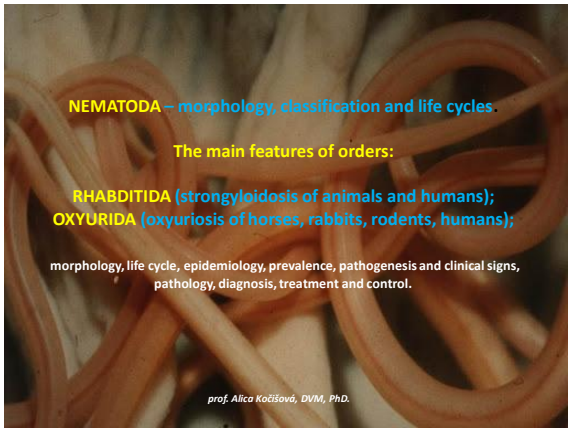
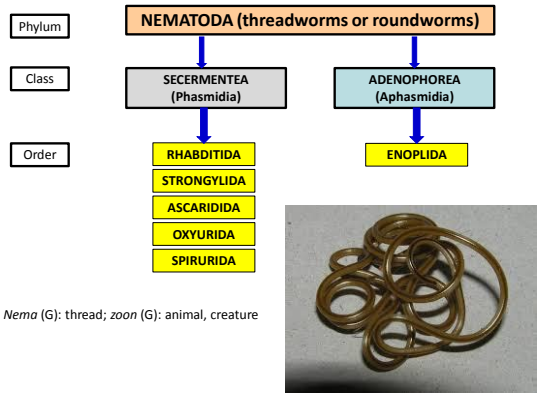




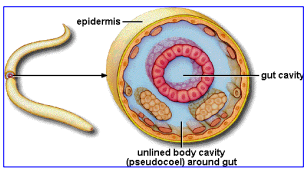
Nema (G): thread; *zoon* (G): animal, creature

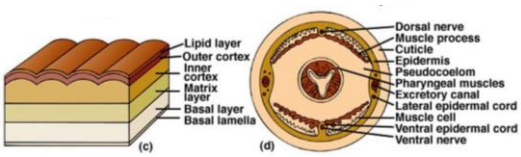
Nematodes

- Found everywhere
  - Soil
  - Oceans
  - Polar ice
  - Hot springs
- Parasites of nearly all plant and animal species!

Nematoda in general

- **Body** is elongate, cylindrical, tapering at both ends, from 1 mm to 1 m in size;
- Body surface is thin transparent **cuticle;**
- There is body cavity , filled with fluid conferring turgidity to the worm;
- There is a tubular **digestive tract** from the mouth and buccal cavity, through the oesophagus (pharynx) and intestine to the anus (in females) or cloaca, common with the male genital system;

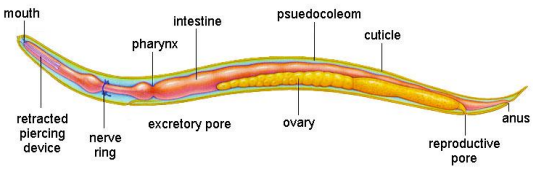


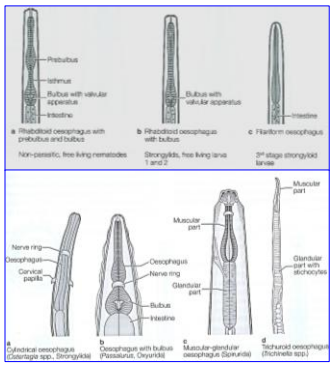


Integument and musculature

- Outer acellular cuticle
- Underlying cellular hypodermis (epidermis)
- Muscle cells

- **Cuticle** not only covers the body surface, but also sections of the digestive tract;
- **Cuticle** is a resilient, flexible, acellular complex structure;
- Epicuticle may be coverd by a **surface coat** (glycocalyx)
- LC includes 4 moultings, during which the cuticle detaches from the underlying hypodermis and is stripped off.



