Microbial Diseases of the Digestive System

Chapter 25
Human digestive system.
Introduction

• Diseases of the digestive system are the second most common illnesses in the United States.

• Diseases of the digestive system usually result from the ingestion of microorganisms and/or their toxins in food and water.

• The fecal-oral cycle of transmission can be broken by the proper disposal of sewage, the disinfection of drinking water, and proper food preparation and storage.
I. Structure and Function of the Digestive System

• The gastrointestinal (GI) tract, or alimentary canal, consists of the mouth, pharynx, esophagus, stomach, small intestine, and large intestine.

• The teeth, tongue, salivary glands, liver, gallbladder, and pancreas are accessory structures.

• In the GI tract, with mechanical and chemical help from the accessory structures, large food molecules are broken down into smaller molecules that can be transported by blood or lymph to cells.

• Feces, the solids resulting from digestion, are eliminated through the anus.
Anatomy of gastrointestinal tract.
Wall of the small intestine. Villi cover the folds of the mucosal layer; in turn each villus is covered with epithelial cells.
II. Normal Microbiota of the Digestive System

• A wide variety of bacteria colonize the mouth, with counts of millions of bacteria/ml.

• The stomach and small intestine have few resident microorganisms, due to acidity produced in stomach.

• The large intestine is the habitat of mostly anaerobes (Lactobacillus, Bacteroides), and facultative anaerobes (E. coli, Enterobacter, Klebsiella, and Proteus).

• Has large #’s of organisms (>100 billion/gm). Up to 40% of fecal mass is microbial cells.

• Bacteria in the large intestine assist in degrading food, make flatus, and synthesizing vitamins.
Ⅲ. Bacterial Diseases of the Mouth

• A. Dental Caries (Tooth Decay)
  – Dental caries begin when tooth enamel and dentin are eroded and the pulp is exposed to bacterial infection.
  – *Streptococcus mutans*, found in the mouth, uses sucrose to form dextran from glucose and lactic acid from fructose. Table sugar = glucose and fructose.
  – Bacteria adhere to teeth and produce sticky dextran, forming dental plaque.
  – Acid produced during carbohydrate fermentation destroys tooth enamel at the site of the plaque.
  – Gram-positive rods and filamentous bacteria can advance decay by penetrate into dentin and pulp.
  – Carbohydrates such as starch, mannitol, and sorbitol (sugarless additives) are not used by cariogenic bacteria to produce dextran and do not promote tooth decay.
  – Caries are prevented by restricting the ingestion of sucrose and by the physical removal of plaque.
The role of *Strep mutans* and sucrose.
Streptococcus mutans colonies on sucrose agar.
Ⅲ. Bacterial Diseases of the Mouth

B. Periodontal Disease

– Periodontal disease characterized by inflammation and degeneration of structures that support the teeth (cementum, gums) are caused by streptococci, actinomycetes (gpr), and anaerobic gram-negative bacteria.

– Gingivitis is infection restricted to the gums (gingivae). 50% of adults.

– Chronic gum disease (periodontitis) can cause bone destruction and tooth loss; periodontitis is due to an inflammatory response to a variety of bacteria growing on the gums. 35% of adults.

– Acute necrotizing ulcerative gingivitis is caused by Prevotella intermedia and spirochetes. Also called ‘Trench Mouth’ or Vincent’s Angina
The stages of tooth decay. The process starts with plaque accumulation. Decay begins as acids are produced by bacteria that attack the enamel. Decay can advance to the dentin and ultimately enter the pulp where abscesses may form.
The stages of periodontal disease. Healthy teeth begin well anchored by bone and gum tissue. Toxins in plaque irritate the gums causing gingivitis. Periodontal pockets form separating the gingiva from the tooth. Gingivitis progresses to periodontitis. Ultimately, the gingiva and bone, and the cementum that protects the root are destroyed that support the tooth.
Dental caries - Extensive tooth decay is present in this 6 year old child. Factors predisposing to such advanced caries include low dietary fluoride intake, high sucrose intake, poor oral hygiene, enamel hypoplasia, and poor parenting.
Acute ulcerative gingivitis (Vincent’s angina) Ulceration of the gingival margin is associated with accumulation of bacterial plaque. The gums are swollen with areas of necrosis and the breath fetid. Borrelia vincentii (a spiral organism) and fusiform anaerobic bacteria are found in the plaque. Prevotella intermedia - >24% of isolates. Anaerobic so can treat with oxidizing agents.
IV. Bacterial Diseases of the Lower Digestive System

