditiform vs. filariform larvae.  

**a.** Anterior end of rhabditiform (J₁) hookworm larva. A corpus, isthmus, and end bulb are all present in the esophagus.  

**b.** Higher magnification of anterior end of rhabditiform hookworm larva, showing large buccal capsule (BC). This feature allows it to be distinguished from the rhabditiform larva of *Strongyloides stercoralis*.  

**c.** Anterior end of filariform (J₃) hookworm larva. No isthmus is present in the esophagus, although a nerve ring is visible (arrow). This is the infective larval stage.

• back to adult hookworm
8.6 *Ascaris lumbricoides* adults.  

**a.** Adult females (top) and males (bottom).  Note curved posterior end of male.  

**b.** Cross section at the level of the esophagus.  Note the triradiate lumen of the esophagus (E), a feature of all nematodes.  

**c.** Cross section of male.  

**d.** Cross section of female.  

CU, cuticle; ET, excretory tubules; I, intestine; IP, innervation processes; LC, lateral cords; MU, longitudinal muscles; O, ovary; OD, oviduct; P, pseudocoel; T, testis; V, vas deferens.  

In heavy infections pneumonitis results from lung damage during larval migration.  Large numbers of adults can cause malnutrition, allergic symptoms, and fatal intestinal blockage, and wandering worms can invade visceral organs or cause asphyxiation if aspirated.  

• back to eggs of *Toxocara canis*

**Life cycle:**

adult in intestine ---► unembryonated eggs in feces --2 wk--► J₂ in egg  

--ingested, hatches--► J₂ in intestine --penetrates mucosa, travels to lungs in blood, penetrates alveolus, moves up to pharynx, swallowed, molts 2x--► adult in intestine
8.7 J₂s of *Ascaris lumbricoides* in lungs. Although larvae hatch from eggs in the duodenum, which is the location for the adult worm, they undergo a complex migration by penetrating into the mucosa and travelling via the blood to the lungs, where they molt twice to the J₄ stage. They then break into an alveolus, pass up to the pharynx, and are swallowed. Upon reaching the duodenum for the second time, they develop into adults. 

a. Juvenile (arrow) breaking into alveolus. Note severe inflammation (pneumonitis) in interstitial tissue. 

b. Bronchus containing inflammatory cells and larvae, which are travelling upward to the pharynx prior to being swallowed. Damage from heavy infections, especially if complicated by bacterial superinfection, can be fatal.

•back to adult of *Ascaris lumbricoides*
8.8 *Enterobius vermicularis*.  

**a.** Adult male (on left) and female. Note long pointed tail of female, hence the name “pinworm.”  

**b.** Histological section of appendix, showing three cross sections of pinworms in the lumen (arrow). Although often residing in the appendix, the worms are not believed to cause appendicitis. Infection occurs when the eggs containing $J_3$s are inhaled or swallowed. The major symptom of infection is perianal itching, although more serious problems can result if tissue invasion occurs, and adults sometimes wander into the female reproductive tract.

**Life cycle:**

- **adult** in ileocecal region → female migrates to perianal skin → unembryonated *eggs* on perianal skin → 6 hr → $J_3$ in egg → swallowed, hatches → $J_3$ in duodenum → molts 2x, migrates posteriorly → **adult** in ileocecal region
8.9  *Dirofilaria immitis.*  

**a.** Microfilaria in dog peripheral blood smear. In this species the microfilaria, which is an incompletely developed J₁, does not possess a sheath (i.e., the egg capsule), and nuclei do not extend to the tip of the pointed posterior end.

**b.** Adults removed from the heart of an infected dog. Note the threadlike appearance, which is typical of filarial worms. Cardiac and pulmonary pathology occurs in heavily infected dogs. In humans, worms die before attaining adulthood, and are washed into the lung microcirculation, where they form granulomas.

**Life cycle:**

**adult** in right heart and pulmonary artery of dog  \(\rightarrow\) **microfilariae** in peripheral blood

--ingested by mosquito, molt twice  \(\rightarrow\) **J₃** in Malpighian tubules

--migrates to mouthparts, invades bite wound, migrates to heart, molts twice  \(\rightarrow\)

**adult** in right heart and pulmonary artery
8.10 Microfilariae in peripheral blood smears, Geimsa stain.  

**a.** Microfilaria of *Brugia malayi*.  **b.** Microfilaria of *Wucheraria bancrofti*. These species are distinguished by the following criteria: presence of a terminal and subterminal nucleus in the tail of *B. malayi* (black arrows), separated by an indentation, vs. the absence of nuclei in the tail of *W. bancrofti* (region enclosed by green bracket); large cephalic space in *B. malayi* vs. small cephalic space in *W. bancrofti* (region enclosed by red bracket); compact column of nuclei in *B. malayi* vs. more dispersed nuclei in *W. bancrofti*. Note the prominent sheath in both specimens (red arrows).
8.11 *Onchocerca volvuluis*. **a.** Histological section of adults in a fibrous capsule below the skin.  **b.** Histological section of uterus of female, showing microfilariae.  **c.** Histological section of dermis, showing wandering microfilariae (arrows).  **d.** *Simulium* sp. (blackfly), the vector of *O. volvuluis*. Note humped appearance of thorax. Due to the inflammatory response against the microfilariae in the skin and eyes, severe dermatitis and blindness (“river blindness”) result from longstanding heavy infections. Human infections occur in Africa and South America.

