Lecture 3: Emerging Parasitic Helminths part 1: Cestodes (Tapeworms)
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Readings-Cestodes
• Ch. 11 (pp. 293-295, 295 [box 11.1], 304 [box 11.2])

Monsters Inside Me
• Just for fun, check out these links:
  • Cysticercosis (Taenia solium, pork tapeworm):
    Background: http://animal.discovery.com/invertebrates/monsters-inside-me/pork-tapeworm-cysticercosis/

Learning Objectives
• Know life cycles, diagnostic criteria, epidemiology, pathogenicity, & treatment
• Know basic attributes of tapeworms and be able to correctly identify the parasites we discuss as cestodes (as compared to other parasites we discuss).
• Know what tapeworms are pseudophyllidean vs. cyclophyllidean
• Understand life cycles of cestodes, noting similarities and significant differences
• Know prevention strategies
• Understand how serious pathological conditions are caused by tapeworms
• For each tapeworm, what could make it an emerging problem in the world

On the Menu
• Diphyllobothrium latum
• Taenia spp.
• Echinococcus spp.

Cestodes (Tapeworms)
• Adult cestodes have been found in virtually every species of vertebrate animal
• Perhaps the most specialized of all parasites
• Two orders encompass cestodes infecting humans: Pseudophyllidae and Cyclophyllidae
  • The life cycles of pseudophyllideans usually involve a crustacean as a first intermediate host and fish as second intermediate hosts
• Unique structure of adults
Tapeworm Terms

- Scolex-knoblike anterior (head) end that has suckers or hooklike parts that in the adult stage serve as organs of attachment to the host
- Procercoid-first stage in the aquatic life cycle of certain tapeworms, such as the pseudophyllideans, following ingestion of the newly hatched larva (coracidium) by a copepod.
- Proceroid-when the procercoid and its host are ingested by a fish, the procercoid enters the new host’s tissues and becomes a plerocercoid
- Oncosphere-larva contained within the external embryonic envelope within the egg and armed with six hooks, undergoes metamorphosis after penetrating into a tissue site in the intermediate host.
- Cysticercus-larval stage of many tapeworms, consisting of a single invaginated scolex enclosed in a fluid-filled cyst.
- Proglottid-part of tapeworm “body” containing a set of reproductive organs.

**Diphyllobothrium latum**

- Pseudophyllidean
- Broadfish tapeworm
- Typically the largest human tapeworm
- Diphyllobothriasis can be a long-lasting infection
- Worldwide infections estimated at 20 million (1999)
- Life cycle requires two intermediate hosts
- Freshwater fish become infected with *Diphyllobothrium* sp.
- Humans, bears are definitive hosts
- Occurs in the Northern Hemisphere (Europe, newly independent states of the former Soviet Union, North America, Asia), Uganda and Chile.

**Re-emerging Diphyllobothrium?**

- Switzerland, northern Italy, eastern France
- Many regional cuisines include raw or undercooked food
  - Sushi and sashimi in Japanese cuisine
  - Carrpaccio di persico in Italian
  - Tartare maison in French-speaking populations
  - Fefilte fish in Jewish populations
  - Ceviche in Latin American cuisine

**D. latum life cycle**

**New cases in Brazil**

- By comparison, 18 cases were diagnosed from March 2004 to January 2005.
  - All patients who became infected ate raw fish in sushi or sashimi.
- New host?
  - *C. undecimalis* has not been reported as a *D. latum* host, but it is a saltwater fish that spends part of its life in fresh water.

**Table 2D: Cestodes of medical importance and their prevalence**

<table>
<thead>
<tr>
<th>Order</th>
<th>Family</th>
<th>Genus and species</th>
<th>Estimated cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pseudophyllidea</td>
<td>Diphyllobothriidae</td>
<td>Diphyllobothrium latum</td>
<td>16 million</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diphyllobothrium pacificum</td>
<td>1 hundreds</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diphyllobothrium steriles</td>
<td>1 hundreds</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Ancylostoma</em> sp.</td>
<td>Rare</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Sangiamum</em> spp.</td>
<td>Rare</td>
</tr>
<tr>
<td>Cyclophyllidea</td>
<td>Anoplocephalidae</td>
<td><em>Parascaris</em> equorum</td>
<td>Rare</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Ancylostoma</em> sp.</td>
<td>Rare</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Hymenolepis</em> diminuta</td>
<td>Rare</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Davilla</em> rasgo</td>
<td>7 million</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Davilla</em> rubio</td>
<td>Rare</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Infesante</em> equorum</td>
<td>Rare</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Microcestus</em> muris</td>
<td>Thousands</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Taenia</em> quadriceps</td>
<td>Rare</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Echinococcus</em> granulosus</td>
<td>Rare</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Echinococcus</em> multilocularis</td>
<td>Rare</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Echinococcus</em> alveolaris</td>
<td>Rare</td>
</tr>
</tbody>
</table>