- A gastrointestinal infection is caused by the growth of a pathogen in the intestines.
  - Incubation times, the times required for bacterial cells to grow and their products to produce symptoms, range from 12 hours to 2 weeks. Symptoms of infection generally include a fever.
  - A bacterial intoxication results from the ingestion of preformed bacterial toxins.
  - Symptoms appear 1-48 hours after ingestion of the toxin. Fever is not usually a symptom of intoxication.

- Infections and intoxications cause diarrhea, dysentery, or gastroenteritis. 6-80 million US cases/yr. 9000 deaths/yr.
  - Dysentery is severe diarrhea accompanied by blood or mucus.
  - Gastroenteritis is inflammation of the stomach and intestinal mucosa; Symptoms are nausea, cramps and vomiting.

- These conditions are usually treated with fluid and electrolyte replacement. Oral rehydration therapy (ORT) using NaCl, KCl, glucose, and NaHCO₃ has halved the mortality of childhood diarrhea. 1 in 4 children dies before age 5 in developing countries.
IV. Bacterial Diseases of the Lower Digestive System

• A. Staphylococcal Food Poisoning – *Staphylococcus aureus*
  – Staphylococcal food poisoning is caused by the ingestion of an enterotoxin produced in improperly stored foods.
  – *S. aureus* is inoculated into foods during preparation. The bacteria grow and produce enterotoxin in food stored at room temperature.
  – Contaminated by Staph on fingers, nares, or skin lesions. Then foods need incubation time for toxin to form.
  – The exotoxin is not denatured by boiling for 30 minutes.
  – Foods with high osmotic pressure and those not cooked immediately before consumption are most often the source of staphylococcal enterotoxicosis.
  – *Custards, cream pies, ham. Due to sugar or curing agents. Suppress non-Staph contamination.*
  – Diagnosis is based on symptoms. Nausea, vomiting, and diarrhea begin 1-6 hours after eating and last about 24 hours.
  – Laboratory identification of *S. aureus* isolated from foods is used to trace the source of contamination.
  – Staph aureus are cat+, coag+ yellowish colonies, ferment mannitol, produce β - hemolysis. Cause no obvious food spoilage.
The sequence of events in a typical outbreak of staphylococcal food poisoning.
IV. Bacterial Diseases of the Lower Digestive System

• B. **Shigellosis (Bacillary Dysentery)**
  – Shigellosis is caused by four species of *Shigella*. Shigella is resistant to stomach acid, then multiplies in small and large intestine.
  – *S. sonnei, dysenteriae, flexneri, & boydii*. *S. sonnei* is most common. US 30k/yr.
  – Symptoms include blood and mucus in stools, abdominal cramps, and fever.
  – Infections by *S. dysenteriae* result in severe diarrhea with ulceration of the intestinal mucosa due to Shiga toxin. Not as common in US and causes a much more serious disease.
  – Isolation and identification of the bacteria from rectal swabs are used for diagnosis.
Invasion of intestinal wall by Shigella bacterium. Bacteria multiply and spread to neighboring cells producing Shiga toxin that destroys tissue. Dysentery is the result.
Shigellosis. This shows the sequence of infection of the intestinal wall. As the bacteria moves inside of host cells, the immune system is avoided.
Direct fecal smear gram-stained to show the presence of white blood cells, indicative of an invasive process and not an enterotoxin.
IV. Bacterial Diseases of the Lower Digestive System