**Life cycle:**

**adult** in subcutaneous nodules $\rightarrow$ **microfilariae** in skin $\rightarrow$ ingested by blackfly, molt twice $\rightarrow$ **J$_3$** in flight muscles $\rightarrow$ migrates to mouth parts, enters bite wound, molts twice $\rightarrow$ **adult** in subcutaneous nodules
8.12 *Gongylonema ingluvicola* in esophageal epithelium of a pig. The worm tunnels through the epithelium, leaving trails of eggs which are shed into the lumen, swallowed, and passed out in the feces. Infection results from ingesting insect intermediate hosts (cockroaches and dung beetles) containing infective J₃ larvae.

**Life cycle:**

- **adult** in esophageal epithelium → unembryonated **eggs** in feces →embryonation→
- J₁ in egg →ingested by insect, molts twice→ J₃ in hemocoel →ingested by mammal,
molts twice→ **adult** in esophageal epithelium.
Eggs of *Trichuris trichiura*. Note the symmetrical barrel shape and plugs on each end. Embryonation to the infective $J_1$ requires approximately two weeks.

- back to **adult** of *Trichuris trichiura*
- back to *Capillaria hepatica*
8.14 Hookworm eggs. The embryo is surrounded by an extremely thin shell, which sometimes collapses during specimen preparation (arrow). Eggs of the two major human-infecting hookworms, *Necator americanus* and *Ancylostoma duodenale*, are indistinguishable. Embryos are usually at the 4 or 8-cell stage when eggs are passed out in the feces.

- back to adult hookworms
- back to eggs of *Trichostrongylus* spp.
8.15 Eggs of *Trichostrongylus* spp. Eggs of these blood-sucking intestinal nematodes appear similar to those of *hookworms*, with a thin shell and morula embryo. However, they are larger, one end is more tapered, and the embryo contains a greater number of cells.
8.16 Eggs of *Ascaris lumbricoides*. The outermost layer of the shell is proteinaceous and mammillated (bumpy). The eggs typically contain a zygote when passed in the feces (top two rows), and the embryo develops to the J<sub>2</sub> (bottom row) in 9-13 days. The eggs are extraordinarily resistant to adverse environmental conditions, and can survive for 10 years in shaded soil. Eggs sometimes are decorticated, i.e., without the mammillated coat, and consequently appear smooth surfaced (last photo, middle row). These can be distinguished from hookworm eggs by their thick shell. Unfertilized eggs also are found; these are more elongate than the fertilized eggs, and do not contain a spherical embryo (last photo, top row).

• back to **adult** of *Ascaris lumbricoides*
8.17 Eggs of *Toxocara canis*. This ascarid parasite infects dogs and has a life cycle similar to that of *Ascaris lumbricoides*. Infection occurs when an egg containing a J₂ is ingested. Although not capable of developing to the adult stage in humans, its larvae wander in the visceral tissues of persons accidentally ingesting the infective egg, causing the condition known as visceral larva migrans. Most larvae become encapsulated in the liver, causing minimal symptoms (fever, eosinophilia), but those wandering into the brain or eye can cause disease. Because the parasite is capable of transplacental infection, most puppies are born infected and therefore are quite hazardous until dewormed. A related species, *T. cati*, infects cats, but is not capable of transplacental infection. Both species have cervical alae, shown in the upper row for *T. cati*. As with *Ascaris lumbricoides*, eggs of *Toxocara* spp. survive for years in the soil, and many backyards and playgrounds in the U.S. are contaminated with infective eggs.
8.18 Eggs of *Enterobius vermicularis*. These eggs are deposited on the perianal skin by the female at night, and embryonate to the infective stage within 6 hours. Eggs soon contaminate bed sheets, clothing, and, because they are easily lifted aloft in air currents, the surrounding room. When viewed on edge, the eggs appear flat on one side.

*back to adult of *Enterobius vermicularis*
8.19 Acanthocephalans. These worms bear some similarity to the nematodes in that they are pseudocoelomates, yet also show affinities with tapeworms in having no digestive tract and possessing a tegument rather than a cuticle. The defining feature is the spiny proboscis.  

a. Egg of *Macracanthorhynchus hirudinaceous* viewed on end and lengthwise. The embryo (acanthor) is surrounded by several membranes.  

b. Anterior end of acanthocephalan from turtle intestine, showing proboscis and proboscis receptacle.  

c. Histological cross section of the body wall of a male acanthocephalan. The tegument has a relatively homogeneous outer layer (yellow arrow) and an underlying radial fiber zone (red arrow), in which are found the longitudinal spaces called lacunae. A layer of circular (blue arrow) and longitudinal (green arrow) muscle lies below. Finally, the ligament sac (black arrow), containing the testis, is found in the pseudocoelom.  

d. Histological section of *Macracanthorhynchus hirudinaceous* nearly perforating the intestinal wall. Infections occur in humans who ingest insects harboring the infective larval stage (cystacanth).
For each specimen, name the genus, species, and stage of development. Hypothetical source of the specimen is usually given. Check your answer by clicking on ? .  🔄 returns you to the photograph of the specimen.  ⬅️ returns you to this slide.

