Pathology of Pulmonary Disease, edited by Mario J. Saldana.
J. B. Lippincott Company, Philadelphia © 1994.

44

Protozoal and Helminthic Diseases

Aileen M. Marty
Ronald C. Neafie

Protozoal and helminthic pulmonary infections are common only in endemic areas, but they can produce great morbidity and mortality, particularly in the compromised host. With the ever-increasing incidence of international travel and the growing spread of AIDS, it behooves all physicians to be acquainted with the myriad protozoa and helmiths of pulmonary significance. Eight genera of Protozoa are known to cause disease in human lungs; the three most commonly encountered are *Toxoplasma, Entamoeba,* and *Plasmodium*. More than thirty genera of helminths occur in human lungs, but most occupy the lung only transiently. Only one genera, *Paragonimus,* normally inhabits the human lung in its adult stage, but others (*e.g., Shistosoma*) more commonly can be encountered and produce equally devastating pulmonary disease with more profound systemic disease.

FREQUENT PROTOZOAL PULMONARY INFECTIONS

Toxoplasmosis

Toxoplasmosis is produced by the coccidian protozoan *Toxoplasma gondii*. Infected immunocompetent persons are often asymptomatic; disseminated disease is associated with immune defects in newborn infants and adults. Pulmonary disease occurs in patients debilitated by immunosuppressive therapy, malignancy, or the acquired immunodeficiency syndrome.[1–3]

The prevalence of infection in the United States is 3% to 20%; the incidence varies with ethnic group and geographic region. Cats are the definitive host, and humans constitute one of many intermediate hosts. People acquire infection from consuming sporozoites derived from contaminated cat excrement; from eating tissue cysts in undercooked pork, mutton, or beef; from handling diseased animals; transplacentally; and by acquiring bradyzoites within an organ transplant.[4] The ingested organisms transform into tachyzoites (*i.e.*, trophozoites) as soon as they reach the gut mucosa. Tachyzoites penetrate the intestinal mucosa, spread through the blood or lymphatic system, and multiply within a large cytoplasmic vacuole in a macrophage, forming a pseudocyst. Lesions are most frequently seen in the brain, heart, liver, intestine, lungs, and lymph nodes.

In pulmonary toxoplasmosis, radiographs reveal diffuse alveolar and interstitial infiltrates with confluent, progressive, and often fatal pneumonia. Focal or cavitary lesions are occasionally seen. Pathologically, alveolar fibrinous exudate and coagulation necrosis occur throughout the lungs (Fig. 44-1), and many alveoli contain cells packed with tachyzoites.[5] Pseudocysts are abundant in areas of necrosis. Numerous chronic inflammatory cells, primarily lymphocytes, occupy the interstitium. In *T. gondii* pneumonia, $CD8^+$ lymphocytes increase markedly; this probably is an integral part of the pathogenesis of the pneumonia.[6]

In Giemsa-stained smears, the tachyzoites are 3 μm by 8 μm, crescent shaped to slightly piriform organisms, with blue cytoplasm and red nuclei. In tissue sections, tachyzoites and cysts are best demonstrated with hematoxylin and eosin (H & E) stain. In tissues, tachyzoites are 2 to 4 μm, round or oval organisms, with an eccentric basophilic nucleus. Bradyzoites contain a glycogen vacuole that is demonstrated by periodic acid-Schiff (PAS) stain. The cyst wall is argyrophilic and stains weakly with PAS. Microorganisms that can be confused for *Toxoplasma* species include *Leishmania*, Microsporida, *Histoplasma capsulatum*, and cytoplasmic inclusions of cytomegalovirus.

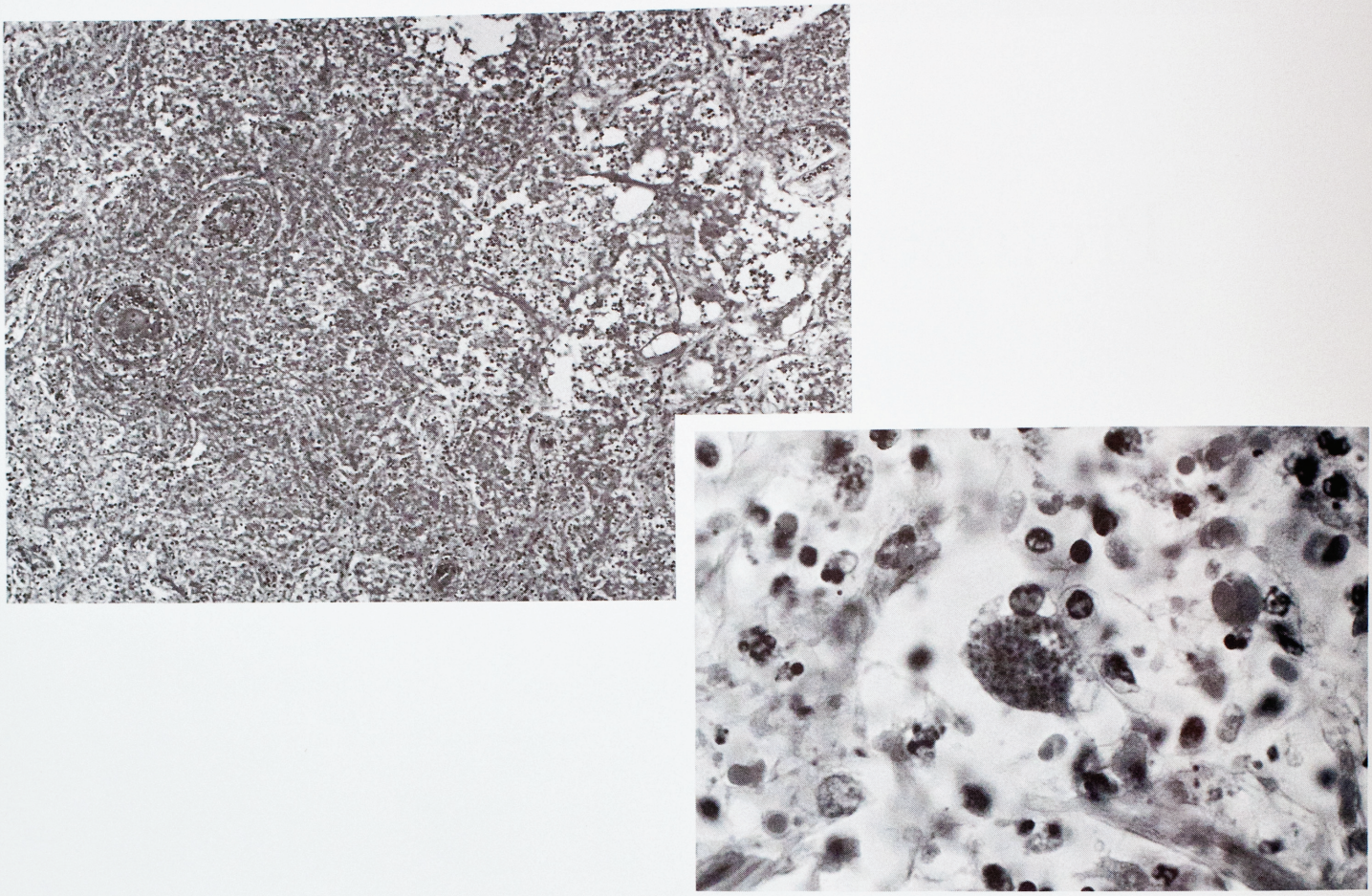

FIGURE 44-1. Necrotizing vasculitis in the lung of a patient with toxoplasmosis. (H & E stain; low magnification.) The pseudocyst contains tachyzoites of *T. gondii* (*inset*). (H & E stain; high magnification.)

Amebiasis

Pulmonary amebiasis occurs as a complication of gastrointestinal infection with *Entamoeba histolytica*. Amebiasis is acquired by ingesting the cysts in fecally contaminated food or water. In the small bowel, each cyst produces four trophozoites that invade the intestinal epithelium and enter the venous circulation. The liver is the most frequent site of secondary amebic abscesses (Fig. 44-2), but they can develop in any organ. Pulmonary amebiasis is produced in two ways. The most common is direct spread of an amebic liver abscess through the liver capsule, peritoneum, diaphragm, and pleura. Pulmonary amebiasis can occur by hematogenous spread. Pulmonary involvement worsens the prognosis of amebiasis. The right lower lobe of the lung is most commonly involved because of contiguity with a liver abscess. The lesions of lung and liver connect by a narrow channel through the hemidiaphragm. Amebic abscesses in other portions of lung develop from hematogenous spread. Abscesses in the lung can produce empyema, and occasionally they extend into the pericardium and cause amebic pericarditis.[7,8]

The prognosis of pulmonary amebiasis is poorer than that of uncomplicated liver abscess and becomes even worse if the pleura is involved. Empyema kills one of five patients.[9] Communication with a bronchus can cause a patient to expectorate an alarming quantity of amebic pus.

Amebic abscesses range from microscopic to 10 cm or more in diameter. The core is composed of yellow-brown, necrotic debris containing inflammatory cells and trophozoites (Color Fig. 44-1). The surrounding viable tissue is inflamed and edematous, with many neutrophils, lymphocytes, macrophages, and plasma cells; eosinophils are sometimes seen. The trophozoites of *E. histolytica* usually have abundant cytoplasmic glycogen and therefore stain intensely with PAS. The features are best appreciated with H & E stain, in which trophozoites have an amphophilic cytoplasm that is often vacuolated, and contain a single small, spherical nucleus with thin, bandlike chromatin and a central karyosome. The trophozoites usually are 15 to 25 μm in diameter. An erythrocyte in the cytoplasm of the trophozoite excludes other amebas. *Entameba coli*, a nonpathogenic ameba found in human intestine, is differentiated from *E. histolytica* by the eccentric location of its karyosome.