See footnote to Table 2D. *The species *Hymenolepis* equorum was formerly known as *Hymenolepis diminuta*.*
Clinical Features, etc

- Most infections are asymptomatic. Manifestations may include abdominal discomfort, diarrhea, vomiting, and weight loss.
- Chemical competition: Vitamin B-12 deficiency with pernicious anemia may occur.
- Massive infections may result in intestinal obstruction.
- Migration of proglottids can cause cholecystitis or cholangitis.
- Treatment: Praziquantel, Niclosamide

Prevention

- Proper sanitation
- Effective treatment
- Fish should be well cooked or deep-frozen
  - Deep-frozen fish and storage (-20°C for 7 days or -35°C until solid, storing at -35°C for 15hrs)
  - Cooking fish at a temperature of 55°C kills plerocercoid larvae in 5 min
- Placing fish in a concentration of brine (12% NaCl)
- Fish inspection

Other important Diphyllobothrium spp.

- *D. nihonkaiense*
  - Japanese broad tapeworm
  - 1986- found to be distinct from *D. latum*
  - Wild Pacific salmon as second intermediate host
  - Cases in Europe emerging
  - In Japan over last 20 years, average of less than 0.5 cases/100,000 people, but increased to 1 case/100,000 in 2008
- Other species linked to Pacific salmon: *D. klebanovskii* (Russia), *D. ursi* (North America)
- 1980 outbreak in the Pacific U.S. of diphyllobothriasis linked to salmon

Taenia spp.

- 1977: 3200 yr old mummy found with *Taenia* egg
- Ancient greeks documented tapeworms
- Worldwide distribution—estimated 50 million affected
- *T. saginata*: beef tapeworm
- *T. solium*: pork tapeworm
- *T. saginata* has higher global prevalence
- *T. solium* is more prevalent in poorer communities where humans live in close contact with pigs
- Humans are the only definitive hosts for *T. saginata* and *T. solium*.

Taenia sp. life cycle

- The majority of *T. saginata* and *T. solium* carriers are unaware of their infection.
- Gastrointestinal symptoms are due to the presence of the tape worm.
- Carriers of *T. solium* carry a substantial risk of acquiring *cysticercosis* by fecal-oral autoinfection and members of their households are also at increased risk

Clinical features
Prevention, Tx, Dx

- Prevention is based on strict meat inspection, health education, cooking pork and beef well, hygiene, and widespread sanitary installations.
- Prevention of fecal contamination of soil, water, food, humans/animals through safe disposal of sewage; avoidance of sewage water for irrigation use.
- Cysterci killed by irradiation or cooking meat at 56°C, freezing at -5°C for 1 week.
- Treatment: Praziquantel.
- Dx: ID of eggs and proglottids in feces, but not possible 3 months following infection, prior to development of adult tapeworms.

Cysticercosis

- Caused by ingestion of T. solium eggs, through fecal-oral transmission or possibly through autoinfection.
- Humans are dead-end hosts of the larval stage and develop cysticercosis similar to pigs.
- Many parts of body are affected, most commonly subcutaneous tissues, eyes, brain.
- 50,000 cases of neurocysticercosis reported each year globally.
- More than 1,000 new cases of neurocysticercosis diagnosed in the U.S. each year.
- A total of 221 cysticercosis deaths were identified in U.S. from 1990-2002.
- Neurocysticercosis: most common parasitic disease of CNS.

Disease Features

- Neurocysticercosis causes diverse manifestations including seizures, mental disturbances, focal neurologic deficits, and signs of intracerebral lesions.
- Severe inflammatory responses to dying cysterci can cause sudden death.
- Extracerebral cysticercosis can cause ocular, cardiac, or spinal lesions with associated symptoms.
- Asymptomatic subcutaneous nodules and calcified intramuscular nodules can be encountered.