By choosing a different Start button, and then proceeding forward ➤ or backward ⇐ , you can vary the sequence of questions each time you take the test.
Iodamoeba butschlii cyst

- oblong
- single nucleus
- large endosome
- large cytoplasmic vacuole
FECAL SPECIMEN
Cryptosporidium parvum oocyst

- small
- spherical
- clear cyst wall
- 4 sporozoites
Plasmodium falciparum young trophozoites

- high parasitemia
- only small signet ring stages present
- double infections
- appliqué forms
- no Schüffner’s dots
- infected RBCs not enlarged or decolorized
Erythrocytic schizont of *Plasmodium ovale*

- enlarged, ovaly-distorted RBC
- prominent Schüffner’s dots
- low number of nuclei
SMEAR OF PERITONEAL FLUID
Toxoplasma gondii tachyzoites

- banana (crescent)-shaped
- central nucleus
- red cytoplasm in hematoxylin & eosin stain
- numerous parasites/infected cell
- no kinetoplast
Chilomastix mesnili cysts

- lemon-shaped
- "cap" at narrow end
- single nucleus
- no endosome
- cytostome present
FECAL SPECIMEN
Balantidium coli cyst

- large
- round
- macronucleus
Isospora belli immature oocyst

- ovoid
- thin cyst wall
- one or two sporoblasts
- polar granule
Trypanosoma cruzi trypomastigote

• undulating membrane
• free flagellum
• prominent kinetoplast
• often “C” or “?” shaped when fixed
• relatively low parasitemia
• nondividing
• no volutin granules
**Entamoeba histolytica** trophozoite

- irregular shape
- central, small discrete endosome
- fine, evenly distributed peripheral ring of chromatin
- relatively clean, finely granular cytoplasm
Microsporidian spores

- ovoid, unicellular spore
- dense, refractile spore wall
- posterior vacuole
- spores single or in groups
Plasmodium falciparum microgametocyte

- presence of hemozoin granules around nucleus
- short, with blunt ends
- nucleus > one-half cell length
Leishmania donovani (or Trypanosoma cruzi) amastigotes

- intracellular parasite
- small, ovoid cell
- uninucleate
- darkly stained kinetoplast
FECAL SPECIMEN
**Giardia lamblia trophozoite**

- rounded anterior end, pointed posteriorly
- dorsoventrally flattened
- two nuclei
- adhesive disk
- intracytoplasmic axonemes
- median bodies
FECAL SPECIMEN
Entamoeba coli cyst

- spherical
- 8 nuclei (6 are visible)
- peripheral chromatin coarse
- cytoplasm coarsely granular
Toxoplasma gondii zoitocyst

- spherical
- intracellular
- contains numerous crescent-shaped bradyzoites
- absence of inflammation
Babesia canis trophozoites

- tear drop-shape
- in pairs or fours, joined at the tip
- no hemozoin granules or Schüffner’s dots
FECAL SPECIMEN
Endolimax nana trophozoite

- small
- oval or irregular shape
- short, blunt pseudopodia
- large endosome
- no peripheral chromatin granules
- glycogen and food vacuoles in cytoplasm
SECTION OF BRAIN
Perivascular cuffing in African trypanosomiasis

- inflammatory cells surrounding blood vessel
Dientamoeba fragilis trophozoite

- round to oval
- 2 nuclei
- fragmented endosome
- vacuolated cytoplasm
Sand fly (*Lutzomyia diabotica*)

- small size
- hairy wings and body
- wings held at 60 degrees from body at rest
- cutting mouthparts
Plasmodium malariae trophozoites

- band shape
- prominent hemozoin granules (not apparent here)
- no Schüffner’s dots
- infected RBC not enlarged or decolorized
Trypanosoma cruzi pseudocyst

- intracellular amastigotes in cardiac myofibers, with recognizable nuclei and kinetoplasts
- inflammation and necrosis at sites of ruptured host cells
*Plasmodium falciparum* erythrocytic schizont

- approximately 20 merozoites/schizont
- very small merozoites
- hemozoin clumped in center
SECTION OF SKELETAL MUSCLE
Sarcocystis sp. zoitocyst (sarcocyst)

- large
- compartmentalized internally by septa
- contains bradyzoites
- radial striations in cyst wall
Endolimax nana cysts

- small
- 4 nuclei
- large endosome
- no peripheral chromatin granules
Trypanosoma cruzi (or Leishmania donovani) amastigotes

- small
- oval
- intracellular
- single nucleus and kinetoplast
Cyclospora cayetanensis oocyst

- round
- unsporulated
- thin walled
- larger than oocyst of Cryptosporidium parvum
**Plasmodium vivax** trophozoites

- ameboid
- enlarged, decolorized (not apparent here) RBCs
- prominent Schüffner’s dots
- hemozoin granules relatively inconspicuous
Chilomastix mesnili trophozoites

- single nucleus at anterior end
- blunt anterior end, pointed posterior end
- cytostomal groove
Pneumocystis carinii cysts

- spherical
- 8 intracystic bodies
- cyst wall unstained with Giemsa stain
Trypanosoma cruzi (or Trypanosoma spp.) epimastigotes

- undulating membrane
- free flagellum
- kinetoplast anterior to nucleus
SECTION OF LIVER
Plasmodium sp. exoerythrocytic schizont

- intracellular
- many (thousands) of nuclei
- no inflammation
FECAL SPECIMEN
Giardia lamblia cysts

- oval
- 4 nuclei, with endosomes
- axonemes visible
- often a clear space between cell and cyst wall
FECAL SPECIMEN
Entamoeba histolytica cyst

- spherical to oval
- 4 nuclei
- small, discrete, centrally located endosome
- fine granules of peripheral chromatin
- finely granular cytoplasm
SECTION OF LIVER
Toxoplasma gondii tachyzoites