Malaria

Acute noncardiogenic pulmonary edema occurs in 3.5% to 7% of patients with *Plasmodium falciparum* malaria.[10,11] The edema usually begins abruptly and progresses rapidly to death. It is not known why acute pulmonary edema occurs, but it may be related to increased capillary permeability due to cytoadherence of malarial parasites.[12,13] A milder, nonfatal form of pulmonary involvement is characterized by pleural effusions, interstitial edema, and lobar consolidation, and it resolves with antimalarial chemotherapy.[14]

In acute pulmonary malaria, chest radiographs show patchy infiltrations in the lower lobes and interstitial markings of pulmo-

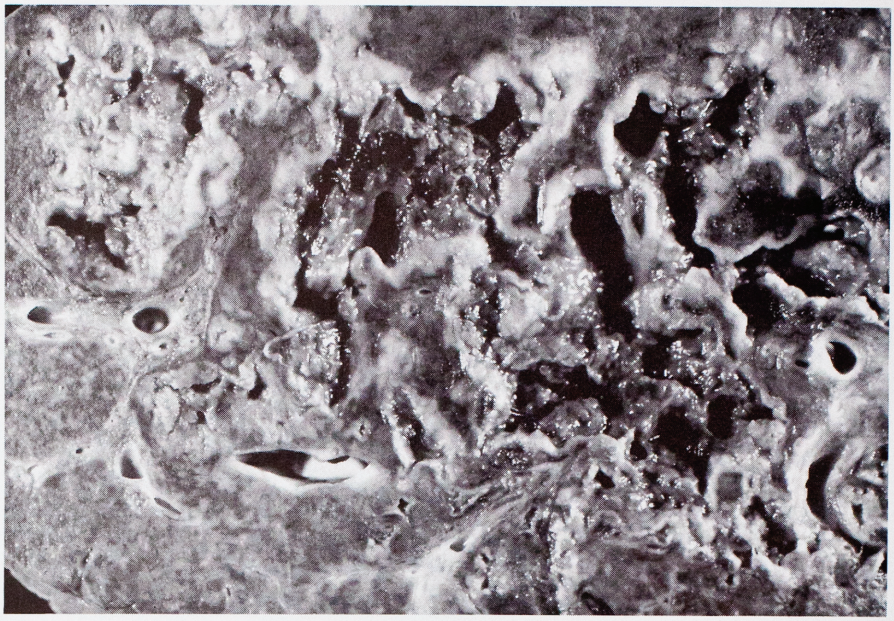

FIGURE 44-2. An amebic liver abscess contains necrotic debris that resembles anchovy paste. (Contributed by the editor.)

nary edema in the upper lobes. Patients often die within a day of developing pulmonary edema despite intensive therapy, probably as a result of disseminated intravascular coagulation.[15]

Grossly, the lungs are heavy, edematous, and congested and have petechial hemorrhages. The trachea often contains pink, foamy fluid. Histologically, capillary congestion, hyaline membranes, thickened alveolar septa, alveolar and interstitial edema, and hemosiderin-laden macrophages are seen. The trophozoites of *P. falciparum* can be readily found within erythrocytes in septal capillaries (Fig. 44-3).[16]

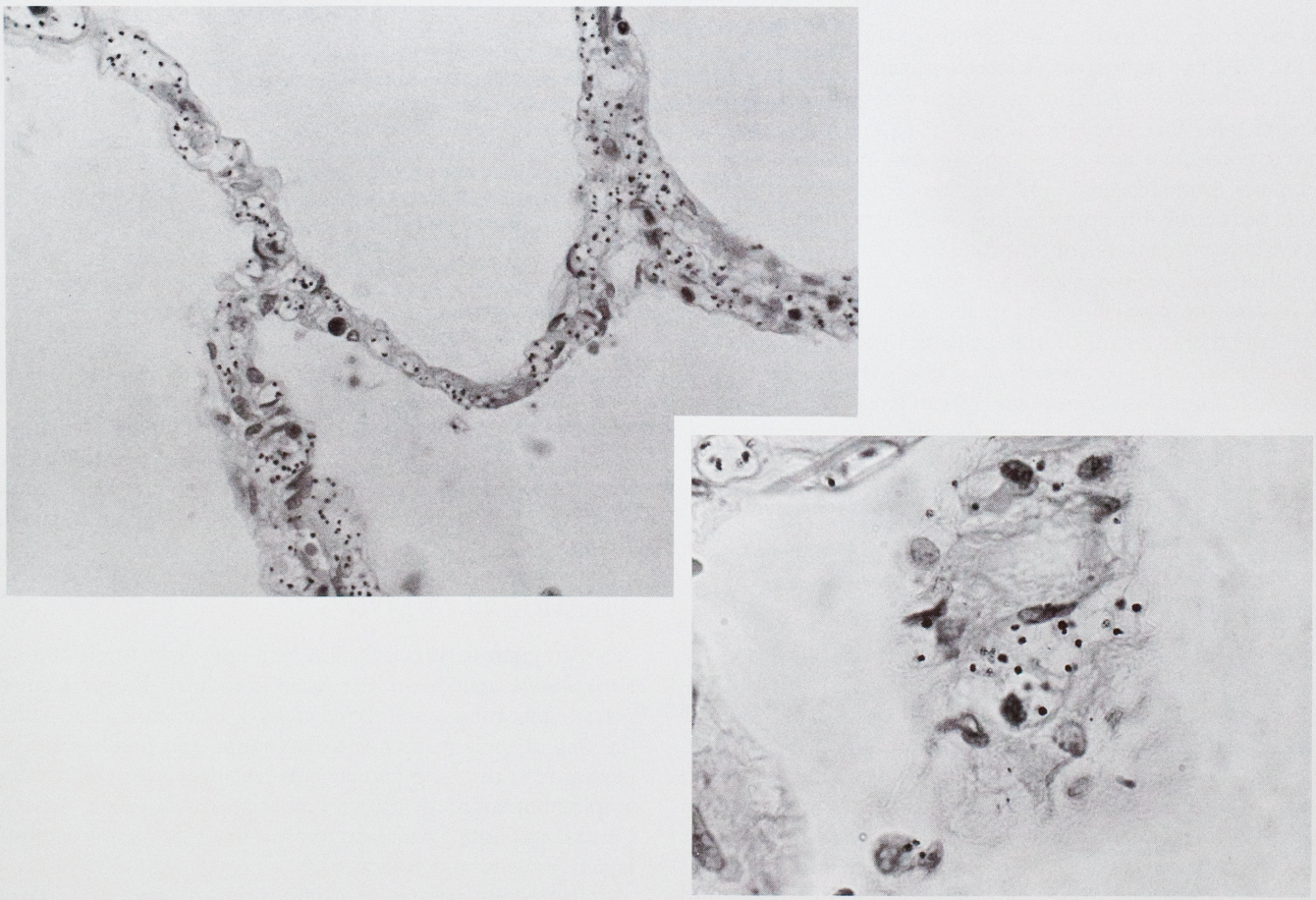

FIGURE 44-3. In *Plasmodium falciparum* infection of the lung, there are numerous black parasites in the septal capillary. (H & E stain; intermediate magnification.) These are best seen at higher magnifications (*inset*). (H & E stain; high magnification.)

INFREQUENT PROTOZOAL PULMONARY INFECTIONS

Trypanosomiasis

Infection with the flagellate *Trypanosoma cruzi* causes Chagas disease, which is endemic to South and Central America. It is most commonly transmitted by bloodsucking hemipterans, the Reduviid bugs. Less commonly, infection results from congenital transmission, infected breast milk, blood transfusions, contaminated food, or accidental exposure in laboratories. *T. cruzi* has a predilection for the myocardium, but other organs are frequently involved. Pulmonary involvement is deadly. It can result from a congenital infection of lung tissue or be secondary to megaesophagus in chronic Chagas disease.[17–19]

Chagasic lungs are nodular with marked interstitial abnormalities. There is obliteration of alveoli and thickened, edematous septa with endothelial swelling. Amastigotes are found in alveolar macrophages, and many can occur within a single cell. They are oval, are 2 to 4 μm in diameter, and have a hyperchromatic nucleus and rod-shaped kinetoplast. *T. cruzi* amastigotes in alveolar macrophages must be differentiated from *T. gondii* bradyzoites, *H. capsulatum*, and the amastigotes of *Leishmania* species. The presence of a kinetoplast in the microorganism excludes toxoplasmosis and histoplasmosis. *Leishmania* amastigotes are slightly smaller and rarely exceed 3 μm in diameter.

Trichomoniasis

Pulmonary trichomoniasis is an infection of the respiratory tract with the flagellate protozoan *Trichomonas tenax*. Most infections involve the buccal cavity and are associated with poor oral hygiene in patients who also have chronic lung disease.[20] Pulmonary trichomoniasis occurs after lobar pneumonia, putrid bronchitis, tuberculosis, bronchiectasis, and bronchogenic carcinoma. The organisms are probably opportunistic, feeding on necrotic tissue. Isolation of the organism from the cavitary lesions of tuberculosis is typical of reported infections.[21] *T. tenax* can be differentiated from *Trichomonas vaginalis* by its smaller size, internal morphology, and the characteristics of its flagella; however, flagella are not usually visible in tissue sections. *T. tenax* is an average of 6 to 7 μm in length; *T. vaginalis* is commonly 13 μm long. The undulating membrane of *T. vaginalis* is relatively shorter, and its cytoplasm has many more and larger siderophil granules. The diagnosis is made by finding *T. tenax* trophozoites in uncontaminated sputum, bronchial washings, or lung tissue.

Cryptosporidiosis

Cryptosporidium species are well-known veterinary pathogens. These organisms are intracellular coccidian parasites first recognized as a cause of acute enterocolitis in humans in 1976. Water or uncooked vegetables contaminated by infected animals or human sewage are the usual sources of infection. In immunosuppressed patients and others with prolonged infection, the infection can spread to the respiratory and biliary tract. *Cryptosporidium* has been found in the tracheal mucosa, bronchioles, alveoli, and sputum.[22–24] *Cryptosporidium* stains well with hematoxylin and eosin and appears as a basophilic body, uniform in size and shape, averaging 2 to 5 μm in diameter.

Leishmaniasis

Leishmania donovani, the cause of visceral leishmaniasis (*i.e.*, kala-azar), occurs as an amastigote in pulmonary macrophages. Amastigotes are spherical cells, 2 to 3 μm in diameter, that contain a rod-shaped kinetoplast. The organisms stain well with hematoxylin and eosin.