C. Salmonellosis (Salmonella Gastroenteritis) – *Salmonella* sp.
   - Salmonellosis, or *Salmonella* gastroenteritis, is caused by many *Salmonella* species. There are >2000 serovars.
   - Symptoms include nausea, abdominal pain, and diarrhea and begin 12-36 hours after eating large numbers of *Salmonella*. Septicemia can occur in infants and in the elderly. Treat with ORT.
   - Common sources are chicken and eggs.
   - Fever might be caused by endotoxin.
   - Mortality is lower than 1%, and recovery can result in a carrier state. Estimated 2-4 million cases/yr.
   - Heating food to 68°C will usually kill *Salmonella*.
   - Laboratory diagnosis is based on isolation and identification of *Salmonella* from feces and foods.
Salmonellosis. This sequence shows the infection of the intestinal wall. Note the invasion of the blood stream which may happen. This can result in septic shock.
IV. Bacterial Diseases of the Lower Digestive System

D. Typhoid Fever - *Salmonella typhi*

- *Salmonella typhi* causes typhoid fever. The bacteria are transmitted by contact with human feces (not an animal pathogen).
- Typhoid Mary (Mallon) classic chronic carrier (gallbladder). 1-3% cases.
- Fever and malaise occur after a 2-week incubation period. Symptoms last 2-3 weeks. Few cases in US but 16 million worldwide with 600K deaths.
- Diarrhea appears late (2-3 weeks).
- Bacteria multiplies in phagocytes and is disseminated to multiple organs.
- Vaccines are available for high-risk people. Antibiotic therapy useful.
The incidence of salmonellosis and typhoid fever. Typhoid fever is transmitted human to human and salmonellosis generally from animal products to humans.
IV. Bacterial Diseases of the Lower Digestive System

E. Cholera - *Vibrio cholerae*

- *Vibrio cholerae* produces an exotoxin that alters the membrane permeability of the intestinal mucosa.
  - The resulting vomiting and diarrhea cause a loss of body fluids.
  - Treatment with ORT and maybe tetracycline is life saving.
- Organism is a curved gnr with a single polar flagellum. Lives in salty estuaries.
- The incubation period is approximately 3 days. The symptoms last for a few days. Untreated cholera has a 50% mortality rate.
- Diagnosis is based on the isolation of *Vibrio* from feces.
- *Vibrio cholerae* non-O:1 causes gastroenteritis in the United States. It is usually transmitted via contaminated seafood.
- The serogroup 0:1, biotype of V. cholera causes the epidemic form. Cholera non 0:1 causes a similar disease that does not have the epidemic characteristics of cholera. Are mostly invasive and cause blood stools and fever.
36 BC –
Gram stained morphology of Vibrio with many comma shaped bacilli. The smear was counterstained with carbol fuchsin.
*Vibrio cholerae*. Notice the slightly curved rods.
Diagrammatic representation of the structure and action of cholera toxin. The final effect is hypersecretion of chloride and bicarbonate followed by water, resulting in the characteristic isotonic voluminous cholera stool. In hospitalized patients, this can result in losses of 20 L or more of fluid per day.
The extent and progress of cholera epidemic in Latin America, 1991-1994. The result was over 1 million cases and 9600 deaths. Outbreak was traced to contaminated ballast water from a freighter ship from Asia that arrived in Peru.
IV. Bacterial Diseases of the Lower Digestive System