Worldwide prevalence of neurocysticercosis

**not acquired by eating infected pork, but by eating eggs**

*Measly pork*
**Echinococcus spp. background**

- Hydatid disease
- Recognized by Hippocrates in 400 BC
- Major species infecting humans
  - *E. granulosus*
  - *E. multilocularis*
- Dogs and wild canids are the definitive host for *Echinococcus* tapeworms, but zoonotic potential is important
  - Humans serve as aberrant intermediate hosts, developing potentially aggressive and damaging tissue cysts
- Unlike most parasitic diseases, echinococcosis is more prevalent in the northern hemisphere.

**Echinococcus granulosus**

- Causes cystic echinococcosis most frequent
- Occurs globally, but more frequently in rural, grazing areas where dogs ingest organs from infected animals.
- Sylastic cycle where humans accidentally infected
  - More typically, humans infected where domestic herbivores raised near dogs
- Hydatid cysts
  - Slowly enlarging, mass lesions producing pain and physical obstruction/pressure on surrounding organs.
  - If the cyst ruptures, "daughter" cysts may be released that spread elsewhere in the body.
  - Most cysts develop in the liver or lungs.

**Echinococcus multilocularis**

- Causes alveolar echinococcosis
- Foxes and other wild canids are the definitive hosts and rodents (voles and deer mice) serve as normal intermediate hosts.
- Alveolar hydatids
  - Much more aggressive lesions than hydatid cysts
  - Fatality rates in infected humans approach 50%

**Global distribution of zoonotic strains of Echinococcus**

- *E. granulosus* occurs in the northern hemisphere, including central Europe and the northern parts of Europe, Asia, northern India, Iraq, Alaska, Canada

**Echinococcus life cycle**

**Table 1. Echinococcus species, strains, isolates, and genotypes**

<table>
<thead>
<tr>
<th>Species</th>
<th>Strains</th>
<th>Genotypes</th>
<th>Human</th>
<th>definitive</th>
<th>intermediate</th>
<th>Probable geographical distribution</th>
<th>Proposed treatment (diagnosis)*</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>E. granulosus</em></td>
<td>sheep</td>
<td>Yes</td>
<td>Dog</td>
<td>40%</td>
<td>60%</td>
<td>Western Europe, North America, Australia, Asia, Africa</td>
<td>E. granulosus</td>
</tr>
<tr>
<td></td>
<td>Tannisian</td>
<td>Yes</td>
<td>Dog</td>
<td>40%</td>
<td>60%</td>
<td>Europe, Asia, Africa, Australia</td>
<td>E. granulosus</td>
</tr>
<tr>
<td></td>
<td>Canine</td>
<td>Yes</td>
<td>Dog</td>
<td>40%</td>
<td>60%</td>
<td>Europe, Asia, Africa, Australia</td>
<td>E. granulosus</td>
</tr>
<tr>
<td></td>
<td>Cattle</td>
<td>Yes</td>
<td>Dog</td>
<td>40%</td>
<td>60%</td>
<td>Europe, Asia, Africa, Australia</td>
<td>E. granulosus</td>
</tr>
<tr>
<td></td>
<td>Pig</td>
<td>Yes</td>
<td>Dog</td>
<td>40%</td>
<td>60%</td>
<td>Europe, Asia, Africa, Australia</td>
<td>E. granulosus</td>
</tr>
<tr>
<td></td>
<td>Lion</td>
<td>Yes</td>
<td>Dog</td>
<td>40%</td>
<td>60%</td>
<td>Europe, Asia, Africa, Australia</td>
<td>E. granulosus</td>
</tr>
<tr>
<td><em>E. multilocularis</em></td>
<td>canine</td>
<td>Yes</td>
<td>Dog</td>
<td>40%</td>
<td>60%</td>
<td>Europe, Asia, Africa, Australia</td>
<td>E. multilocularis</td>
</tr>
<tr>
<td></td>
<td>European isolates</td>
<td>Yes</td>
<td>Dog</td>
<td>40%</td>
<td>60%</td>
<td>Europe, Asia, Africa, Australia</td>
<td>E. multilocularis</td>
</tr>
<tr>
<td></td>
<td>Asian isolates</td>
<td>Yes</td>
<td>Dog</td>
<td>40%</td>
<td>60%</td>
<td>Europe, Asia, Africa, Australia</td>
<td>E. multilocularis</td>
</tr>
<tr>
<td></td>
<td>North American isolates</td>
<td>Yes</td>
<td>Dog</td>
<td>40%</td>
<td>60%</td>
<td>Europe, Asia, Africa, Australia</td>
<td>E. multilocularis</td>
</tr>
<tr>
<td></td>
<td>South American isolates</td>
<td>Yes</td>
<td>Dog</td>
<td>40%</td>
<td>60%</td>
<td>Europe, Asia, Africa, Australia</td>
<td>E. multilocularis</td>
</tr>
<tr>
<td><em>E. vogeli</em></td>
<td>canine</td>
<td>Yes</td>
<td>Dog</td>
<td>40%</td>
<td>60%</td>
<td>Europe, Asia, Africa, Australia</td>
<td>E. vogeli</td>
</tr>
<tr>
<td></td>
<td>European isolates</td>
<td>Yes</td>
<td>Dog</td>
<td>40%</td>
<td>60%</td>
<td>Europe, Asia, Africa, Australia</td>
<td>E. vogeli</td>
</tr>
<tr>
<td></td>
<td>Asian isolates</td>
<td>Yes</td>
<td>Dog</td>
<td>40%</td>
<td>60%</td>
<td>Europe, Asia, Africa, Australia</td>
<td>E. vogeli</td>
</tr>
</tbody>
</table>