L. donovani is endemic in Asia, Africa, and South America, and it is transmitted to humans through the bite of an infected sand fly. Amastigotes multiply in macrophages, especially those of the spleen, lymph nodes, and bone marrow, and in the Kupffer cells of the liver. *L. donovani* amastigotes can be found in pulmonary macrophages.[25]

Free-Living Ameba

The recognition that free-living ameba cause human disease is relatively recent, and the organisms involved include *Naegleria fowleri*, several species of *Acanthamoeba*, and amebas belonging to the order Leptomyxida.[26–28] All can cause fatal amebic encephalitis. *N. fowleri* trophozoites enter the brain after invading the olfactory mucosa. The portal of entry for leptomyxid ameba and *Acanthamoeba* is probably the respiratory tract, and the trophozoites may be more plentiful there than in the brain in fatal cases of amebic encephalitis.[29,30] *Acanthamoeba* organisms are not readily distinguishable from leptomyxid amebas in tissue sections. They overlap in size and configuration of the nucleus, and the cyst forms of both occur in human tissue. The round trophozoites are 13 to 45 μm in diameter and have a foamy cytoplasm. Unlike *Entamoeba* species, the cytoplasm of *Acanthamoeba* organisms does not stain with PAS. The nucleus is nearly filled by a large, centrally placed karyosome. The spherical cysts are 9 to 14 μm in diameter and have double walls, foamy cytoplasm, and a single nucleus. *Acanthamoeba* and leptomyxid amebas are differentiated using electron microscopy or immunofluorescence studies. *N. fowleri* is identified by its smaller size, absence of a cyst form in tissue, and its ability to elicit a more suppurative reaction.

HELMINTHIC INFECTIONS

Trematodes

Trematodes are flukes belonging to the phylum Platyhelminths, the flatworms. Two groups of flatworms are significant pulmonary pathogens: *Paragonimus* species, which are the only known adult worms that preferentially reside in human lungs, and *Schistosoma* species.

PARAGONIMIASIS

Paragonimiasis is infection by a lung fluke, most commonly *Paragonimus westermani*, the Asian lung fluke. People acquire the parasite by eating raw infected crabs or crayfish. Larvae penetrate the wall of the gut, then the diaphragm, and finally settle in the pleura or in the lung parenchyma. Adult worms can live for 20 years in human lungs. Paragonimiasis occurs in Asia, Africa, and Central and South America, but it is most frequently acquired in Japan, Taiwan, and Korea.

Paragonimiasis has an insidious clinical onset, and classically, patients have a diagnostic triad of cough, hemoptysis, and *Paragonimus* eggs in sputa or feces. Chest radiographs show transient,

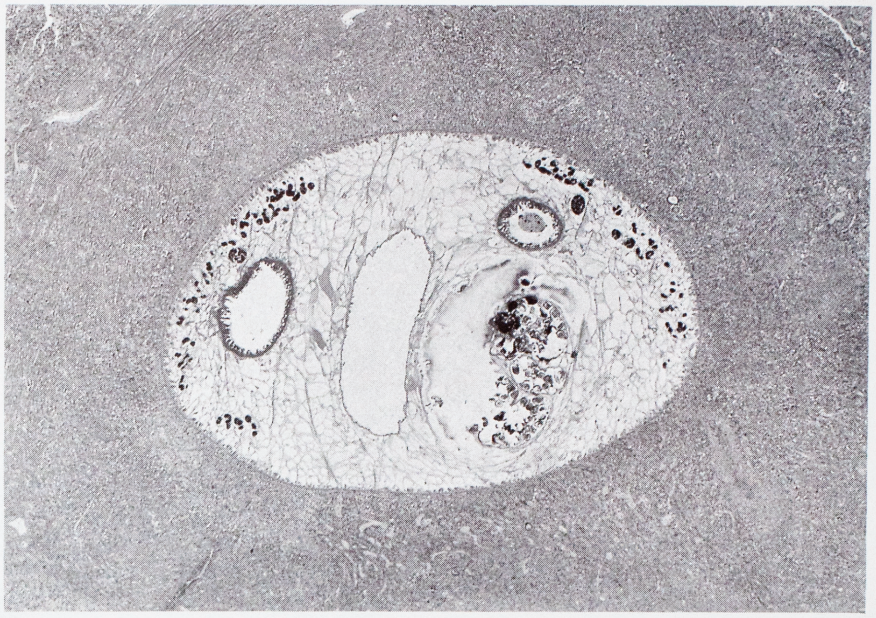

FIGURE 44-4. A section through an adult *Paragonimus westermani* within an inflammatory infiltrate of eosinophils and neutrophils shows the solid, spongy body, the absence of a body cavity, the central excretory bladder, the paired transverse sections of ceca, and the peripheral vitellaria. (H & E stain; low magnification.)

diffuse pulmonary infiltrates and ring shadows.[31] Pleural effusion is common and may be the only clinical sign. Rarely, *Paragonimus* adult worms occur in other organs after aberrant migration of the larvae.

Adult worms are usually found near bronchioles or bronchi and elicit an inflammatory infiltrate of eosinophils and neutrophils (Fig. 44-4). Fibrous encapsulation occurs later. The adult worms are ovoid, 7 to 12 mm long, and 4 to 6 mm wide, and the tegument is covered by toothlike spines (Fig. 44-5). Eggs can lodge in the parenchyma and produce granulomas. The growth of fibrous walls results in the formation of cysts, which are about 1.5 cm in diameter and contain worms, eggs, and necrotic debris.[32] If a cyst ruptures into a bronchiole or bronchus, the spilled contents can produce bronchopneumonia. The eggs of different species of *Paragonimus* have subtle morphologic differences. The eggs of *P. westermani* are 75 to 110 μm by 45 to 60 μm, oval, birefringent, and gold-brown (Fig. 44-6), and they have a flattened operculum. The diagnosis is usually made by identifying the eggs in sputa or feces. In patients who have only pleural involvement, it is necessary to aspirate the pleura to obtain eggs. Various serologic methods are especially helpful in egg-negative or extrapulmonary cases.

SCHISTOSOMIASIS

Schistosomiasis is caused by blood flukes of the genus *Schistosoma*. The species known to infect humans include *Schistosoma haematobium, Schistosoma mansoni, Schistosoma japonicum, Schistosoma intercalatum*, and *Schistosoma mekongi*. Schistosomes differ from most other flukes in that the sexes are separate. People acquire the infection by swimming or wading in cercariae-infected fresh water. Specific species of aquatic snails serve as intermediate hosts. Cercariae penetrate the skin, enter dermal capillaries, and travel through the venous circulation to the heart and lungs, where they squeeze through pulmonary capillaries en route to the liver.

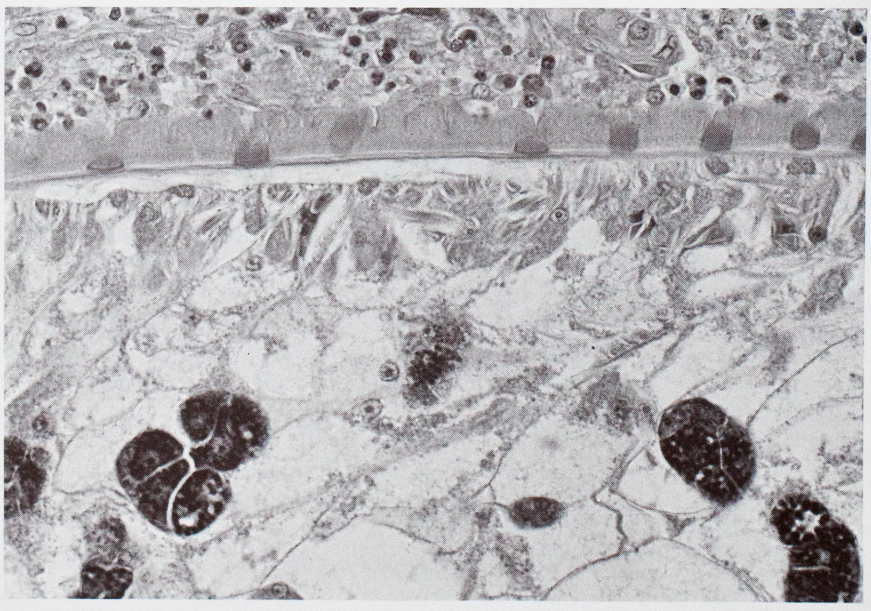

FIGURE 44-5. A higher magnification of Figure 44-4 shows the tegument with spines and pigmented vitellaria. (H & E stain; intermediate magnification.)

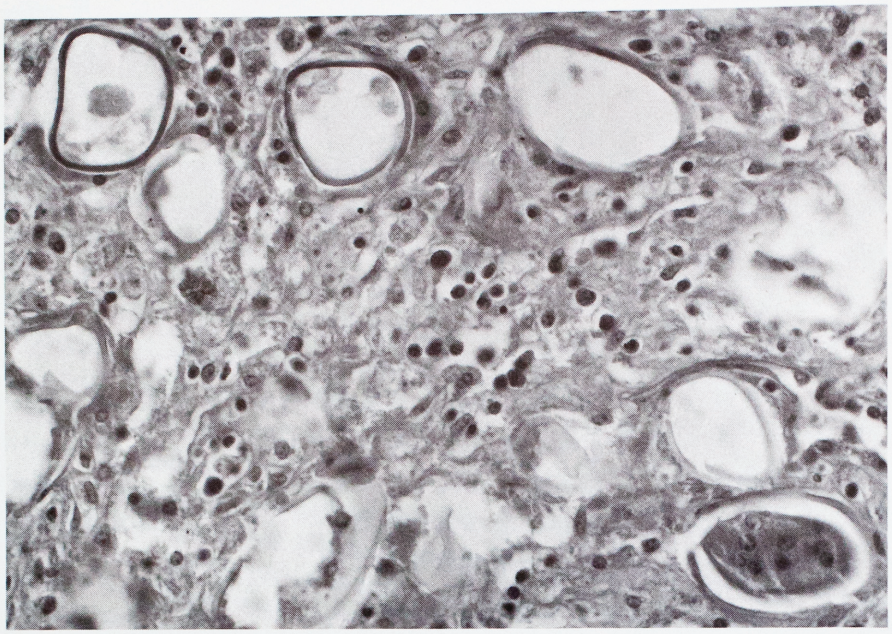

FIGURE 44-6. The eggs of *Paragonimus westermani* have thick, golden shells. (H & E stain; intermediate magnification.)

Worms mature to adults in the liver, where females lay eggs. Eventually, worm pairs migrate to mesenteric veins, where they remain. Adult worms do not directly cause disease, but they release large numbers of eggs that lodge in tissue and provoke pathologic changes.

Lung lesions can arise when the larvae migrate through the lungs by means of the hemolymphatic system. Allergic reactions to worm antigens can produce a pneumonitis, particularly after heavy infection, and a Loeffler-like pneumonitis is also well recognized. Larval pneumonitis occurs weeks to days after heavy cercarial exposure. Patients manifest low-grade fever, mild cough, and eosinophilia, and chest radiographs demonstrate basilar mottling. Spontaneous resolution is common. Embolic worms can cause more localized mass lesions in the lung. A Loeffler-like syndrome can occur during chemotherapy of heavy infections, because the sudden release of antigens from dying worms presumably provokes an allergic response.