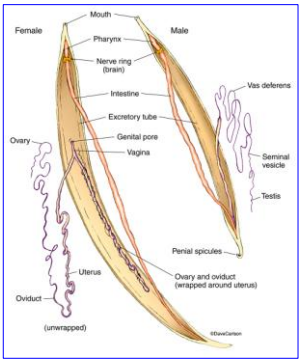


Digestive tract

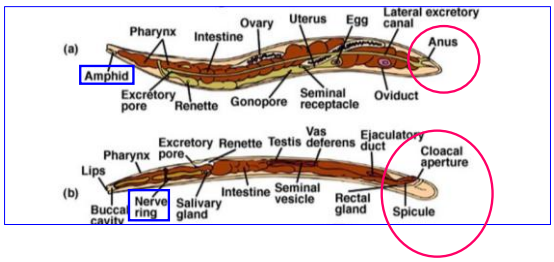
- Mouth opening (stoma) – cuticular lips (labia), protuberances, leaf crowns, sensory organs;
- Buccal cavity – dilated to a thick-walled buccal capsule, equipped with tooth / blade like structures;
- Oesophagus – oesophageal glands; bulb, isthmus, bulbus, muscular or glandular cells (stichocytes);
- Intestine – epitelial cells;
- Rectum
- Anus (male – cloaca)

Circulatory and respiratory organs are missing;

- They **feed on** intestinal debris, mucus, bacteria, cells of the intestinal mucosa, etc., some species are haematophagous;
- **Sexes are separate**; males are usually smaller in size and presence of accessory copulatory structures;
- **Life cycle**: direct or indirect;
- During development, a nematode **moulds** at intervals **shedding** its old cuticle (sheat);
- Usually there are **four moults** or ecdyses;
- Egg, L_1, L_2, L_3, L_4, and (L_5 – juvenile form) adult

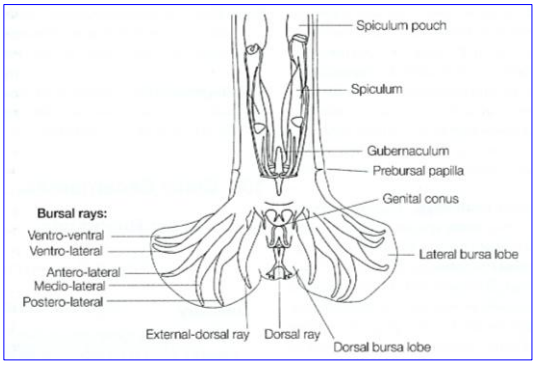


Internal Features of a Nematode



Sensory organs and nervous system

- Anterior and posterior end + genital area - amphids (near mouth); phasmids (paired at the posterior end); sensory papillae, sensory bristles;
- Nerve ring – peripheral nerves run forward and backward with branches to supply the organs;



Life cycle


ovipara


ovovivipara

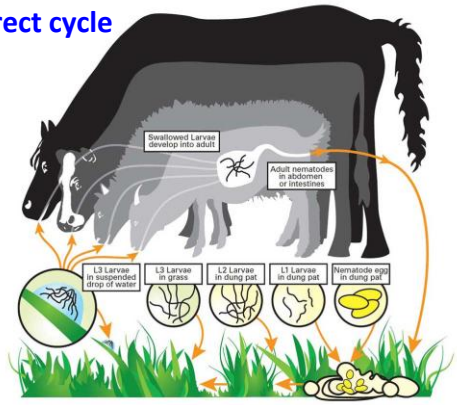

vivipara

Direct cycle

Egg, L_1, L_2, L_3, L_4, and (L_5 – juvenile form) adult

Indirect cycle L_1–L_3 in IH

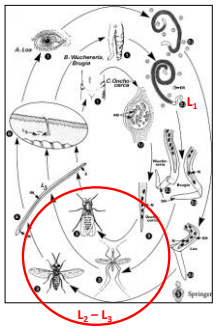
Direct cycle



Indirect cycle

$L_1 - L_2 - L_3 -$ Endogenous IH

$L_4 - L_5$ Endogenous FH



Pathways of infection

- Orally by eating an egg with an infectious larvae or infectious larvae;
- Infectious larvae actively penetrate the body surface (percutaneously);
- Via uterus;
- Lactogenically;
- Vector;