F. Vibrio Gastroenteritis - *V. parahaemolyticus* and *V. vulnificus*.

- Vibrio gastroenteritis can be caused by *V. parahaemolyticus* and *V. vulnificus*.
- Parahaemolyticus = shrimp and crab. The onset of symptoms begins within 24 hours after eating contaminated foods. Recovery occurs within a few days.
- Vulnificus = raw oysters. *Can cause life threatening invasion of bloodstream or skin lesions*
- The disease is contracted by eating contaminated crustaceans or contaminated mollusks, especially immunocompromised and liver diseased persons at high risk.
IV. Bacterial Diseases of the Lower Digestive System

G. *Escherichia coli* Gastroenteritis

- *E. coli* gastroenteritis may be caused by enterotoxigenic, enteroinvasive, or enterohemorrhagic strains of *E. coli*.
- The disease occurs as epidemic diarrhea in nurseries, as traveler’s diarrhea, as endemic diarrhea in less developed countries, and as hemorrhagic colitis.
- Sources of infection include meats, petting zoo/farm visits, produce. "Boil it, peel it, or don't eat it" when traveling in suspect areas.
- In adults, the disease is usually self-limiting and does not require chemotherapy.
- Enterohemorrhagic *E. coli*, such as *E. coli* O157:H7, produces Shiga-like toxins that cause inflammation and bleeding of the colon. Shigella and *E. coli* are very closely related.
- Shiga-like toxins can affect the kidneys to cause hemolytic uremic syndrome.
Enterohemorrhagic E. coli (EHEC) O157:H7. Bacteria adhere to epithelial cell and form a pedestal-like projection. The surface microvilli are destroyed.
IV. Bacterial Diseases of the Lower Digestive System

H. *Campylobacter jejuni* Gastroenteritis

- *Campylobacter* is the second most common cause of diarrhea in the US.
- Organism is microaerophilic. Need low O$_2$ and high CO$_2$ and 42°C incubation.
- Gram negative curved rods that are part of intestinal normal flora of animals such as chicken (100%) and cattle (60%, milk too).
- Thought Campy is linked to Guillain-Barre’s syndrome, an autoimmune rxn to nerve myelin.
Gram stain of *Campylobacter* with dilute counterstaining of carbol fuchsins. Various characteristic arrangements can be seen including ‘gullwing’, ‘S’, and spiral shaped. It is found in milk and water born infection and is transmitted from infected animals (cattle, dogs, and poultry) which are reservoirs of infection.
IV. Bacterial Diseases of the Lower Digestive System

• I. *Helicobacter* Peptic Ulcer Disease
  – *Helicobacter pylori* produces ammonia, which neutralizes stomach acid; the bacteria colonize the stomach mucosa and cause peptic ulcer disease.
    • Has an enzyme called urease, so can use to detect in clinical examination to indicate infection or antigen detection.
  – Bismuth, combination antibiotics, and acid suppressors may be useful in treating peptic ulcer disease.
Helicobacter pylori infection, leading to ulceration of the stomach wall. Note the use of ammonia by the bacterium to protect itself from stomach acid.
IV. Bacterial Diseases of the Lower Digestive System

• J. *Clostridium perfringens* Gastroenteritis
  – A self-limiting gastroenteritis is caused by *C. perfringens* an anaerobic gpr with endospores. Found in animal GI tracts.
  – *Actually are common but unrecognized. Same organism that causes gas gangrene.*
  – Endospores survive heating and germinate when foods (usually meats) are stored at room temperature.
  – Exotoxin produced when the bacteria grow in the intestines is responsible for the symptoms. (8-12 hours post ingestion).
  – Diagnosis is based on isolation and identification of the bacteria in stool samples.