Katayama fever, can occur in a nonimmune person 4 to 6 weeks after heavy infection with *Schistosoma* organisms. Patients present with fever, chills, cough, abdominal pain, diarrhea, nausea, vomiting, headache, urticaria, hepatosplenomegaly, and lymphadenopathy. The syndrome can be life threatening and resembles serum sickness. There is prominent eosinophilia and marked elevation of IgE and IgG.

In chronic schistosomiasis, long-standing egg granuloma formation causes most symptoms. Pulmonary involvement is usually accompanied by involvement of other organs. Chest radiographs reveal micronodules that must be differentiated from tuberculosis or large masses (*e.g.*, bilharziomas).[33,34]

Schistosomal cor pulmonale, although uncommon, occurs in all endemic areas of schistosomiasis in the world, but it is most often reported in *S. mansoni* infections from Egypt and Brazil. Eggs that lodge in arterioles provoke granulomatous endarteritis, leading to pulmonary hypertension, and cor pulmonale. Schistosomal cor pulmonale occurs primarily in patients with hepatosplenic schistosomiasis and portal hypertension with shunting of eggs to the lungs. Patients present with hemoptysis and right ventricular hypertrophy, and the prognosis is poor.[35]

Large numbers of eggs provoke focal granulomatous endarteritis and fibrosis described as angiomatoid or plexiform lesions, and there can be aneurysmal dilation of the pulmonary artery. The eggs are surrounded by epithelioid cells and a collar of concentric collagen. The eggs of *S. haematobium* and *S. mansoni* are large, 110 to 175 μm by 40 to 70 μm. They can be differentiated from each other by their spines. The eggs of *S. mansoni* have a prominent sharply pointed lateral spine (Fig. 44-7); the spine of an *S. haematobium* egg is small and terminal. The eggs of *S. japonicum* are ovoid, nonoperculate, and 55 to 65 μm by 70 to 100 μm (rarely >80 μm in tissues), and they have tiny lateral spines that are not usually seen in tissue sections. Less common *Schistosoma* species in humans are *S. intercalatum* and *S. mekongi*. The eggs of *S. intercalatum* are 140 to 240 μm by 50 to 85 μm and have a larger terminal spine than *S. hematobium*. *S. mekongi* eggs are similar to those of *S. japonicum*, but they are smaller, only 51 to 78 μm by 39 to 66 μm. *Schistosoma* eggs must be differentiated from those of *Paragonimus* species. Rarely, adult schistosomes are found within the lumens of pulmonary vessels. The tuberculations of the tegument in adult male *S. haematobium* and *S. mansoni* serve as good diagnostic features (Fig. 44-8). The diagnosis of schistosomiasis is usually established by identifying schistosome eggs in feces or urine. Pulmonary schistosomiasis can be established by lung biopsy.

MISCELLANEOUS TREMATODES

Fasciola hepatica, the liver fluke of sheep, can parasitize the bile ducts of human liver and cause hepatic disease. Migrating larvae occasionally infect other tissues, most commonly subcutaneous tissue. Worms in the pharynx can produce the halzoun (*i.e.*, suffocation) syndrome; those in the lung can provoke lung abscesses.[36]

Alaria species are intestinal flukes of canids in North America. Two intermediate hosts are needed, a snail followed by an amphibian or a reptile, usually a frog or a snake. Mesoacercariae develop and concentrate in the muscles of the hind legs of frogs. When undercooked frog legs are eaten, the mesocercariae emerge and penetrate the wall of the gut, migrate to the diaphragm, and enter the lung.[37] The patients affected by this rare disease manifest cough, hemoptysis, dyspnea, and tightness in the chest.[38,39] Pathologic findings are diffuse interstitial hemorrhage without inflammation around mesocercariae. The mesocercariae are 300- to

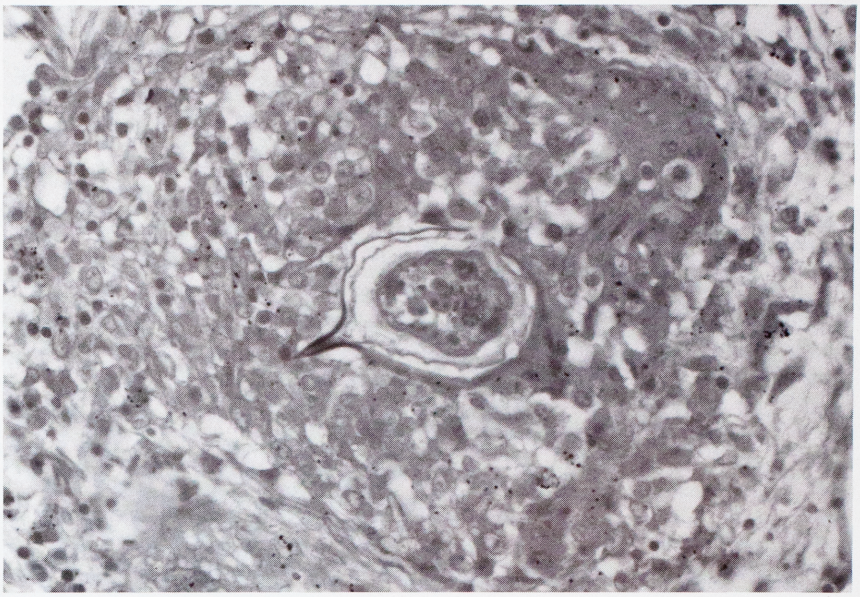

FIGURE 44-7. A granuloma in the lung contains an egg of a *Schistosoma mansoni* organism with the typical lateral spine. (H & E stain; intermediate magnification.)

800-μm-long larvae, with four penetration glands and rings of spines on the ventral sucker.

A rare cause of pulmonary fluke infection in man is *Opisthorchis viverrini*, which is a liver fluke that occurs in Southeast Asia and is acquired by eating raw infected fish.[40]

Cestodes

The three larval cestodes that commonly infect humans produce echinococcosis, sparganosis, and cysticercosis. All can induce pulmonary lesions, but only echinococcosis frequently involves the lungs. In the rare instances that cysticercosis or sparganosis involve the lung, they do not produce serious disease.

ECHINOCOCCOSIS

Echinococcosis or hydatid disease is caused by infection of larval tapeworms of the genus *Echinococcus*. The species that cause human infection are *Echinococcus granulosus, Echinococcus multilocularis*, and *Echinococcus vogeli*. Adult worms live in the small intestine of carnivorous canids (*e.g.*, wolf, dingo, dog, jackal, hyena), and the intermediate hosts are usually grazing ungulates (*e.g.*, sheep, goats, deer, elk, bison, moose, antelope, pacas). Only the larval stage develops in humans, and it is acquired by consuming eggs passed in the feces of a definitive host.

There are clinical differences in the human diseases caused by the three species of *Echinococcus*. *E. granulosus* causes cystic hydatid disease, producing unilocular, slow-growing cysts in the tissues, especially liver and lungs. Symptoms are caused by pressure from the cyst's mass or to hypersensitivity reactions from release of the cyst contents. It is only life threatening if the cyst grows within or compresses a vital organ. *E. multilocularis* causes the deadly alveolar hydatid disease by proliferating indefinitely and infiltrating like a neoplasm. It occurs throughout the world, including the United States.[41–43] *E. vogeli* causes polycystic hydatid disease, and the manifestations are intermediate between those of *E. granulosus* and *E. multilocularis*. *E. vogeli* occurs in rural areas of Latin America.[44]

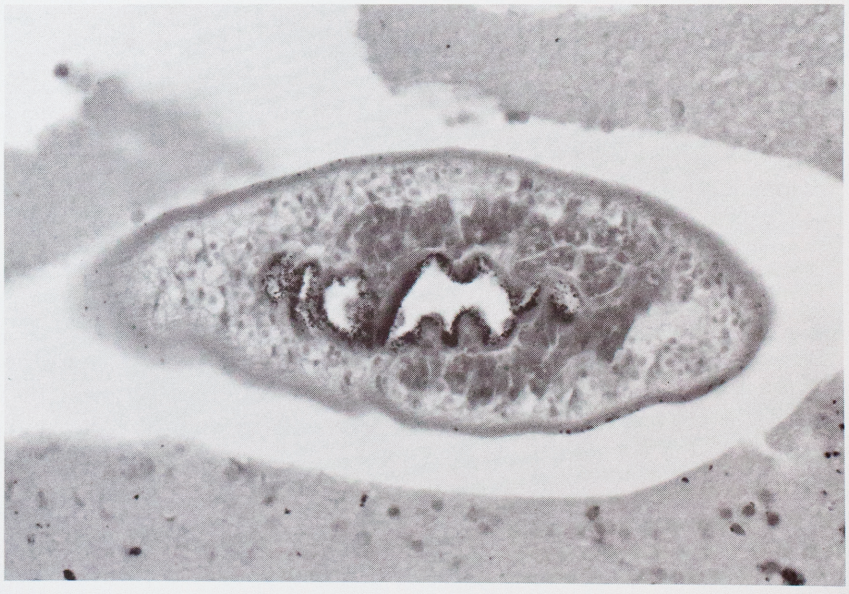

FIGURE 44-8. In a higher magnification of Figure 44-7, the pigment in the cecum (*i.e.*, intestine) is visible. The lack of tuberculations indicates that this is a female *Schistosoma* organism. (H & E stain; intermediate magnification.)

Pulmonary cystic hydatid disease occurs in about 25% of adults (Color Fig. 44-2) and 50% of children infected by *E. granulosus*.[45,46] The cyst can rupture into a bronchus or into the pleural space, producing pneumothorax and empyema.[47] The rupture of a cyst in the right heart can produce pulmonary emboli.[48]

Alveolar hydatid disease, caused by *E. multilocularis*, is a slowly progressive but deadly infection. Children can acquire the infection and live for 30 to 40 years before manifesting disease. Most untreated patients die. Pulmonary disease is uncommon and is caused by hematogenous seeding from another cyst or from penetration of a liver lesion through the diaphragm. Cysts in the liver are usually resistant to treatment, but pulmonary cysts are easily resectable or respond to standard antiparasitic drugs. Polycystic hydatid disease due to *E. vogeli* can involve the lung, but most patients have only liver involvement. Polycystic hydatid disease progresses more rapidly than cystic or alveolar disease. The mortality caused by polycystic hydatid disease is unknown.