} **Hypobiotic larvae**

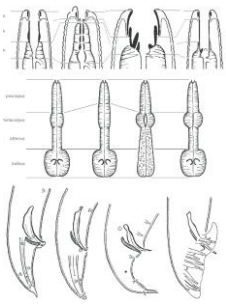
Phylum	**NEMATODA (threadworms or roundworms)**
Class	**SECERMENTEA (Phasmidia)** / **ADENOPHOREA (Aphasmidia)**
Order	**RHABDITIDA**, **STRONGYLIDA**, **ASCARIDIDA**, **OXYURIDA**, **SPIRURIDA** / **ENOPLIDA**

Class: SECERMENTEA (Phasmidia)

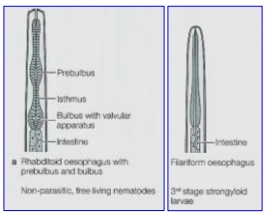
Order: **RHABDITIDA**

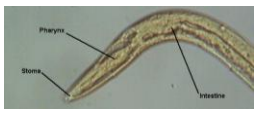
Family: Rhabditidae (*Rhabditis*; *Pelodera*; *Caenorhabditis*)
Cephalobidae (***Halicephalobus***, *Turbatrix*)
Strongyloididae (***Strongyloides***)

Order: RHABDITIDA



A: Stoma and its sections;
B: Pharynx and its sections;
C: Male caudal region.





Distribution: cosmopolitan, especially in tropical areas;

Genus: ***Strongyloides*** **(Strongyloidosis)**

- ***Strongyloides ransomi***, 4 - 6 mm, pigs
- ***Strongyloides papillosus***, 6 - 8 mm, ruminants, rabbits
- ***Strongyloides westeri***, 8 – 9 mm, horses, donkeys
- ***Strongyloides stercoralis***, 2 – 3 mm, dogs, cats, humans, monkeys
- ***Strongyloides ratti***, 2-3 mm, rats

Parasitize only parthenogenetic females

The *Strongyloides* life cycle is more complex than that of most nematodes with its **alternation between free-living and parasitic cycles**, and its potential for autoinfection and multiplication within the host.

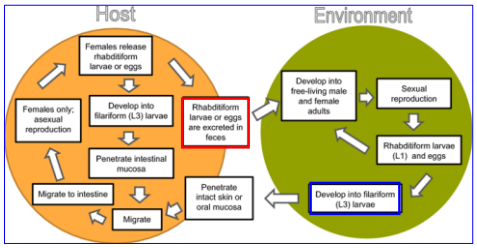
Life cycle (*S. westeri, S. suis/S. ransomi, S. papillosus*)

EXTERNAL/ENVIRONMENTAL PHASE

INTERNAL/PARASITIC DEVELOPMENT IN HOSTS

Life cycle (*S. westeri, S. suis/S. ransomi, S. papillosus*)

EXTERNAL/ENVIRONMENTAL PHASE



Rhabditiform - **non-infective**, feeding form
Filariform - non-feeding, **infective form**

Systemic migrations

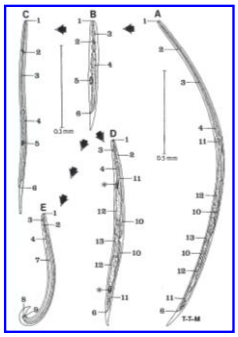
- **TRACHEAL ROUTE (pulmo-tracheal)**
- **SOMATIC ROUTE**
- **ACTOGENIC INFECTION**

Routes of infection:

1. **By skin penetretion**: larvae travel **via the blood** to the duodenum or jejunum and become adult by day 6 in pigs and day 9 in ruminants;
   In older hosts, larvae are transported to the **subcutis, striated muscles**, etc., where they stay developmentally arrested for long periods; shortly before birth, the dormant larvae are activated and migrate to the mammary gland enabling colostral and lactogenic infection of the offspring for a period of **3 weeks after birth.**
2. **Peroral** (including colostral and lactogenic infection); in this case larvae usually **develop to maturity in the small intestine without an extraintestinal migration**; the prepatent period is shorter: 3 and 6 days (pigs , ruminants).
3. **Autoinfection (in man and dog only)**; L_1 develop very fast to L_3 in the intestine, and penetrate the mucosa of the rectum.