• K. *Bacillus cereus* Gastroenteritis
  – Ingesting food contaminated with the soil saprophyte *Bacillus cereus* (GPR with endospores) can result in diarrhea, nausea, and vomiting.
  – *Associated with “Rice” and Oriental Buffet table servings. Cooking activates endospores.*
  – 2 toxins:
    • 1. 8-16 hrs diarrhea
    • 2. 2-5 hrs vomiting
    • Toxins resemble Staph enterotoxin.
V. Viral Diseases of the Digestive System

A. Mumps - Mumps virus Family: Paramyxoviridae Genus: Rubulavirus

- Mumps virus enters and exits the body through the respiratory tract.
- About 16-18 days after exposure, the virus causes inflammation of the parotid glands, fever, and pain during swallowing. About 4-7 days later, orchitis may occur (in males past puberty).
- After onset of the symptoms, the virus is found in the blood, saliva, and urine.
- A measles, mumps, rubella (MMR) attenuated live vaccine is available.
- Diagnosis is based on symptoms, serology, or an ELISA test is performed on viruses cultured in embryonated eggs or cell culture.
This patient shows the typical swelling of mumps.
26 BC
Child with mumps and swollen parotid glands
Mumps virus, electron micrograph
V. Viral Diseases of the Digestive System

• B. Hepatitis
  – Inflammation of the liver is called hepatitis. Symptoms include loss of appetite, malaise, fever, and jaundice.
  – Viral causes of hepatitis include hepatitis viruses, Epstein-Barr (EB) virus, and CMV.

    • *Hepatitis A virus (HAV) causes hepatitis A; at least 50% of all cases are subclinical.*
    • *HAV is ingested in contaminated food or water, grows in the cells of the intestinal mucosa, and spreads to the liver, kidneys, and spleen in the blood.*
    • *The virus is eliminated with feces and urine. Jaundice and dark urine may occur. Often spread by food handlers, mollusks from contaminated waters.*
    • *The incubation period is 2- 6 weeks; the period of disease is 2- 21 days, and recovery is complete in 4- 6 weeks.*
    • *Diagnosis is based on tests for IgM antibodies.*
    • *Passive immunization can provide temporary protection. A vaccine is available.*
V. Viral Diseases of the Digestive System

• B. Hepatitis
  – 2. Hepatitis B  dsDNA  enveloped  Family:  *Hepadnaviridae*  Genus:  *Orthohepadnavirus*
    • *Hepatitis B virus (HBV)* causes *hepatitis B*, which is frequently serious.
    • *HBV* is transmitted by blood transfusions, contaminated syringes, saliva, sweat, breast milk, and semen.
    • *Blood is tested for HBsAg before being used in transfusions.*
    • *The average incubation period is 3 months; recovery is usually complete, but some patients develop a chronic infection or become carriers.*
    • *A vaccine against HBsAg is available.*
  – 3. Hepatitis C  ssRNA  enveloped  Family:  *Flaviviridae*  Genus:  *Hepadnavirus*
    • *Hepatitis C virus (HCV)* is transmitted via blood. Needle sharing, sexual contact.
    • *The incubation period is 2-22 weeks; the disease is usually mild, but some patients develop chronic hepatitis. Liver damage can be slow and severe.*
    • *Blood is tested for HCV antibodies before being used in transfusions.*
    • *Can be treated with alpha interferon and ribavirin.*
Hepatitis B virus (HBV), showing variation in particle types that may appear.
Healthy liver
Liver damaged by hepatitis C
Illustrations of hepatitis A virus (HAV), B, Hepatitis B virus (HBV). C, Hepatitis C virus (HCV). D, Hepatitis D, or delta hepatitis, virus (HDV).
V. Viral Diseases of the Digestive System

• B. Hepatitis
  – 4. Hepatitis D (Delta Hepatitis) ssRNA Genus: Deltavirus
    • Hepatitis D virus (HDV) must use HBsAg as a coat, so coinfection is the rule.
  – 5. Hepatitis E ssRNA noneveloped
    • Hepatitis E virus (HEV) is spread by the fecal-oral route, with high mortality in pregnant women. Not common in US.
  – 6. Other Types of Hepatitis
    • There is evidence of the existence of hepatitis types F and G.
V. Viral Diseases of the Digestive System