Cysts of *E. granulosus* and *E. vogeli* are typically surrounded by a 3-mm-thick wall of fibrous tissue. The spherical cyst of *E. granulosus* is as large as 20 cm in diameter. The cyst wall is composed of a thick laminated inert layer on the outside and a thin, living, interior germinal membrane. Clusters of cells bud from the germinal membrane and develop into brood capsules (Fig. 44-9). Each brood capsule produces several infective protoscolices that can also be found free in the lung and can provoke an inflammatory response. Examination often reveals only the collapsed, sterile cyst walls of *E. granulosus*, surrounded by necrotic debris and resembling the cyst of *E. multilocularis*. *E. vogeli* cysts are translucent, and brood capsules are visible through the surface. The laminated membrane of the cyst wall is 8 to 65 μm thick. Cysts of *E. multilocularis* are surrounded by necrotic debris and may cavitate. The alveolar hydatid cyst of *E. multilocularis* is a mass of sterile, amorphous, proliferative membranes without fluid. Cysts of all three species can rupture into bronchi and produce acute and chronic inflammation. Cyst fragments in the lung parenchyma produce suppurative granulomas and occasionally calcify. Dead cysts can provoke secondary bacterial infections.

The diagnosis is usually made by radiographic imaging and serology.[49] The Gomori methenamine silver stain can simplify the recognition of the cyst wall of echinococcosis.[50] Sputum can contain protoscolices, hooklets, or pieces of cyst wall.

SPARGANOSIS

Spirometra species are tapeworms of carnivorous animals, and human infection with the pierocercoid larva is known as sparganosis. Humans can acquire infection by swallowing an infected crustacean or by eating raw flesh of an amphibian, reptile, or mammal. Spargana usually produce subcutaneous nodules in humans. Pulmonary sparganosis occurs infrequently.[51] The lesion typically contains a single, living motile worm that is sluggish, opaque, and measures 0.5 cm by 10 cm. Intact spargana provoke acute and chronic inflammation with eosinophilia; degenerating or necrotic worms become surrounded by dense fibrous tissue. Spargana are recognized by their tegument, calcareous corpuscles, and absence of digestive and reproductive tracts; they differ from other larval cestodes by the presence of an anterior bothrium and absence of scolices.

CYSTICERCOSIS

Cysticercosis is human infection by the larval stage of *Taenia solium*, a human tapeworm. Intestinal infection by an adult worm is called teniasis. People acquire the adult tapeworm by consuming infected undercooked pork. Pigs, the usual intermediate hosts, become infected by ingesting eggs of *T. solium* from contaminated human feces, and humans acquire cysticercosis in the same manner. Cysticerci can lodge anywhere in the body but usually occur subcutaneously or intramuscularly. Lung lesions are uncommon, and patients are usually asymptomatic.[52] The 1-cm larval form is a spherical, milky white, fluid-filled cyst that contains an invaginated scolex with four large suckers and an armed rostellum. The rostellum has a double row of 22 to 32 birefringent hooklets. The cyst wall away from the scolex is 100 to 200 μm thick and raised into projections 10 to 25 μm in diameter. The tegument is 5 μm thick, and the outer surface is covered with microvilli. Viable cysticerci cause little reaction, but dead cysticerci provoke an in-

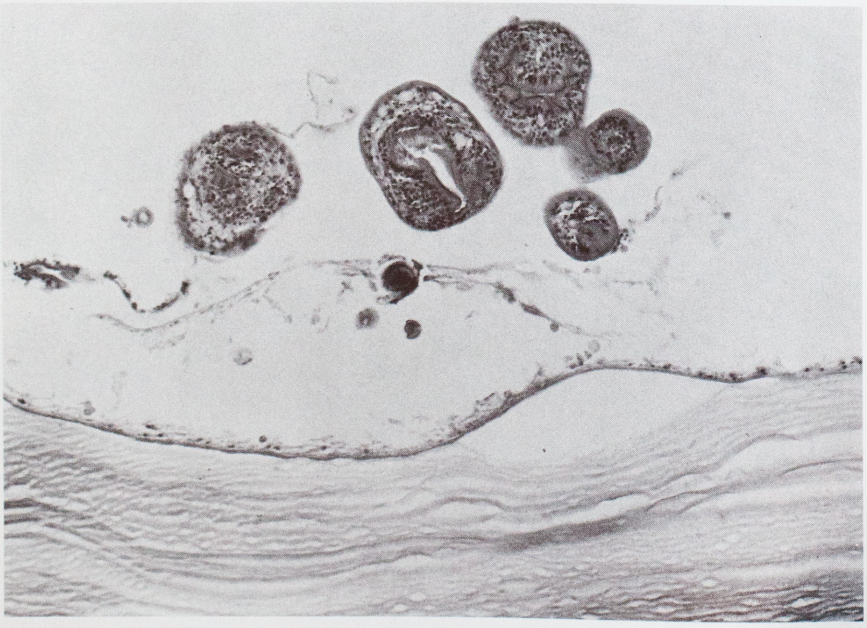

FIGURE 44-9. A cyst of *Echinococcus granulosus* in a lung has a laminated membrane, a germinal membrane, and a brood capsule with protoscolices. (H & E stain; low magnification.)

flammatory reaction followed by a granulomatous change. Nonviable cysts often calcify and can be seen on the radiograph.

Nematodes

Myriads of nematode larvae migrate through human lungs as part of their normal life cycle, but they produce little damage.

FILARIASIS

Wuchereria bancrofti, Brugia malayi, *Onchocerca volvulus*, and *Dirofilaria immitis* are filarial worms capable of causing pulmonary disease. When they occur ectopically in pulmonary arteries, they produce pulmonary emboli.[53] Hypereosinophilia with lung involvement is known as tropical eosinophilia.[54]

Wuchereria bancrofti and *Brugia malayi* are mosquito-transmitted, lymphatic-dwelling worms. Although rare, adult *B. malayi* and *W. bancrofti* can embolize to a pulmonary artery and produce infarction. Worms are coiled in pulmonary arteries (Fig. 44-10), with periarterial granulomas demonstrating central coagulative necrosis. Female filarial worms are usually immature, small (*i.e.*, *B. malayi*, 100 μm; *W. bancrofti*, >140 μm), and infertile. Adult *W. bancrofti* and *B. malayi* are morphologically similar and virtually indistinguishable except for size.

The Weingarten syndrome, also known as tropical eosinophilia, cryptic filariasis, or filarial hypereosinophilia, is thought to be caused by filariae. Tropical pulmonary eosinophilia (TPE) represents the pulmonary manifestation of the Weingarten syndrome and is thought to be caused by a hyperimmune response to microfilariae. No adult worms or microfilariae are found, but patients with TPE have high antibody titers to filarial worms. The disease occurs in regions endemic for brugian and bancroftian filariases, and volunteers inoculated with *B. malayi* develop the syndrome. Patients present with an asthmalike syndrome, malaise, episodes of nocturnal coughing, wheezing, dyspnea, chest pain, low-grade fever, and weight loss. Extreme eosinophilia (*i.e.*, >3000/mm^3) and high IgE levels persist for weeks. Pleural effusions are rare.[55] A lung biopsy of TPE reveals granulomas with giant cells and central eosinophilic abscesses near pulmonary venules. Rarely, a lung biopsy of TPE patients reveals microfilariae surrounded by eosinophils.

ONCHOCERCOSIS

Onchocerca volvulus, transmitted by several species of blackflies of the genus *Simulium*, causes a variety of skin and lymphatic changes and is a major cause of blindness. Microfilariae of *O. volvulus* migrate to the lung and other deep organs after treatment with diethylcarbamazine.[56] The microfilariae are surrounded by eosinophilic abscesses.

Microfilariae of *O. volvulus* are identified by their 7- to 13-μm-long cephalic space and distinctive, finely pointed tail with its 9- to 15-μm-long caudal space.

DIROFILARIASIS

D. immitis, the dog heartworm, produces pulmonary dirofilariasis in humans.[57–60] *D. immitis*–infected dogs occur in North and South America, Asia, and, rarely, in Europe. Mosquitoes, especially *Aedes* species, are the intermediate hosts and serve as the vector. Canids are the usual definitive hosts. Humans acquire the worm when an infected mosquito inoculates an infective third-stage larva subcutaneously. Some inoculated larvae grow, but virtually none reach sexual maturity in humans. The immature worms die and are swept into the pulmonary arteries, where they are entrapped and provoke disease.

Sixty percent to 70% of the patients infected with *D. immitis* are asymptomatic.[58] Those with symptoms have chest pain, cough, hemoptysis, fever, chills, malaise, and infrequent eosinophilia.[59] Chest radiographs typically show a 2- to 3-cm coin lesion, usually at the periphery and fixed to the pleura. The intact or degenerating worm is usually lodged in pulmonary arteries or arterioles, surrounded by coagulative necrosis (*i.e.*, infarction), inflammation, and a granulomatous reaction. The immature *D. immitis* found in human lungs is 100 to 359 μm in diameter with a 5- to 25-μm-thick cuticle containing three layers. The cuticle projects inwardly at the lateral chords, forming two prominent, opposing, internal, longitudinal ridges.[60] The musculature is prominent, but lateral

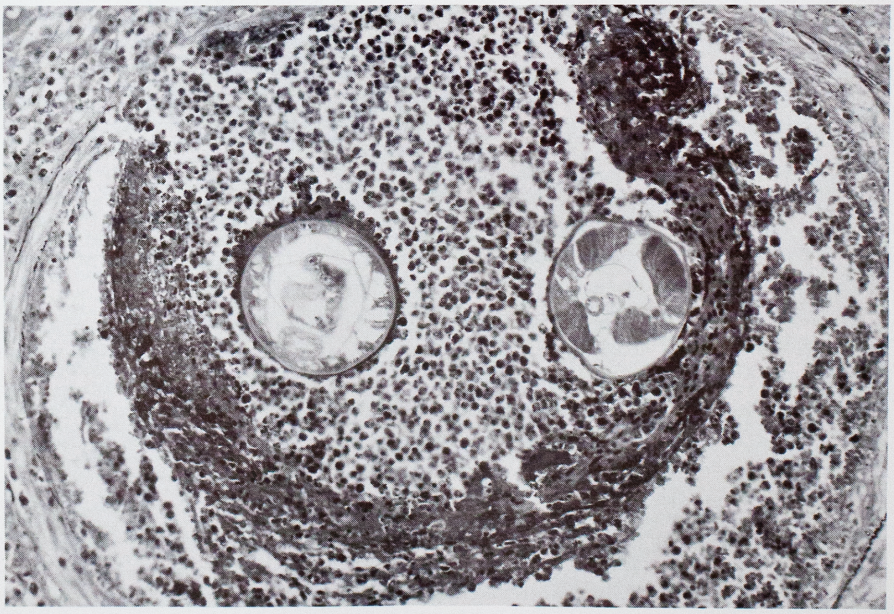

FIGURE 44-10. Two sections of an adult male *Wuchereria bancrofti* coiled within a thrombosed vessel demonstrate the intense inflammatory response provoked by the worm, including the Splendore-Hoeppli reaction around one section. (Movat stain; low magnification.)