- intracellular
- small number (8 to 32)/cell
- no kinetoplast
Reduviid kissing bug (*Triatoma gerstaeckeri*)

- large
- cone nosed with prominent eyes
- dorsoventrally flattened
- wings in concavity on top of abdomen
- edge of abdomen with orange stripes
Trichomonas vaginalis trophozoite

- pyriform shape
- 4 anteriorly directed flagella
- 1 posteriorly directed flagellum as an undulating membrane
- nucleus with evenly distributed chromatin at anterior end
- axostyle protruding from posterior end
Plasmodium falciparum macrogametocyte

- elongate
- pointed ends
- nucleus < one half of cell length
- hemozoin granules around nucleus
FECAL SPECIMEN
Iodamoeba butschlii trophozoite

- irregular shape
- large endosome
- no peripheral chromatin granules
- vacuolated cytoplasm
- food vacuoles with bacteria
Anopheles sp. female

- palps almost same length as proboscis
- non plumose antennae
Charcot-Leyden crystal

• possible indicator of infection with *Entamoeba histolytica*
Plasmodium ovale trophozoite

- oval distortion of infected cell
- prominent Schüffner’s dots
- large chromatin mass
- enlarged RBC
SECTION OF SMALL INTESTINE
Cryptosporidium parvum infection

• round bodies (oocysts) in brush border
Fecal Specimen
Balantidium coli trophozoite

- large
- ciliated
- curved macronucleus
- cytostome
- food vacuoles
SECTION OF LIVER
Leishmania donovani amastigotes

- numerous small intracellular parasites in macrophages
- several kinetoplasts visible
*Plasmodium malariae* erythrocytic schizont

- merozoites arranged in a rosette around periphery
- 8 merozoites/schizont
- prominent hemozoin granules in center
- RBC not enlarged
Fecal Specimen
Entamoeba coli trophozoite

- irregular shape
- eccentric endosome
- coarse peripheral chromatin granules
CULTURE SMEAR
Leishmania sp. promastigotes

- no undulating membrane
- kinetoplast anterior to nucleus
- free flagellum
Balantidium coli trophozoites

• ulcer in mucosa
• large trophozoites visible at base of ulcer
Plasmodium sp. sporozoites

- small
- long, slender
- central nucleus
Fecal specimen
Cryptosporidium parvum oocyst

- small (compare to bacteria)
- spherical
- thin wall
- 4 sporozoites
SMEAR OF TISSUE ABCESS
Acanthamoeba sp. trophozoite

- irregular shape
- branched pseudopodia (rhizopodia)
- large endosome
Cerebral malaria due to *Plasmodium falciparum*

- small blood vessels packed with hemozoin-containing cells
*Plasmodium vivax* erythrocytic schizont

- 10 merozoites
- Schüffner’s dots
- enlarged RBC
SECTION OF BRAIN
\textit{Naegleria fowleri} trophozoites (primary amebic meningoencephalitis)

- irregular shape
- large endosome
- extensive tissue destruction
- absence of cyst forms
Entamoeba histolytica ulcerative colitis

- flask-shaped ulcer in mucosa and submucosa
Blastocystis hominis cysts

- round to oval refractile body
- central inclusion
- peripheral cytoplasm
- peripheral granules
SECTION OF HEART
Sarcocystis sp. zoitocyst

- cyst within cardiac myofiber
- contains merozoites (which are larger than those of *Toxoplasma gondii*)
*Plasmodium* sp. oocysts

- spherical bodies bulging into hemocoel
- contain many nuclei (developing sporozoites)
Trypanosoma brucei rhodesiense or T. b. gambiense trypomastigotes

- high parasitemia
- undulating membrane
- free flagellum
- small kinetoplast, posterior to nucleus
- elongate “S” when fixed
- dividing forms present
- volutin granules present (not apparent here)
For each specimen, name the genus, species, and stage of development. Hypothetical source of the specimen is usually given. Check your answer by clicking on \( ? \). \( \uparrow \) returns you to the photograph of the specimen. \( \downarrow \) returns you to this slide.

By choosing a different \( \text{Start} \) button, and then proceeding forward \( \rightarrow \) or backward \( \leftarrow \), you can vary the sequence of questions each time you take the test.
Enterobius vermicularis egg

- hyaline color
- thick shell
- unembryonated or with larval nematode
- flat on one side
- usually recovered from perianal skin, but will occur in feces
FECAL SPECIMEN
Paragonimus westermani egg

- medium to large egg
- oval
- golden brown
- unembryonated
- operculate
- abopercular thickening
Taenia saginata gravid proglottid

- elongate
- > 14 side branches of uterus
- single lateral genital pore
SECTION OF SUBCUTANEOUS TISSUE
Onchocerca volvulris in nodule

- coiled thread-like worms
- fibrous connective tissue surrounding worms
FECAL SPECIMEN
Taeniid egg

- small to medium size
- oval to round shape
- brown color
- oncosphere within 2-layered embryophore
- outer embryophore layer with striations
- gelatinous layer and outer capsule often lost
- non operculate
FECAL SPECIMEN
Diphyllobothrium latum egg

- medium sized
- ovoid
- light yellow color
- unembryonated
- operculate
- abopercular process
Hymenolepis nana egg

• medium size
• round to oval
• hyaline color
• contains oncosphere within embryophore
• embryophore with polar filaments
• gelatinous granular layer around embryophore
• outer capsule
• non operculate
Fecal Specimen
Ascaris lumbricoides egg