• C. Viral Gastroenteritis - Rotavirus or the Norwalk agent (noroviruses).
• Viral gastroenteritis is most often (90%) caused by a rotavirus or the Norwalk agent.
  – 1. Rotavirus most common cause of gastroenteritis, about 3 million US cases/yr. 90% of children infected by age 3.
    • Incubation 2-3 days then low grade fever and gastroenteritis for a week or so.
  – 2. Norwalk-like viruses (noroviruses) of the family Calciviruses (ssRNA) cause gastroenteritis in major local epidemics.
    • 1-2 days incubation then gastroenteritis for 2-3 days. 50% of adults infected. Shed in stools for 10-14 days post recovery.
    • Infectious dose is small and virus is environmentally hardy. Easily spread in schools, day care, cruise ships. > 20 million cases per year in US.
Electronmicrograph showing rotaviruses. This virus is responsible for a large majority of all cases of infantile gastroenteritis, manifest clinically by diarrhea and dehydration. The virus particle has a diameter of about 60-65 nm and has the appearance of radial spokes projecting from a central core of double-stranded DNA.
VI. Fungal Diseases of the Digestive System

• None discussed.
VII. Protozoan Diseases of the Digestive System

• A. Giardiasis
  – *Giardia lamblia* grows in the intestines of humans and wild animals and is transmitted by cysts in contaminated water.
  – Symptoms of giardiasis are malaise, nausea, flatulence, weakness, and abdominal cramps that persist for weeks.
  – The general population has many carriers who may excrete the cyst stage that is relatively resistant to the chlorine used to disinfect drinking water, so use filtration. Infections common in US.
  – Diagnosis is based on identification of the protozoa in the small intestine.
  – Treated with metronidazole and quinacrine hydrochloride.
The trophozoite of *Giardia lamblia* that causes giardiasis.
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*Giardia lamblia* trophozoite (trichrome stain)
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*Giardia lamblia* cyst (trichrome stain)
VII. Protozoan Diseases of the Digestive System

• B. Cryptosporidiosis - Cryptosporidium parvum
  – Cryptosporidium parvum causes diarrhea (10-14 days duration); in immuno-suppressed patients, the disease is prolonged for months.
  – The pathogen is transmitted by oocysts in contaminated water (animal wastes, esp. cattle). Remove by filtration.
  – Diagnosis is based on the identification of oocysts in feces.
Cryptosporidiosis. Oocysts of *Cryptosporidium hominis* shown embedded in gut mucosa.
*Cryptosporidium* - Modified Kinyoun acid-fast under oil immersion. Oocysts (acid-fast) stain red.
VII. Protozoan Diseases of the Digestive System

• C. Cyclospora Diarrheal Infection - *Cyclospora cayetanensis*
  – *C. cayetanensis* causes diarrhea; the protozoan was first identified in 1993.
  – It is transmitted by oocysts in contaminated produce (berries and other uncooked foods) and water. Remove by filtration. Cannot effectively wash off contaminated fruits/vegetables.
  – Diagnosis is based on the identification of oocysts in feces.

Oocysts from feces
VII. Protozoan Diseases of the Digestive System

D. Amoebic Dysentery (Amoebiasis) - *Entamoeba histolytica*

- Amoebic dysentery is caused by *Entamoeba histolytica* growing in the large intestine. Cysts found in contaminated food and water.
- The amoeba feeds on red blood cells and GI tract tissues. Severe infections result in abscesses and may extend to the liver.
- Diagnosis is confirmed by observing trophozoites in feces and by several serological tests. 1 in 10 people infected worldwide.
- Also treated with metranidazole and iodoquinol
Entamoeba histolytica trophozoites (trichrome stain)
Section of intestinal wall showing a typical flask-shaped ulcer caused by *Entamoeba histolytica*.
Amoebic colitis. More severe cases show the textbook lesions: deep ulcers with overlying purulent exudate.
VIII. Helminthic Diseases of the Digestive System