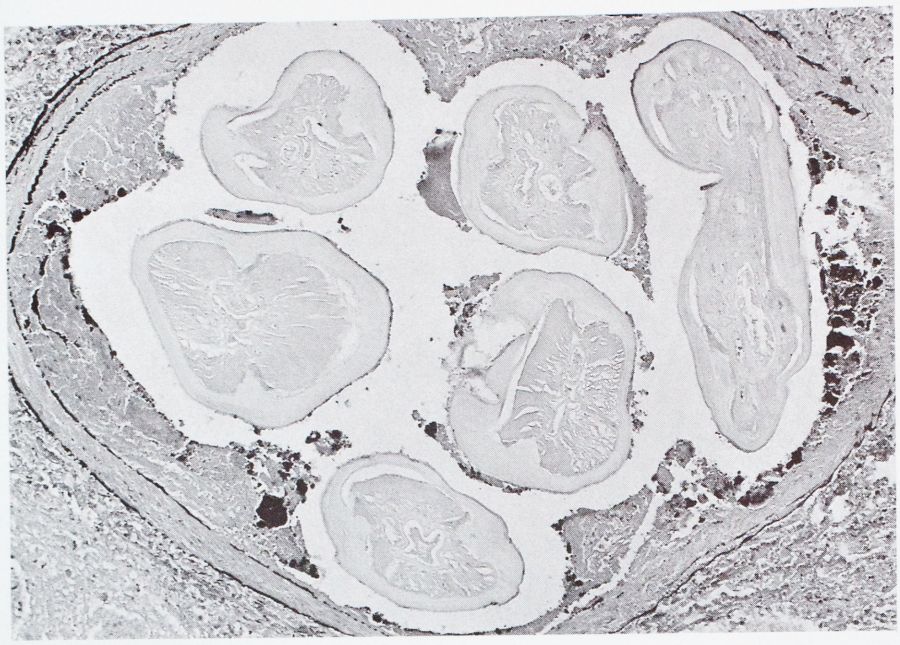

FIGURE 44-11. The immature, coiled, degenerated male *Dirofilaria immitis* within pulmonary vessel has a thick cuticle, prominent musculature, and bilteral internal longitudinal cuticular ridges. (Movat stain; low magnification.)

chords are poorly preserved (Fig. 44-11). Biopsy of the lesion with identification of the worm is required for diagnosis, but the worm can degenerate completely, making the diagnosis uncertain.

STRONGYLOIDIASIS

Strongyloides stercoralis, the threadworm, produces strongyloidiasis in humans. Larval migration through the lungs occurs as part of its life cycle. The severity of the pulmonary symptoms is directly related to the worm burden, and heavy infection occurs in patients with impaired T-lymphocyte function.[61,62] *S. stercoralis* is ubiquitous, but infection is more common in tropical and subtropical environments. Eggs in the soil become rhabditiform larvae that mature into free-living adults or transform into filariform larvae, which are ineffective. Filariform larvae penetrate the skin, enter blood vessels, migrate to pulmonary capillaries, and invade alveoli. The larvae molt once and migrate to the trachea, where they are coughed up and swallowed. In the duodenum, they mature into adult female worms that embed in the intestinal epithelium. Migration of the larvae through the lungs is not an obligatory part of the life cycle, but it is the main route by which the worms reach the gut. In the gut, adult female worms produce eggs that release rhabditiform larvae, which become filariform larvae that penetrate the wall of the intestine, resulting in autoinfection. In immunocompromised patients, the autoinfection leads to life-threatening hyperinfection with severe pulmonary disease.

Most patients have no significant pulmonary symptoms despite the production of mild tissue damage by migrating filariform larvae, but many patients have larvae in the sputum. Eosinophilia may occur, and the prognosis is poor for patients who do not have eosinophilia. Some patients have viable adult worms in bronchial epithelium, which produce chronic bronchitis, asthmalike symptoms, or respiratory failure.[63] Fatal adult respiratory distress syndrome is uncommon but can occur despite successful treatment.[64]

Filariform larvae in the lung produce petechial hemorrhages and infiltrates of neutrophils and monocytes; pulmonary abscesses and cavities may also occur.[65] The filariform larvae are 600 μm by 16 μm, have a characteristic notched tail, and lack a buccal cavity. Parasitic adult female worms are only 1.5 to 2.5 mm long and 30 to 40 μm wide. Filariform larvae must be differentiated morphologically from other small, parasitic larvae, such as those of hookworms (*i.e., Necator* and *Ancylostoma* species), which produce visceral larva migrans (VLM). Eggs produced by adult worms can release rhabditiform larvae which are 380 μm by 20 μm; these can be found in the patient's sputum.

ASCARIASIS

Ascaris lumbricoides is the cause of one of the most common helminthic infections of humans. People acquire the infection by eating food contaminated with mature eggs. The eggs hatch in the gut and release larvae that penetrate the small intestine and enter the portal circulation. The larvae pass through the liver and heart and lodge in pulmonary capillaries. The larvae molt once and then migrate up the trachea, where they are coughed up and swallowed. In the small intestine, they mature into adult worms, copulate, and release eggs into the feces. Most patients are asymptomatic, but heavily infected patients can develop life-threatening pulmonary disease or intestinal obstruction.

Ascaris suum, the ascarid of pigs, can infect persons exposed to soil contaminated by feces from infected pigs.[66] *A. suum* provokes more severe symptoms in humans than does *A. lumbricoides*. Adult *A. suum* are morphologically indistinguishable from *A. lumbricoides* but are not adapted to humans.

Most patients infected with *A. lumbricoides* have no pulmonary symptoms. Allergic patients can develop ascaris pneumonitis, an asthmalike reaction to migrating larvae with acute eosinophilic pneumonia, or the Loeffler syndrome. Symptoms resolve spontaneously in 2 to 3 weeks, when the larvae migrate out of the lungs.

Lungs heavily infected with *Ascaris* organisms have small gray areas of consolidation, predominantly in the lower lobes.[67] Larvae provoke interstitial pneumonitis or foci of bronchopneumonia (Fig. 44-12). They occur throughout the lung, in alveoli, alveolar walls, bronchioles, and bronchi. In some patients, larvae die in the lung and provoke granulomas composed of eosinophils, macrophages, and epithelioid cells. Larvae in the lungs are 2 mm by 75 μm and have prominent single lateral alae (Fig. 44-13).

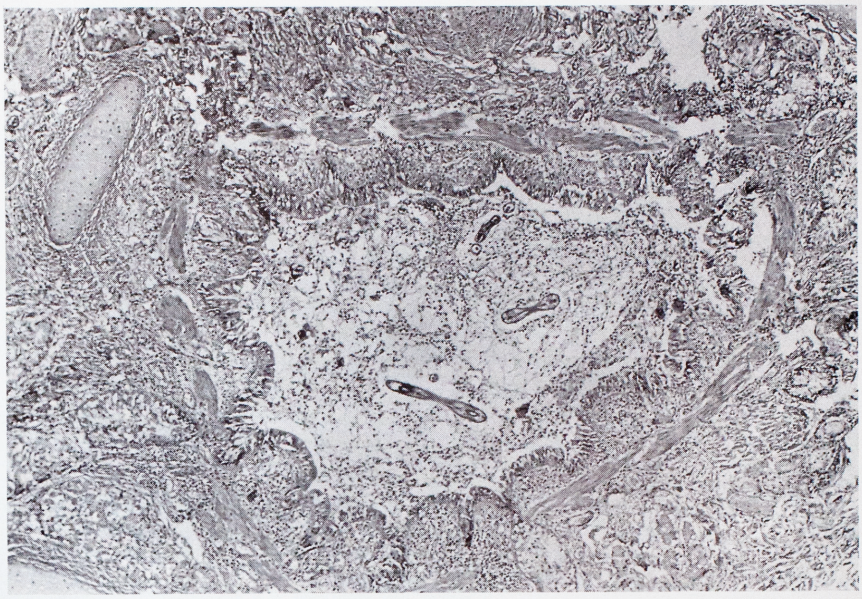

FIGURE 44-12. Several larvae of *Ascaris lumbricoides* are within the bronchus, causing bronchopneumonia (H & E stain; low magnification.)

VISCERAL LARVA MIGRANS

VLM is produced by larval worms wandering aimlessly in aberrant hosts. *Toxocara canis*, the intestinal ascarid of dogs, is by far the most common worm causing VLM in humans. Other worms that can cause the syndrome include *Toxocara cati*, the ascarid of cats; *Baylisascaris procyonis*, the ascarid of raccoons; *Gnathostoma spinigerum*, a gastric nematode of cats; *Alaria* species, intestinal flukes of canids; *Spirometra* species, tapeworms of carnivorous animals; and pentastomids, the arthropodlike worms of the pulmonary passages of tropical reptiles and other vertebrates.

VLM occurs throughout the world, but most known infections occur in the United States, especially in the southeastern and eastern states. The disease occurs most often in young children exposed to the feces of dogs. Children are infected by ingesting eggs, which produce larvae that penetrate the gut and enter the blood stream. Larvae travel throughout the body and can lodge in any organ, particularly the liver, lung, brain, and eye. Children with significant numbers of larvae develop Loeffler syndrome, but severe lung disease is rare.[68] Larval hookworms (*e.g., Ancylostoma, Necator*) can also cause Loeffler syndrome. *T. canis* larvae are 500 μm by 20 μm and have minute, single, lateral alae. Larvae provoke an interstitial inflammatory exudate followed by granulomas, which may be numerous.

MISCELLANEOUS NEMATODES

Capillaria aerophila, a natural parasite of cats, dogs, and foxes, can produce pulmonary capillariasis in humans.[69] In humans, worms invade the mucosal epithelium of bronchioles, where they lay eggs and provoke eosinophilic infiltrates. Diagnosis is made by identifying the characteristic eggs of *C. aerophila* in sputum or feces. Eggs are 65 μm by 35 μm, barrel-shaped, unsegmented, and have distinctive bipolar plugs.