- medium size
- oval
- brown color
- mammillated surface
- unembryonated
- non operculate
FECAL SPECIMEN
**Schistosoma japonicum** egg

- medium size
- oval to round
- hyaline to yellow brown color
- thin shell
- contains miracidium
- small lateral spine
- often with adhering fecal debris
Microfilaria of *Wucheraria bancrofti*

- sheathed
- short cephalic space
- dispersed column of nuclei
- no nuclei in tail
Fasciola hepatica adult

- leaf shape
- cephalic cone with shoulders
- branched intestinal ceca
Hookworm egg (*Ancylostoma duodenale* or *Necator americanus*)

- medium size
- oval with rounded ends
- hyaline color
- very thin shell
- usually 4 or 8-cell stage embryo
- non operculate
SECTION OF LIVER
Capillaria hepatica eggs

- medium sized
- barrel-shaped
- thick shell wall with pits or striations
- polar plugs
- unembryonated
- large masses of eggs displacing liver tissue
- relatively little inflammation
Schistosoma haematobium eggs

- calcified, elongate eggs in muscularis, lamina propria, and epithelium
Fecal Specimen
Taenia solium  scolex

- rostellum with two rows of hooks
- 4 suckers
Fecal specimen
Trichuris trichiura egg

- medium size
- barrel shape
- golden brown color
- polar plugs
- unembryonated
- non operculate
Granuloma surrounding *Schistosoma mansoni* egg

- multilayered fibrotic lesion
- egg with prominent lateral spine
Trichostrongylus spp. egg

- medium size, longer than hookworm egg
- oval shape, slightly pointed at one end
- thin shell
- hyaline color
- unembryonated, usually with more cells than hookworm egg
- non operculate
Hydatid cyst of *Echinococcus granulosus*

- multilayered cyst wall with thick, acellular ectocyst
- germinal layer with brood capsule containing protoscolices
FECAL SPECIMEN FROM DOG
Toxocara canis egg

- round to oval
- pitted, golf ball-like surface
- light brown color
- unembryonated in freshly passed feces
- non operculate
Schistosoma spp. cercaria

- forked tail
- apharyngeate
- pre- and post-acetabular penetration glands
Ascaris lumbricoides larvae

- nematode larvae breaking into alveoli
- marked inflammation
- alternative identifications: larvae of hookworms or Strongyloides stercoralis
SECTION OF ESOPHAGUS
Gongylonema sp. adult and eggs

- multiple sections of adult nematode and eggs in esophageal epithelium
*Clonorchis sinensis* adults in bile duct

- cross sections of trematodes (dorsoventrally flattened shape, no cuticle, presence of digestive tract)
- unbranched intestinal ceca
- could also be *Opisthorchis* spp. or *Dicrocoelium dendriticum*
Fasciolopsis buski adult

- absence of cephalic cone and shoulders
- unbranched intestinal ceca
- dendritic, tandem testes
Male hookworm

- dorsal curvature of anterior end
- copulatory bursa
*Dipylidium caninum* mature proglottid

- elongate proglottid
- two genital pores
- two ovaries
PERIPHERAL BLOOD SMEAR FROM DOG
**Dirofilaria immitis** microfilaria

- Nematode embryo in peripheral blood
- Nuclei do not extend to the tip of tail (pointed end)
OBJECT REMOVED FROM BRAIN
Taenia solium cysticercus

- scolex invaginated and introverted in a fluid-filled bladder
Trematode miracidium

- multicellular, ciliated organism
- narrow anterior end
- lateral papillae
- posterior germinal cells
Microfilaria of *Brugia malayi*

- sheathed
- long cephalic space
- compact column of nuclei
- terminal and subterminal nuclei in tail
Schistosoma mansoni, male and female
in copula

- slender female within gynecophoral canal of male
- grossly tuberculated tegument of male
Ancylostoma duodenale anterior end

- ventral teeth in buccal cavity
Fecal Specimen
Fasciola hepatica egg

- large size
- oval shape
- yellowish brown color
- unembryonated
- indistinct, small operculum
FECAL SPECIMEN
**Schistosoma haematobium eggs**

- large, elongate egg
- hyaline to light yellow color
- prominent terminal spine
- miracidium within egg
- non operculate
**Enterobius vermicularis** adult female

- pointed tail
- swollen cuticle at anterior end
- prominent esophageal end bulb
FECAL SPECIMEN
Ascaris lumbricoides decorticated egg

- oval to round shape
- thick shell
- hyaline to light brown color
- unembryonated
- non operculate
FECAL SPECIMEN
**Taenia solium** gravid proglottid

- elongate
- single genital pore
- < 14 lateral branches of uterus
SOIL SAMPLE
Rhabditiform first stage hookworm larva

- corpus, isthmus, and end bulb in esophagus
- large buccal cavity (not visible here)
OBJECT FROM TISSUES OF CRAB
Paragonimus westermani metacercaria

- round
- thick cyst wall
- acetabulum visible
- undulating intestinal ceca
SECTION OF SMALL INTESTINE
Macracanthorhynchus hirudinaceus

- proboscis with spines (none visible here)
- no digestive tract
- pseudocoelom
SECTION OF SKELETAL MUSCLE FROM PIG
Taenia solium cysticerci

- scolex inside bladder
- absence of inflammation
Clonorchis sinensis adult

- elongate
- tandem, dendritic, posterior testes
- straight intestinal ceca, reaching posterior end
- prominent seminal receptacle
SECTION OF SMALL INTESTINE
Schistosoma mansoni eggs