Strongyloides stercoralis

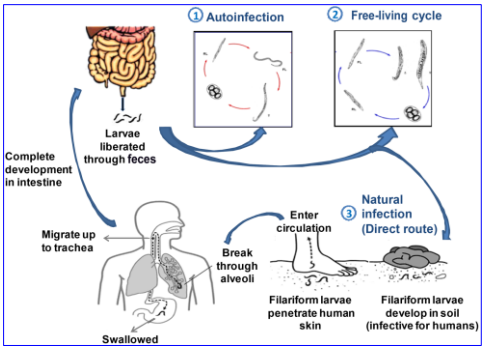
Hosts: humans, dogs, cats, monkeys



Adults and larvae of ***Strongyloides strecoralis***
A: filariform adult female of parasitic generation
B: rhabditiform larva
C: filariform larva
D: rhabditiform adult female of free-living generation
E: rhabditiform adult male of free-living generation

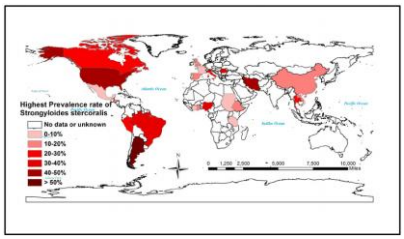
Parasitic females – hair-thin nematodes; only a few millimetres long; cylindrical oesophagus; vulva as transverse slit behind the middle of the body, leading into two uterine tubes;

Life cycle *Strongyloides stercoralis*



Geographic Distribution

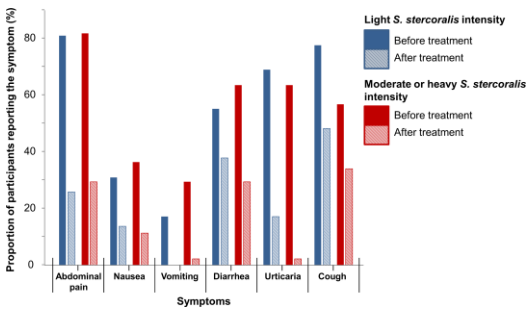
- Tropical and subtropical areas, but cases also occur in temperate areas;
- More frequently found in rural areas, institutional settings, and lower socioeconomic groups;



Clinical Features

- **Frequently asymptomatic**.
- **Gastrointestinal symptoms** include abdominal pain and diarrhoae.
- **Pulmonary symptoms** can occur during pulmonary migration of the filariform larvae.
- **Dermatologic manifestations** include urticarial rashes in the buttocks and waist areas.
- Disseminated strongyloidiasis occurs **in immunosuppressed patients**, can present with abdominal pain, distension, shock, pulmonary and neurologic complications and septicemia, and is potentially fatal.
- **Blood eosinophilia** is generally present during the acute and chronic stages, but may be absent with dissemination.

Skin lesions

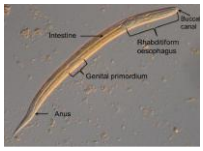


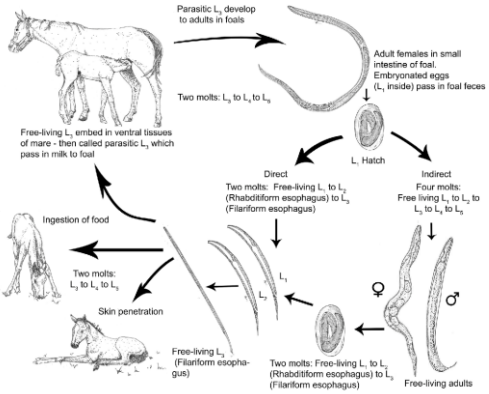
Proportion of participants harboring *S. stercoralis* mono-infections and reporting abdominal pain, nausea, vomiting, diarrhea, urticaria, and cough before and 21 days after ivermectin (200 μg/kg BW) treatment.