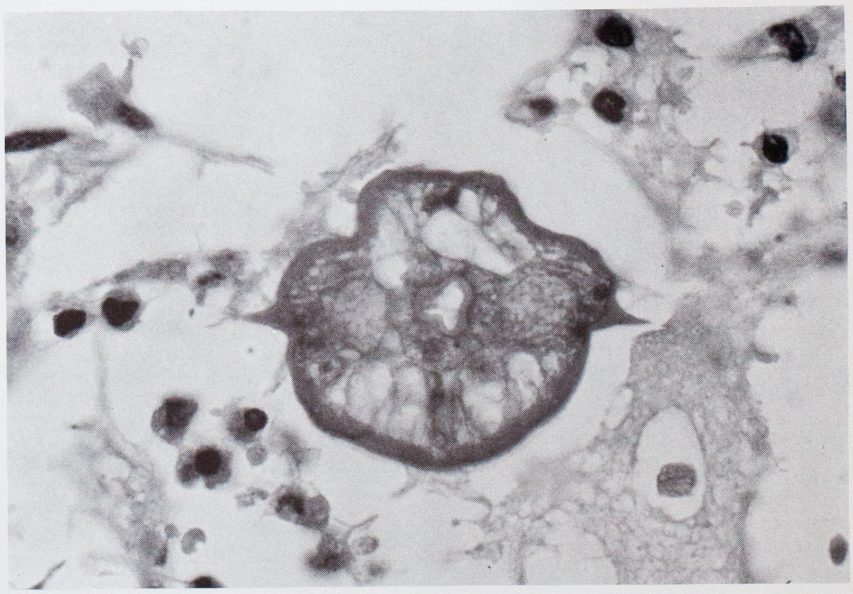

FIGURE 44-13. A transverse section of the *Ascoris lumbricoides* larvae in the exudate of a lung shows the lumen of the gut (*center*) and the prominent lateral alae of cuticle. (H & E stain; high magnification.)

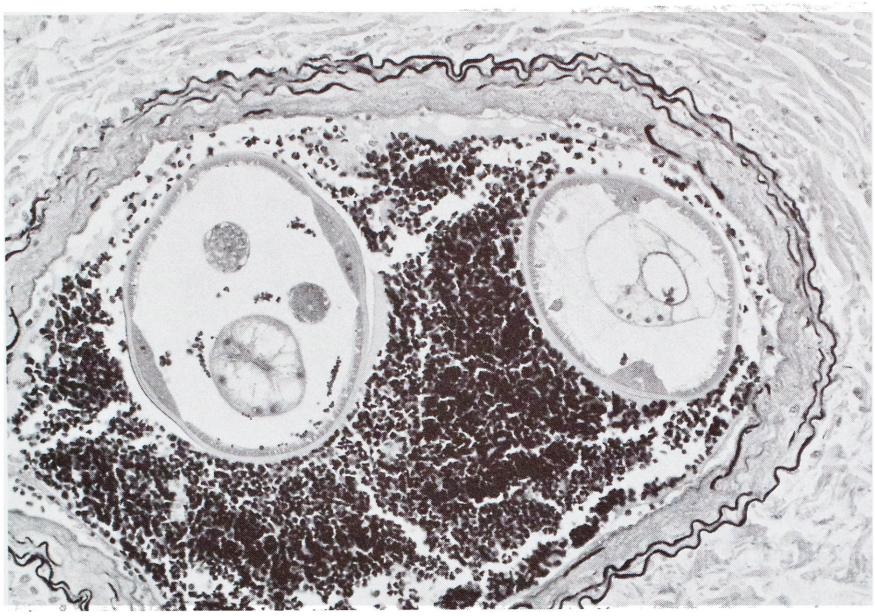

FIGURE 44-14. Two transverse sections of an adult *Angiostrongylus cantonensis* organism in a pulmonary vessel show the prominent intestine (*i.e.*, large duct). (Movat stain; low magnification.)

Mammomonogamus laryngeus, the laryngeal worm of cattle, water buffalo, and goats, causes mammomonogamiasis (*i.e.*, syngamiasis) in humans.[70,71] The worms, in permanent male and female pairs, attach to the mucosa of the throat, trachea, or bronchi, where they copulate and lay eggs. Patients present with cough, hemoptysis, and weight loss.[72,73] The adults can be removed by bronchoscopy, or patients can be treated with thiabendazole.

Enterobius vermicularis, the pinworm, is a common human parasite in temperate regions. The worm is transmitted from person to person by the fecal-oral route. *E. vermicularis* ordinarily lives in the colon, and rarely, adult *E. vermicularis* infect the lung. An adult worm in the lung can produce a necrotic pulmonary nodule (Color Figs. 44-3 and 44-4).[74]

Trichinella spiralis causes trichinosis. People acquire the infection by eating raw or undercooked infected meat, especially pig, wild boar, or bear meat. Rarely, larvae occur in the lungs, where they cause dilation and congestion of pulmonary vessels and hemorrhagic lesions.[75]

Mansonella perstans, a filarial worm infecting humans in Africa and in South and Central America, inhabits serous body cavities, including the pleural spaces.[76] *M. perstans* in the pleural spaces can produce pleural effusions.[77] Larvae of *G. spinigerum*, a spiruroid of wild and domestic cats, causes gnathostomiasis in humans.[78] Worms are rarely found in the lungs or respiratory tracts of infected humans.

Other nematodes that rarely cause pulmonary disease in humans include *Angiostrongylus cantonensis*, the lungworm of rats (Fig. 44-14); *Metastrongylus elongatus*, the lungworm of pigs; members of the Anisakid group, intestinal nematodes of marine mammals; *Halicephalobus deletrix*, a free-living saprophytic nematode that can cause disease in people and horses; *B. procyonis*, the ascarid of raccoons; and *Lagochichascris minor*, an ascrid that produces excruciating lesions of the head, neck, and nasopharynx.[79–86]

REFERENCES

1. Oksenhendler E, Cadranel J, Sarfati C, et al. Toxoplasma gondii pneumonia in patients with the acquired immunodeficiency syndrome. Am J Med 1990;88:18N.
2. Evans TG, Schwartzman JD. Pulmonary toxoplasmosis. Semin Respir Infect 1991;6:51.
3. Garcia LW, Hemphill RB, Marasco WA, Ciano PS. Acquired immunodeficiency syndrome with disseminated toxoplasmosis presenting as an acute pulmonary and gastrointestinal illness. Arch Pathol Lab Med 1991;115:459.
4. Wreghitt TG, Hakim M, Gray JJ, et al. Toxoplasmosis in heart and lung transplant recipients. J Clin Pathol 1989;42:194.
5. Yermakov V, Rashid RK, Vuletin JC, Pertschuk LP, Isaksson H. Disseminated toxoplasmosis. Case report and review of the literature. Arch Pathol Lab Med 1982;106:524.
6. Pomeroy C, Miller L, McFarling L, Kennedy C, Filice GA. Phenotypes, proliferative responses, and suppressor function of lung lymphocytes during Toxoplasma gondii pneumonia in mice. J Infect Dis 1991; 164:1227.
7. Furst SR, Weinger MB, Simons SM. Pleuropulmonary amebiasis. Chest 1991;100:293.
8. MacLeod IN, Wilmot AJ, Powell SJ. Amebic pericarditis. Q J Med 1966;25:293.
9. Ibarra-Perez C, Seiman-Lama M. Diagnosis and treatment of amebic empyema. Report of 88 cases. Am J Surg 1977;134:283.
10. Appelbaum IL, Shrager J. Pneumonitis associated with malaria. Arch Intern Med 1944;74:155.
11. Lutalo SK, Mabuwa C. Complications of seasonal adult malaria at a central hospital. Cent Afr J Med 1990;36:268.
12. Deaton JG. Fatal pulmonary edema as a complication of acute falciparum malaria. Am J Trop Med Hyg 1970;19:196.
13. Corbett CE, Duarte MI, Lancellotti CL, Silva MA, Andrade HF Jr. Cytoadherence in human falciparum malaria as a cause of respiratory distress. J Trop Med Hyg 1989;92:112.
14. Cayea PD, Rubin E, Teixidor HS. Atypical pulmonary malaria. AJR 1981;137:51.
15. Punyagupta S, Srichaikul F, Nitiyanat P, Petchclai B. Acute pulmonary insufficiency in falciparum malaria: summary of 12 cases with evidence of disseminated intravascular coagulation. Am J Trop Med Hyg 1974;23:551.
16. Duarte MIS, Corbett CEP, Boulos M, Neto VA. Ultrastructure of the lung in falciparum malaria. Am J Trop Med Hyg 1985;34:31.
17. Bittencourt AL, Rodrigues de Freitas LA, Galvo de Arujo MO, Jacomo D. Pneumonitis in congenital Chagas' disease. A study of ten cases. Am J Trop Med Hyg 1981;30:38.
18. Bittencourt AL. Congenital Chagas' disease. A review. Am J Dis Child 1976;130:97.