- elongate eggs in submucosa
- inflammatory reaction around eggs
FECAL SPECIMEN
Hymenolepis diminuta egg

- medium to large size
- round to oval shape
- brown color
- oncosphere within embryophore
- embryophore lacks polar filaments
- surrounding gelatinous layer and capsule
- non operculate
Capillaria hepatica eggs

- barrel shape
- polar plugs
- pits in shell
- unembryonated
- non operculate
Ascaris lumbricoides unfertilized egg

- elongate shape
- brown mammillated surface
- relatively thin shell
- disorganized contents, filling interior
- non operculate
FECAL SPECIMEN
Diphyllobothrium latum gravid proglottid

- wider than long
- follicular vitellaria
- bilobed ovary
- eggs released through uterine pore
FECAL SPECIMEN
Acanthocephalan egg

- medium size
- ellipsoidal shape
- 3-layered egg shell
- contains acanthor larva
- non operculate
WORMS REMOVED FROM DOG HEART
Dirofilaria immitis adults

- long, threadlike nematodes
SECTION OF SKELETAL MUSCLE
Trichinella spiralis larvae

- coiled nematode larvae within nurse cells
Paragonimus westermani adult

- coffee bean shape
- undulating intestinal ceca
- deeply lobate, para testes
- off-centered, lobed ovary
Necator americanus anterior end

- ventral cutting plates in buccal cavity
FECAL SPECIMEN
Dipylidium caninum eggs

- light brown color
- contain hexacanth larva (oncosphere)
- eggs occur in packets
- non operculate
Taenia saginata scolex

- 4 suckers
- no rostellum or hooks
FECAL SPECIMEN
Schistosoma mansoni egg

- large size
- elongate
- yellow brown color
- contains miracidium
- prominent lateral spine
- non operculate
Trichuris trichiura adult male

- long, thin anterior end
- whip-like shape
- curved posterior end (typical of male nematodes)
FECAL SPECIMEN FROM DOG.
Echinococcus granulosus adult

- only 3 proglottids, immature, mature, and gravid
- 4 suckers
- armed rostellum
- single, lateral, equatorial genital pore
Onchocerca volvulitis microfilariae

- microfilariae wandering in the dermis
- note: smaller microfilariae of Mansonella spp. may also be found in skin snips
FECAL SPECIMEN
Diphyllobothrium latum scolex

- solid body
- presence of slit-like bothria
- absence of suckers or hooks
Fecal Specimen
Clonorchis sinensis egg

- small size
- vase shaped
- yellow brown color
- contains miracidium
- prominent operculum in a rim
- small abopercular knob
Echinostoma revolutum adult

- collar surrounding mouth
- anterior acetabulum
- pretesticular ovary
- tandem testes
vitelline glands
testes
ootype
ovary
uterus
acetabulum
internal seminal vesicle
mouth with collar of spines
Mature taeniid proglottid

- vitelline gland in one mass
- follicular testes
- blind-ended uterus
- single, lateral genital pore
- bilobed ovary
uterus
ovary
collecting tubule
follicular testes
vitelline gland
vagina
vas deferens
genital pore
Nematode (*Ascaris lumbricoides*) adults, cross sections

- triradiate esophageal lumen
- cuticle
- pseudocoel
pseudocoelom
esophagus
lateral hypodermal cord
longitudinal muscle fibers
cuticle
testis
vas deferens
intestine
ovary
oviduct
uterus with eggs
excretory canal
innervation process
How to use this CD

• The icon (in the lower left of a photograph) takes you to a text page describing the picture.

• The icons (in the lower right) take you to
  – the beginning of the chapter
  – the next photo in the series
  – the prior photo in the series
  – the last page you visited

• This symbol shows the approximate scale of the picture: 10 µm

• A miniature picture takes you from the text page back to the picture associated with that text.

• Hypertext links are shown in red. Visited links are in blue.

• takes you to the Index, and to the Table of Contents.

• Use the Esc key to exit from anywhere in the program.
Unlike navigation on the Internet, this program “remembers” only the last slide you visited. Therefore, if you follow a hyperlink to a second slide, you can return to the first with the icon. However, if you follow a link to a third slide, you will not be able to immediately go back to the first slide, unless a “hard” return link has been provided, e.g.,

• back to *Trypanosoma b. gambiense*

If no return link is available, or if you get lost, then return to the chapter table of contents with the icon or to the book table of contents with the icon.
All of the photographs in this CD were taken by the author. Most were made with a Sony DXC-970 video camera mounted on an Olympus BH-2 or SZH10 microscope and attached to an Integral Technologies Flashpoint PCI or 128 video capture card installed in a computer. Several pictures were scanned from 35-mm slides, and the adult *Ascaris lumbricoides* and *Dirofilaria immitis* were photographed with a hand-held Olympus digital camera. Images were saved as JPEG or bitmap files, modified with Adobe PhotoDeluxe software, and inserted into Microsoft PowerPoint slides.
A color laser-printed version of the photographs in chapters 1-8 of this CD also is available. For more information, please visit:

http://www.geocities.com/SunsetStrip/Venue/2851/parasitology.html
Sources of Specimens

Source is listed by figure number. Where appropriate, catalogue numbers are provided. Unfortunately, some of these slides are no longer commercially available, and now exist only in teaching collections.