(Forrer A, Khieu V, Schär F, Hattendorf J, Marti H, Neumayr A, et al., 2017. PLoS Negl Trop Dis 11(10): e0005685. https://doi.org/10.1371/journal.pntd.0005685)

Strongyloides westeri
horses & donkeys

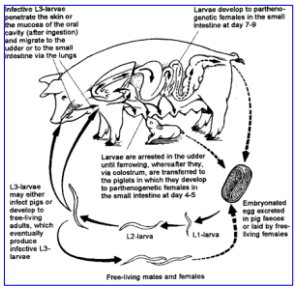
- **Scientific name: *Strongyloides westeri***
- **Morphology: Threadworms are long and hair like. Adults grow to be 8 to 9 mm in length;**
- **Stages/life cycles: Larvae mature to adult worms in the small intestine;**
- **Infection can occur by eating infective larvae or by penetration through the skin;**





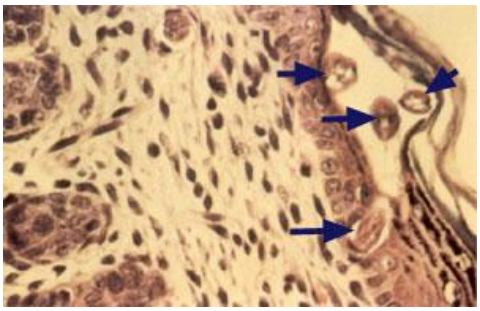
Strongyloides ransomi

- ***S. ransomi*** **is more important in warm climates where it is a major parasite of the sucking pig;**
- **Infection is uncommon in good dry farrowing houses;**

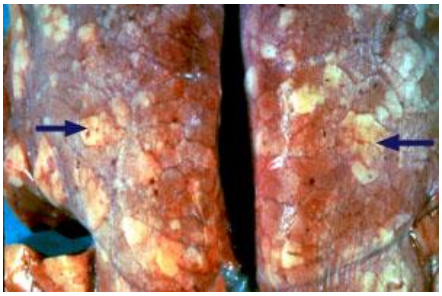


Clinical signs

- **Acute Strongyloidosis in piglets usually presents as a bloody diarrhea.**
- **In the absence of treatment, infected piglets may show rapid emaciation and mortality rates can reach 50% or more in heavy infections.**
- **Survivors are anorexic, anemic and their growth rates are significantly reduced.**
- **Recovered animals show strong immunity to reinfections and this explains the low frequency of infections in older pigs.**



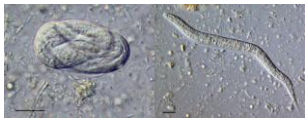
Tissue section of piglet showing L3s following percutaneous infection by *Strongyloides ransomi*



Lungs of Strongyloides-infected piglet showing areas of consolidation following tracheal migration of larvae

Diagnosis

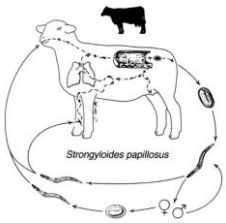
- Strongyloidosis must be differentiated from other causes of **diarrhea** in nursing piglets.
- The short prepatent period of 2-4 days following transmammary transmission means that characteristic embryonated eggs may be detected in the feces of infected piglets by the time they are 4-5 days old.



Treatment

- **Ivermectin, Doramectin, Levamisole** and **Thiabendazole** are highly effective against Strongyloides.
- A dose of Ivermectin up to 16 days before farrowing in sows is effective against L3s in the mammary glands and will prevent any mammary transmission to nursing piglets.

Strongyloides papillosus
(Ruminants, rabbits)

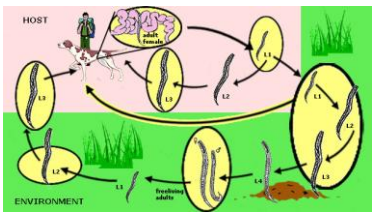


Dogs, Cats - strongyloidosis

- ***Strongyloides tumefaciens*** the feline intestinal threadworm
- ***S. stercoralis*** can infect dogs and cats (human). It is thought that each species of **host**, e.g., dog or cat, is infected by a different strain or variety of the parasite.
- **However, *Strongyloides stercoralis* can pass from man to dog, and dog to man.**
- *Strongyloides* are common in the southern Gulf states of the United States.

Life cycle

- The severity and length of infection, the species, age of the host, and the status of the host's immune system affect the development of the larvae.
- Some migrating larvae may remain in the tissues of a dog.
- In a bitch, these larvae can make their way to the mammary glands, and infection can be passed **directly to her puppies through her milk**. This is one reason why puppies can have severe infections at such a young age.