• A. Tapeworm Infestations - *Taenia solium*, *Taenia saginata*
  – Tapeworms are contracted by the consumption of undercooked beef, pork, or fish containing encysted larvae (*cysticerci*).
  – Tapeworms are:
    • *T. solium* – pork
    • *T. saginata* – beef
    • *Diphyllobothrium latum* – fish (*sashimi, sushi*)
  – *Adult may be up to 6-7 m. long.*
  – The scolex attaches to the intestinal mucosa of humans (the definitive host) and matures into an adult tapeworm.
  – Eggs are shed in the feces and must be ingested by an intermediate host.
  – *T. solium* can produce larval stages in human host. (called cysticercosis). Get after ingesting eggs. Neurocysticercosis in humans occurs when the pork tapeworm larvae encyst in humans.
  – Diagnosis is based on the observation of proglottids and eggs in feces.
Adult *Taenia saginata* worm
11 BC
*Taenia solium* proglottids. Note the extensive uterine structure.
12 BC

*Taenia solium* scolex ‘armed’ with hooks.
13 - BC

*Taenia solium* cysticerci in pork ("measly pork")
Taeniasis - Egg of either *T. solium* or *T. saginata* in feces containing hexacanth larva.
Taeniasis – Note the extensive number of cysticerci visible just under the skin.
Radiograph of leg showing characteristic elongated calcified cysts of *T. solium*. At this site they produce no symptoms. When they occur in the brain they result in seizures or evidence of intracranial mass lesions.
Ophthalmic cysticercosis, showing a cysticerci inside the eye.
VIII. Helminthic Diseases of the Digestive System

• B. Hydatid Disease - *Echinococcus granulosus*
  
  – Humans infested with the eggs of tapeworm *Echinococcus granulosus* might have hydatid cysts in their liver, lungs, or other organs. Intermediate host condition.

  – Only a few mm in length at first but can grow to immense sizes (15 liters).

  – Hydatid cysts are damaging because of large size and if they rupture can cause anaphylactic shock. Treat by surgery or drugs.

  – Dogs and wolves are usually the definitive hosts, and sheep or deer are the intermediate hosts for *E. granulosus*. Humans are an accidental host.
Hydatid disease. Man can be an accidental host for the dog tapeworm, Echinococcus granulosus, of which the usual intermediate host is sheep or cattle. Hydatid cysts are found most commonly in the liver but can also occur in the lung, brain, bones, peritoneum and in other organs. These radiographs show well defined rounded cysts in the right lower lobe.
Echinococcus cysts are most commonly found in the liver and lung. Rupture of a cyst through the capsule of the liver into the peritoneal cavity results in formation of daughter cysts throughout the peritoneum and omentum, as shown in this surgical specimen.
Echinococcis. New larvae (scolices) develop in large numbers from the germinal layer of brood capsules within the walls of a cyst. Note both invaginated and evaginated hooklets and suckers.
A hydatid cyst formed by *Echinococcus granulosus* as seen on X ray of the cranium.
VIII. Helminthic Diseases of the Digestive System

• **C. Nematode Infestations**
  - 1. Pinworm Infestation - *Enterobius vermicularis*.
    - *Humans are the definitive host for pinworms, Enterobius vermicularis.*
    - *The disease is acquired by ingesting Enterobius eggs.*
    - *The tiny worms migrate out the anus of the human host and lay eggs. 8-13 mm long. Causes itching. Whole households my become infected.*
    - *Treated with pyrantel pamoate or mebendazole.*
Life cycle of *Enterobius vermicularis*. 
Enterobius vermicularis egg - (pinworm or threadworm infection). This infection usually causes perianal itching, which may interfere with sleep. Diagnosis is made by finding the worm on the perianal region by flashlight at night, or more easily by pressing a strip of adhesive tape or a pinworm paddle against the perianal region early in the morning and visualizing the characteristic eggs.
C. Nematode Infestations