**Abbreviations:** C, Carolina Biological Supply Co, Burlington, NC; M, Midwest Biological, Menomonee Falls, WI; S, Southern Biological Supply Co., McKenzie, TN; T, Turtox (presently part of Ward’s); TR, Triarch, Ripon, WI; W, Ward’s Biology, Rochester, NY; LU, Lamar University Collection; UIW, University of the Incarnate Word Collection.

1.1 W: 92W4354
1.2 W: 92W4330
1.3 W: 92W4355
1.4 W: 92W6592
1.5 Source unknown, UIW
1.6 W: 92W4304
1.7 W: 92W4303
1.8 W: 92W4301
1.9 Collected by Mr. Greg Coussoulis
1.10 W: 92W4252
1.11 W: 92W4253
1.12 W: 92W4255
1.13 Collected by Mr. Brian Ostrander
2.1 W: 92W4213
2.2 W: 92W4214
2.3 W: 92W4235
2.4 W: 92W4235
2.5 W: 92W4043
2.6 W: 92W4273
3.1 W: 92W4083
3.2 W: 92W4084 & C: Z115
3.3 W: 92W4063
3.4 W: 92W4064
3.5 W: 92W4103
3.6 W: 92W4104
3.7 W: 92W4123
3.8 W: 92W4124
3.9 Specimen provided by Academy of Health Sciences, Ft. Sam Houston
3.10 W: 92W4132
3.11 W: 92W4128 & 92W4129
3.12 C: PS1100
3.13 W: 92W4444
3.14 W: 92W4445 & 92W4086
4.1 Top row - W: 92W4580; Wet mounts - Specimen provided by Dr. Sam R. Telford III
4.2 Specimen provided by AFIP Registry of Veterinary Pathology
4.3 & 4.4 Specimen provided by Dr. Sam R. Telford III
4.5 W: 92W4839 & 92W4836
5.10 C: Z363
5.11 C: Z363
5.12 Specimen provided by Dr. William E. Collins
5.13 Specimen provided by Academy of Health Sciences, Ft. Sam Houston
5.14 W: 92W4572
5.15 W: 92W4700
6.1 W: 92W4940
6.2 W: 92W4985
6.3 W: 92W4970
6.4 C: PS1230
6.5 C: PS1210
6.6 W: 92W4930
6.7 C: PS1414
6.8 W: 92W5152
6.9 C: PS1218
6.10 C: PS1260
6.11 C: PS1415
6.12 W: 92W5123
6.13 C: PS1301
6.14 C: PS1310
6.15 Specimen provided by Dr. Eric S. Loker
6.16a C: PS1461; 6.16b W: 92W4958; 6.16c W: 92W5008; 6.16d Experimental infection
6.17a TR: ZD5-421; 6.17b C: PS1310; 6.17c-j Experimental infection
6.18 C: PS1308
6.19 Snails provided by Dr. Fred Lewis
6.20 W: 92W4909
6.21 Tissue provided by Dr. Fred Lewis
6.22 Specimen provided by Academy of Health Sciences, Ft. Sam Houston
7.1a C: PS1605; 7.1b-d W: 92W5300
7.2 W: 92W5400
7.3 W: 92W5400
7.4a W: 92W5435; 7.4b W: 92W5432; 7.4c C: PS1864; 7.4d W: 92W5452
7.5a W: 92W5463; 7.5b W: 92W5462
7.6 W: 92W5320
7.7a W: 92W5322; 7.7b C: PS1718
7.8a W: 92W5362; 7.8b W: 92W5360
7.9 W: 92W5300
7.10 W: 92W5257
7.11 W: 92W5361
7.12 W: 92W5341
7.13 W: 92W5407
7.14 C: Z967
8.1 W: 92W5790 & 92W5791
8.2a-c W: 92W5770; 8.2d Specimen provided by Academy of Health Sciences, Ft. Sam Houston

8.3a C: PS2418; 8.3b T: P6.32
8.4a,b,f,g C: PS2380; 8.4c,e,h Specimen provided by Dr. Sam R. Telford III; 8.4d W: 92W5650
8.5a,b C: PS2506; 8.5c W: 92W5725
8.6a C: D8-P265C; 8.6b W: 92W5674; 8.6c,d W: 92W5672
8.7 W: 92W5679
8.8a C: PS2100; 8.8b W: M3596
8.9a Preserved specimen, source unknown, UIW; 8.9b C: PS2250
8.10 Specimens provided by Academy of Health Sciences, Ft. Sam Houston
8.11a-c  W: 92W5710; 8.11d  W: 92W6567

8.12  Reproduced from 35-mm slide, source unknown, LU

8.13  C: PS2505

8.14  W: 92W5727

8.15  Specimen provided by Academy of Health Sciences, Ft. Sam Houston

8.16  W: 92W5673

8.17  W: 92W5823

8.18  W: 92W5693

8.19a  W: 92W5555; 8.19b  Specimen from turtle, LU; 8.19c  C: PS2610

8.19d  Reproduced from 35-mm slide, source unknown, LU
Index

A
Acanthamoeba culbertsoni
trophozoite 3.10
Acanthocephalan
body wall 8.19
egg 8.19
proboscis 8.19
Ancylostoma duodenale
buccal capsule 8.4
copulatory bursa 8.4
Anopheles sp.
mouthparts 5.1
Ascaris lumbricoides
adult 8.6
egg 8.16
larva in lung 8.7