19. Camara EJN, Lima JAC, Olivera GB, Machado AS. Pulmonary findings in patients with Chagasic megaesophagus. Chest 1983;83:87.
20. Walton BC, Bachrach T. Occurrence of trichomonads in the respiratory tract. Report of 3 cases. J Parsitol 1963;49:35.
21. Fardy PW, March S. Trichomonads in resected lung tissue. Am Rev Respir Dis 1969;100:893.
22. Brady EM, Margolis ML, Korzeniowski OM. Pulmonary cryptosporidiosis in acquired immunodeficiency syndrome. JAMA 1984; 252:89.
23. Kocochis SA, Ciball ML, Davis TE, Hinton JT, Seip M, Banwell JF. Intestinal and pulmonary cryptosporidiosis in an infant with severe combined immune deficiency. J Pediatr Gastroenterol Nutr 1984; 3:149.
24. Miller RA, Wasserheit JN, Kirihaara J, Coyle MB. Detection of Cryptosporidium oocysts in sputum during screening for Mycobacterium. J Clin Microbiol 1984;20:1992.
25. Matzner Y, Behar A, Beeri E, Gunders AE, Hershko C. Systemic leishmaniasis mimicking malignant histiocytosis. Cancer 1979;43: 398.
26. Visvesvara GS. Classification of Acanthamoeba. Rev Infect Dis 1991; 13(Suppl 5):S39.
27. Martinez AJ. Infection of the central nervous system due to Acanthamoeba. Rev Infect Dis 1991;13(Suppl 5):S399.
28. Visvesvara GS, Martinez AJ, Schuster FL, et al. Leptomyxid ameba, a new agent of amebic meningoencephalitis in humans and animals. J Clin Microbiol 1990;28:2750.
29. Isvesvara GS, Ballamuth W. Comparative studies on related free-living and pathogenic amebae with special reference to Acanthameba. J Protozool 1975;21:239.
30. Visvesvara GS, Mira SS, Brandt FH, Moss DM, Mathews HM, Martinez AJ. Isolation of two strains of Acanthameba castellanii from human tissues and their pathogenicity and isoenzyme profiles. J Clin Microbiol 1983;18:1405.
31. Johnson RJ, Johnson JR. Paragonimiasis in Indochinese refugees. Roentgenographic findings with clinical correlation. Am Rev Respir Dis 1983;128:534.
32. Collins MS, Phelan A, Kim TC, Pearson RD. Paragonimus westermani: a cause of cavitary lung disease in an Indochinese refugee. South Med J 1980;74:14118.
33. Schaberg T, Rahn W, Racz P, Lode H. Pulmonary schistosomiasis resembling acute pulmonary tuberculosis. Eur Respir J 1991;4:1023.
34. Thompson HG, Pettigrew R, Johnson EA. Solitary pulmonary bilharzioma. Thorax 1979;34:401.
35. Sadigursky M, Andrade ZA. Pulmonary changes in schistosomal cor pulmonale. Am J Trop Med Hyg 1982;31:779.
36. Watson JH, Kermin RA. Observations on the various forms of parasitic pharyngitis known as "halzoun" in the Middle East. J Trop Med Hyg 1956;59:147.
37. Shoop WL, Corkum KC. Epidemiology of Alaria marcianae mesocercaria in Louisiana. J Parasitol 1981;67:928.
38. Freeman RS, Stuart PF, Cullen JB, et al. Fatal human infection with mesocercariae of the trematode Alaria americana. Am J Trop Med Hyg 1976;25:803.
39. Fernandes BJ, Cooper JD, Cullen JB, et al. Systemic infection with Alaria americana (Trematoda). Can Med Assoc J 1976;115:1111.
40. Priyanonda B, Tandhanand J. Opisthorchiasis with pulmonary involvement. Ann Intern Med 1961;54:795.
41. Gamble WG, Segal M, Schantz PM, Rausch RL. Alveolar hydatid disease in Minnesota. First human case acquired in the contiguous United States. JAMA 1979;241:904.
42. Leiby PD, Kritsky DC. Echinococcus multilocularis: a possible domestic life cycle in central North America and its public health implications. J Parasitol 1972;58:1213.
43. Wilson JF, Rausch RL. Alveolar hydatid disease. A review of clinical features of 33 indigenous cases of Echinococcus multilocularis infection in Alaskan Eskimos. Am J Trop Med Hyg 1980;29:1340.
44. D'Alessandro A, Rausch RL, Cuello C, Aristizabal N. Echinococcus vogeli in man, with a review of polycystic hydatid disease in Colombia and neighboring countries. Am J Trop Med Hyg 1979;28:303.
45. Pineyro JR. Hydatid disease of the lung. Prog Pediatr Surg 1982; 15:113.
46. Matsaniotis N, Karpathios T, Koutoyzis J. Hydatid disease in Greek children. Am J Trop Med Hyg 1983;32:1075.
47. Munzer D. New perspectives in the diagnosis of Echinococcus disease. J Clin Gastroenterol 1991;13:415.
48. Bayezid O, Ocal A, Isik O, Okay T, Yakut C. A case of cardiac hydatid cyst localized on the interventricular septum and causing pulmonary emboli. J Cardiovasc Surg 1991;32:324.
49. Schantz PM, Wilson JF, Wahlquist SP. Serologic tests for diagnosis and post-treatment evaluation of patients with alveolar hydatid disease. Am J Trop Med Hyg 1983;32:1381.
50. Marty AM, Hess SJ. Tegumental laminations in echinococci using Gomori's methenamine silver stain. Lab Med 1991;22:419.
51. Connor DH, Sparks AK, Strano AJ, Neafie RC, Juvelier B. Disseminated parasitosis in an immunocompromised patient. Possibly a mutated sparganum. Arch Pathol Lab Med 1976;100:65.
52. Choi JH, Chung SI, Whang YS, et al. A case of pulmonary cysticercosis. Korean J Intern Med 1991;6:38.
53. Beaver PC, Fallon M, Smith GH. Pulmonary nodule caused by a living Brugia malayi-like filaria in an artery. Am J Trop Med Hyg 1971;23:869.
54. Neva FA, Ottesen EA. Tropical eosinophilia. N Engl J Med 1978; 298:1129.
55. Boornazian JS, Fagan MJ. Tropical pulmonary eosinophilia associated with pleural effusions. Am J Trop Med Hyg 1985;34:473.
56. Meyers WM, Neafie RC, Connor DH. Onchocerciasis: invasion of deep organs by Onchocerca volvulus. Autopsy findings. Am J Trop Med Hyg 1977;26:650.
57. Cordero M, Munoz MR, Muro A, Simon F. Transient solitary pulmonary nodule caused by Dirofilaria immitis. Eur Respir J 1990; 3:1070.
58. Dayal Y, Neafie RC. Human pulmonary dirofilariasis. A case report and review of the literature. Am Rev Respir Dis 1975;112:437.
59. Ro JY, Tsakalakis PJ, White VA, et al. Pulmonary dirofilariasis: the great imitator of primary or metastatic lung tumor. A clinicopathologic analysis of seven cases and a review of the literature. Hum Pathol 1989;20:69.
60. Gutierrez Y. Diagnostic features of zoonotic filariae in tissue sections. Hum Pathol 1984;15:514.
61. Stone WJ, Schaffner W. Strongyloides infections in transplant recipients. Semin Respir Infect 1990;5:58.
62. Gompels MM, Todd J, Peters BS, Main J, Pinching AJ. Disseminated strongyloidiasis in AIDS: uncommon but important. AIDS. 1991; 5:329.
63. Strazzella WD, Safirstein BH. Asthma due to parasitic infestation. N J Med 1989;86:947.
64. Thompson JR, Berger R. Fatal adult respiratory distress syndrome following successful treatment of pulmonary strongyloidiasis. Chest 1991;99:772.
65. Ford T, Reiss-Levy I, Clark E, Dyson AJ, Schonell W. Pulmonary strongyloidiasis and lung abscess. Chest 1981;79:239.
66. Phills JA, Harrold AJ, Whiteman GV, Perelmutter L. Pulmonary infiltrates, asthma, and eosinophilia due to Ascaris suum infestation in man. N Engl J Med 1972;286:965.
67. Neafie RC, Connor DH. Ascariasis. In: Binford CH, Connor DH, eds. Pathology of tropical and extraordinary diseases. Washington, DC: Armed Forces Institute of Pathology, 1976;460.
68. Beshear JR, Hendley JO. Severe pulmonary involvement in visceral larva migrans. Am J Dis Child 1973;125:599.
69. Aftandelians R, Raafat F, Taffazoli M, Beaver PC. Pulmonary capillariasis in a child in Iran. Am J Trop Med Hyg 1977;26:64.
70. Van Aken D, De Bont J, Fransen J, Vercruysse J. Mammomonogamus laryngeus (Raillet, 1899) infections in cattle from Sri Lanka. J Helminthol 1989;63:47 [and erratum in 63:352].

71. Cunnac M, Magnaval JF, Cayarci D, Leophonte P. Three cases of human syngamiasis in Guadeloupe. Rev Pneumol Clin 1988;44:140.
72. Mornex JF, Magdeleine J. Parasitic pulmonary disease: human bronchial syngamiasis (letter). Am Rev Respir Dis 1983;127:525.
73. Timmons RF, Bowers RE, Price DL. Infection of the respiratory tract with Mammomonogamus laryngeus: a new case in Largo, Florida, and a summary of previously reported cases. Am Rev Respir Dis 1983;128:566.
74. Beaver PC, Kriz JJ, Lau TJ. Pulmonary nodule caused by Enterobius vermicularis. Am J Trop Med Hyg 1973;22:711.
75. Goldwater LJ, Steinberg I, Most H, Connery J. Hemoptysis in trichiniasis. N Engl J Med 1935;213:849.
76. Meyers WM, Connor DH, Neafie RC. Dipetalonemiasis. In: Binford CH, Connor DH, eds. Pathology of tropical and extraordinary diseases. Washington, DC: Armed Forces Institute of Pathology, 1976;382.
77. Kahn JB. Pleural effusion associated with Dipetalonema perstans. J Infect Dis 1983;147:166.
78. Nagler A, Pollack S, Hassoun G. Human pleuropulmonary gnathostomiasis: a case report from Israel. Isr J Med Sci 1983;19:834.
79. Sonakal D. Pathological findings in four cases of human angiostrongyliasis. Southeast Asian J Trop Med Public Health 1978; 9:220.
80. Beaver PC, Jung RC, Cupp EW. Clinical parasitology. 9th ed. Philadelphia: Lea & Febiger, 1984;291.
81. Kobayashi A, Tsuji M, Wilbur DL. Probable pulmonary anisakiasis accompanying pleural effusions. Am J Trop Med Hyg 1985;34:310.
82. Spalding MG, Greiner EC, Green SL. Halicephalobus (Micronema) deletrix infection in two half-sibling foals. JAMA 1991;196:1127.
83. Connor DH, Gibson DW, Zeifer A. Diagnostic features of three unusual infections: micronemiasis, phaeomycotic cysts, and protothecosis. In: Majno C, Cotran RS, eds. Current topics in inflammation and infection. Baltimore: Williams & Wilkins, 1982;205.
84. Huff DS, Neafie RC, Binder MJ, DeLeon GA, Brown LW, Kazakos KR. The first fatal Baylisascaris infection in humans: an infant with eosinophilic meningoencephalitis. Pediatr Pathol 1984;2:345.
85. Fox AS, Kazakos KR, Gould NS, Heydemann PT, Thomas C, Boyer KM. Fatal eosinophilic meningoencephalitis and visceral larva migrans caused by the raccoon ascarid Baylisascaris procyonis. N Engl J Med 1985;312:1619.
86. Botero D, Luttle MD. Two cases of human *Lagochilascaris* infection in Columbia. Am J Trop Med Hyg 1984;2:345.