*Note: This table is based on current research information.*
Other species

- *E. oligarthrus* and *E. vogeli*: neotropical species localized exclusively in Central and South America
  - Only 3 cases of *E. oligarthrus* infection have been reported in the literature (1 from Brazil, 1 from Venezuela, and 1 from Surinam);
  - 168 *E. vogeli* cases have been reported in 12 countries in Central and South America
- There are periodic reports of these species infecting humans, but since the case fatality rate is often very high, it is important to discuss them (as we will see later).

Clinical Disease

- Location of cyst determines extent of pathological conditions associated with disease
- *E. granulosus* infections remain silent for years before the enlarging cysts cause symptoms in the affected organs.
- Hepatic involvement can result in abdominal pain, a mass in the hepatic area, and biliary duct obstruction.
- Rupture of the cysts can produce fever, eosinophilia, and anaphylactic shock, as well as cyst dissemination.
- *E. multilocularis* affects the liver as a slow growing, destructive tumor, with abdominal pain, biliary obstruction, and occasionally metastatic lesions into the lungs and brain.

Diagnosis

- X-rays, ultrasonography and/or other imaging techniques supported by positive serologic tests.
- A: Protoscoleces in a hydatid cyst removed from lung tissue
- F: *E. multilocularis* in liver tissue.

Treatment

**E. granulosus** (hydatid cyst)
- Surgery + Albendazole
- Praziquantel is useful preoperatively or in case of spillage of cyst contents during surgery.
- Percutaneous aspiration-injection-reaspiration (PAIR) with ultrasound guidance plus albendazole therapy has been effective for management of hepatic hydatid cyst disease

**E. multilocularis** (alveolar cyst)
- Surgical excision is the only reliable means of cure.
- Albendazole can stabilize and sometimes cure infection

Prevention

- Removal of dogs from areas where domesticated herbivores
- Deworming dogs
- Removal of infected entrails from abattoirs
- Precautions handling wild animals by hunters, trappers

Echinococcosis: scope of problem

- Multiple hosts that can spread the disease
- Importation of hosts
- Certain cultural practices deter prevention and control strategies, resistance to control mechanisms
- Diseases cause severe monetary losses due to disability and sickened livestock
  - Tunisia: significant direct and indirect losses in both humans and animals of between $10-19 million annually.
  - The reported incidence in humans is 1.5 to 2.05 cases per 100,000 inhabitants and between 12% and 17% of the cattle at slaughter is infected.
- The estimated global human burden of echinococcosis may be as high as 1,009,662 DALYs - or an annual loss of $7.8 million. A maximum annual livestock production loss of over 2 billion dollars is also estimated.

Source: WHO
2006 Case Study

- 72 yr old man from French Guiana - abdominal pain and a palpable epigastric mass. The patient hunted jaguars in the rain forest of French Guiana and owned dogs. An exploratory laparotomy showed a hard, whitish liver tumor. Histopathologic examination of a biopsied sample of the tumor showed multilocular cysts. Albendazole treatment was started immediately after surgery.
- Computer tomography showed a multilocular cystic mass in the left side of the liver
- Serological, hook morphology, and molecular confirmation of *E. vogeli*
- 1st *E. vogeli* case reported in French Guiana

- Problem: *E. vogeli* and *E. oligarthrus* have primarily sylvatic life cycles and the number of human cases might be underestimated because of the small number of patients who receive surgical treatment
- Significance: Healthcare providers need to be alert to the existence of neotropical echinococcosis and should consider the possibility of its emergence in Central and South America. Although rare, this disease is still lethal in untreated cases.