2. Hookworm Infestation - *Necator americanus*

- Hookworm larvae found in soil bore through skin and migrate to the intestine to mature into adults. In the soil, hookworm larvae hatch from eggs shed in feces. Wear shoes in endemic (SE US) areas!
- Feed on blood and tissue in the GI tract.
- Symptoms: Get large #’s of worms and lot of blood loss (anemia) and lethargy. ↓ Hgb. Pica – Cravings for starch or clay.
Life cycle of hookworm.
Hookworm egg - Diagnosis is made by finding the eggs in the feces. In freshly passed stool the eggs are seen non-embryonated, but if the specimen has been at room temperature for several hours, as in this case, embryos of various stages may be seen within the eggs.
An *Ancylostoma* hookworm attached to intestinal mucosa where it feeds on tissue juice.
Hookworm rhabditiform larva. These emerge from the egg in stool.
Adult Hookworm in intestine
VIII. Helminthic Diseases of the Digestive System

• C. Nematode Infestations
  – 3. Ascariasis - *Ascaris lumbricoides*
    • *The disease is acquired by ingesting Ascaris eggs.* *Ascaris lumbricoides adults live in human intestines.*
    • *Adults can be up to one foot in length. Live on partially digested food.*
    • Hatch into wormlike larvae that pass from GI tract to blood to lungs. In lungs migrate to throat, swallowed and develop into adult worm in intestine. May migrate from nostril or be coughed up in pneumonia stage.
    • *Effectively treated with mebendazole.*
Life cycle of *Ascaris lumbricoides*. 
Ascaris lumbricoides adult worms: smaller one male, larger female.
Ascaris lumbricoides egg, fertile.
Ascariasis - The large adult worms, which may reach a foot long in length, live in the lumen of the small intestine. In this barium study the intestinal tract of one of the adult worms is also well outlined with the barium which it has ingested. Most infections are asymptomatic but heavy infection can be associated with malabsorption and malnutrition, or obstruction of the intestine or biliary tract.
VIII. Helminthic Diseases of the Digestive System

C. Nematode Infestations
   - 4. Trichinosis - *Trichinella spiralis*
      - *Trichinella spiralis* larvae encysts in muscles of humans and other mammals to cause trichinosis.
      - The roundworm is contracted by ingesting undercooked meat containing larvae.
      - Freezing kills most larvae in meat but only cooking is reliable.
      - Adults mature in the intestine and lay eggs; the new larvae migrate to invade muscles of the host (human), commonly diaphragm and eye muscle.
      - Symptoms include fever, swelling around the eyes, and gastrointestinal upset as the larvae become encysted in various muscles.
      - Biopsy specimens and serological tests are used for diagnosis.
      - No egg stage when larvae are laid.
      - See increased eosinophils and leukocytosis.
Life cycle of *Trichinella spiralis*.

1. *Trichinella spiralis* adults develop, invade intestinal wall of pig, and produce larvae that invade muscles.

2. Section showing *T. spiralis* larvae encysted in pig’s muscle tissue.

3. Human eats undercooked pork containing cysts.

4. In human intestine, cyst walls are removed, and *T. spiralis* adults develop. Adults produce larvae that encyst in muscles.

5. Meanwhile, other animals are infected by eating infected meat that has been dumped.

(a) Life cycle of *Trichinella spiralis*, the causative agent of trichinellosis.

(b) *T. spiralis* adult.
Muscle tissue, directly viewed. Encysted calcified larvae. Morphology consistent with *Trichinella spiralis*. Impression: Trichinosis.
Trichinella spiralis larva, biopsy.
Trichinosis. This disease is characterized by fever, muscle pain, periorbital edema and eosinophilia. Occasionally severe conjunctivitis with conjunctival hemorrhages and splinter hemorrhages in the nail bed are seen.
Worldwide prevalence of human infections with selected intestinal helminths.