B
Babesia canis
trophozoites 5.14
Balantidium coli
cyst 3.13
in intestinal lesion 3.14
trophozoite 3.12
Biomphalaria glabrata 6.18
Blastocystis hominis 3.9
Brugia malayi
microfilaria 8.10
Bulinus truncatus 6.18

C
Capillaria hepatica
adult & eggs in liver 8.2
cercaria 6.17
 cerebral malaria 5.15
 Chilomastix mesnili
cyst 2.2
trophozoite 2.1
Clinostomum sp.
metacercaria 6.16
Clonorchis sinensis
adult 6.5
egg 6.9
in bile duct 6.19
Cryptosporidium parvum
oocyst 4.1
in cow small intestine 4.2
Cyclospora cayetanensis
oocyst 4.3
cysticercoid 7.8
cysticercus 7.5

D
Dicrocoelium dendriticum
adult 6.6
Dientamoeba fragilis
trophozoite 2.5
Diphyllobothrium latum
adult 7.1
egg 7.10
Dipylidium caninum
adult 7.9
egg capsule 7.14
Dirofilaria immitis
adult 8.9
microfilaria 8.9
Echinococcus granulosus
  adult 7.6
  hydatid cyst 7.7
Echinococcus multilocularis
  hydatid cyst 7.7
Echinostoma paraensei
  egg 6.15
  metacercaria 6.16
Echinostoma revolutum
  adult 6.1
Endolimax nana
  cyst 3.6
  trophozoite 3.5
Entamoeba coli
  cyst 3.4
  trophozoite 3.3
Entamoeba histolytica
  cyst 3.2
  in intestinal lesion 3.14
  trophozoite 3.1
Enterobius vermicularis
  adult 8.8
  egg 8.18
  in appendix 8.8

Fasciola hepatica
  adult 6.4
  egg 6.10
  metacercaria 6.16
Fasciolopsis buski
  adult 6.3
G
Giardia lamblia
cyst 2.4
trophozoite 2.3
Glossina sp. 1.4
Gongylonema ingluvicola
in esophageal mucosa 8.12

H
Heterophyes heterophyes
adult 6.2
hookworm
adult 8.4
egg 8.14
larva 8.5
hydatid cyst 7.7
Hymenolepis diminuta
egg 7.12
Hymenolepis nana
adult 7.8
cysticercoid 7.8
egg 7.11
I
Iodamoeba butschlii
cyst 3.8
trophozoite 3.7
Isospora belli
oocyst 4.4

K
kissing bug 1.9
L
*Leishmania donovani*
  - amastigote
  - liver smear 1.10
  - section of liver 1.11
  - promastigote 1.12
*Lutzomyia diabolica* 1.13

M
*Macracanthorhynchus hirudinaceus*
  - adult in intestine 8.19
  - metacercariae 6.16
*microsporidian*
  - spore 4.9
  - miracidium 6.17

N
*Naegleria fowleri*
  - trophozoite in brain 3.11
*Necator americanus*
  - adult 8.4

O
*Onchocerca volvulus*
  - adults in capsule 8.11
  - microfilaria 8.11
*Oncomelania hupensis* 6.18

P
*Paragonimus westermani*
  - adult 6.7
  - egg 6.11
  - metacercaria 6.16
Plasmodium
EE schizont 5.4
falciparum
erthrocytic schizont 5.8
gametocyte 5.9
trophozoite 5.7
malariae
erythrocytic schizont 5.11
trophozoite (band) 5.10
oocyst in mosquito 5.2
ovale
erythrocytic schizont 5.13
trophozoite 5.12
sporozoite 5.3
vivax
erthrocytic schizont 5.6
trophozoite 5.5

Pleistophora husseyi
spore 4.9
Pneumocystis carinii
cyst, lung smear 4.10
S
Sarcocystis sp.
sarcocyst 4.8
Schistosoma
haematobium
egg 6.12
in bladder 6.22
japonicum
egg 6.13
mansoni
  adult 6.8
egg 6.14
life cycle 6.17
liver granuloma 6.20
intestinal lesion 6.21
Simulium sp. 8.11
sporocyst 6.17

Taenia solium
cysticercus 7.5
gravid proglottid 7.4
taeniid egg 7.13
Toxocara canis
egg 8.17
Toxocara cati
cervical alae 8.17
Toxoplasma gondii
enteroepithelial cycle, cat
  schizont, oocyst 4.7
extraintestinal cycle, mouse
  bradyzoite, brain 4.6
tachyzoite, liver 4.5
tachyzoite, smear 4.5
  zoitocyst, brain 4.6

Taenia pisiformis
  scolex 7.2
  strobila 7.3
Taenia saginata
  gravid proglottid 7.4
Trichinella spiralis
  larvae in muscle 8.3
  larvae in utero 8.3
Trichomonas vaginalis
  trophozoite 2.6
Trichostrongylus sp.
  egg 8.15
Trichuris trichiura
  adult 8.1
  egg 8.13
Trypanosoma brucei gambiense
  trypomastigote 1.2
Trypanosoma brucei rhodesiense
  trypomastigote 1.1

Trypanosoma cruzi
  amastigote
    section of heart 1.7
    spleen smear 1.6
    epimastigote 1.8
    trypomastigote 1.5
  trypanosomiasis in brain 1.3
  tsetse fly 1.4

Wuchereria bancrofti
  microfilaria 8.10
References

Most of the textual information in this CD has been obtained from the following:


For the following specific topics, additional sources were consulted:

  Diagnosis of malaria parasites


  Tissue sporozoans