Clinical signs

- Most infections in dogs are inapparent or cause only mild diarrhea.
- Infections in young puppies can become extremely serious and ultimately fatal. This can be of major importance in pet stores and kennels.
- In severe infections, dogs may show **diarrhea, loss of appetite, loss of weight, weakness**, and **dehydration**. Younger animals can be especially affected. Infections are more common during the summer with its high temperature and humidity.
- ***S. tumefaciens*** generally does not result in disease in cats, but in some individuals, small white **nodules** can develop in the colon. If this occurs, **chronic** diarrhea may develop.

Diagnostic methods

- A diagnosis can be made when the eggs, or more commonly, the larvae are found in the feces through microscopic examination.
- Often, the moving larvae are best seen by just smearing a small amount of feces on a microscope slide and examining it.
- The solutions used for a routine fecal examination will deform the larvae and make them indistinguishable.
- Larvoscopic methods (Baermann technique): to concentrate the larvae and make them easier to find;



Treatment

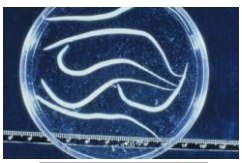
- **Thiabendazole** was the most common drug used to treat infections with *Strongyloides*;
- **Fenbendazole** and ivermectin (off label!);
- **Albendazol, flubendazol, levamizol**;
- In general, these medications are not very useful for eliminating the larvae that may be encysted in the tissues.

Control

- *Strongyloides* larvae are killed by cold temperatures and in dry environments.
- It is imperative that animals be kept in dry and clean environments.
- As with other parasites spread by faeces, the yard and litter boxes should be kept clean.
- Good hygiene measures (use of gloves and hand washing) should be used by persons who may have contact with faeces.
- Cats should not be allowed to use a sandbox or garden as their toilet area.
- Control and elimination of *Strongyloides* from a breeding facility is very difficult because the larvae can be transmitted to the young through nursing.
- Repeated treatment of the young during nursing and for several weeks after, will help to prevent them from having threadworm larvae encysted in their tissues.
- If breeding females can not be cured of their **infestation**, it may be necessary to remove them from the breeding colony if a total elimination of *Strongyloides* from the facility is to be accomplished.

Order: **OXYURIDA**

Family: OXYURIDAE (*Aspiculuris, Enterobius, Oxyuris, passalurus, Skrjabinema, Syphacia*)

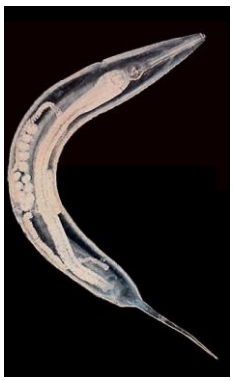


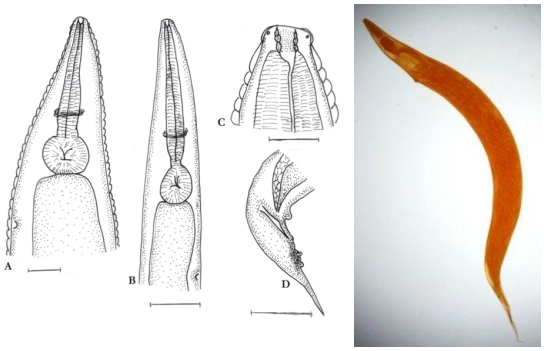


Species	Hosts	Predilection sites
Enterobius vermicularis	Humans & other primates	Cecum & appendix
Passalurus ambiguus	Rabbits & hares	Cecum & colon
Skrjabinema ovis	Sheep & goats	Colon
Syphacia obvelata	Mice(laboratory & wild)	Cecum
Aspiculuris tetraptera	Mice (laboratory & wild) & rats	Small & large intestines
Oxyuris equi	Horses & donkeys	Cecum & colon

Order: Oxyurida

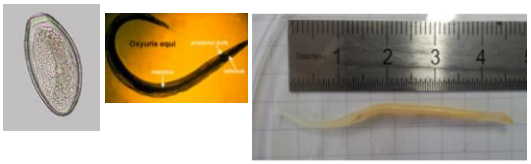
- **Commonly called the pinworms because females typically have slender, sharp-pointed posterior end of females;**
- **Have a large esophogeal bulb and cuticle is swollen in anterior;**
- **Pinworms are common among birds, mammals, reptiles and amphibians, but are rare among fishes;**
- **Two species are known to infect humans: *Enterobius vermicularis* and *E. gregorii***



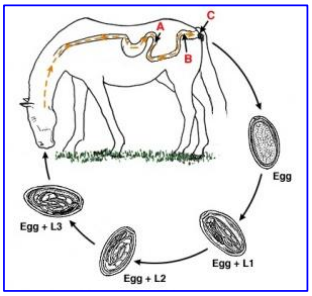


Oxyuris equi

- The esophagus has a prominent posterior bulb.
- They are commonly called ***pinworms*** because of their pointed tails and the **single** pin-shaped spicule of males.
- Females are larger than males, measuring from 5 to 15 cm in length while males are approximately 1 cm long. The female vulva is situated anteriorly.



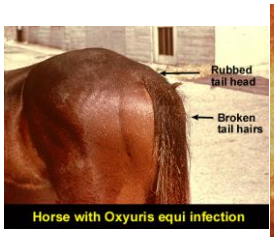
Life cycle

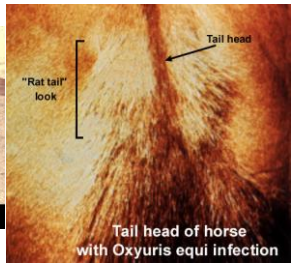


Pathogenesis

- **Fourth stage larvae have a relatively large buccal capsule and they feed by ingesting plugs of intestinal mucosa to which they are attached.**
- **This causes mucosal erosions which appear to produce little in the way of clinical signs.**
- **Adult worms live freely in the intestinal lumen feeding on gut contents.**
- **The main pathogenic effects appear to be related to the egg laying habits of the female worms.**
- **Fertilized females travel down to the rectum and extrude their anterior end through the host's anal opening.**
- **This causes an irritation resulting in anal and perineal pruritis.**

Clinical signs





Diagnosis

- According clinical signs
- Coprological examination (perianal swab)

Therapy

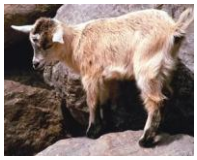
Drug	Dose	Number of doses
Mebendazol	5 – 10 mg/kg	for 3 days p.o.
Tiabendazol	100mg/kg	single dose p.o.
Febantel	10mg/kg	for 3 days p.o.
Pyrantel	12.5mg/kg	single dose p.o.
Ivermektin	0.2mg/kg	single dose p.o.
Moxidectin		

… **Wash the perineum with soap to remove the eggs**

Skrjabinema ovis
Skrjabinema caprae

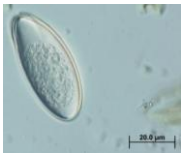
3-8 mm

- ***Skrjabinema ovis* – egg 51-59x27-34 µm, asymetrical, non embryonated**
- **Prepatent** period 25 days

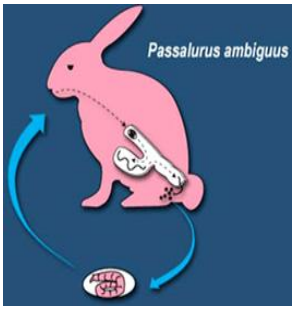


Passalurus ambiguus

- ♂ (4,3-5 mm), unpaired spike, tail has a whip-like protrusion
- ♀ (9-11 mm), the tail tapers into a point, the cuticle has 40 circular grooves
- Eggs 95-105x43 µm, asymetrical with plug, non-embryonated
- The esophagus has a prebulbus and a strong bulbus



Life cycle



The infection of animals is caused by the ingestion of infectious eggs. Rabbits are often self-infected and also infect young animals by coprophage, eating their own faeces.

Females lay eggs on the surface of faeces or in perianal folds. The infectious larva develops within 24-48 hours in the egg.

Pathogenesis and clinical signs

- A large number of worms (≥ 1000) may cause granulomatous appendicitis and lymphadenitis;
- Relatively harmless, they also occur in very young rabbits;
- Larval stages in submucosis - **necrotic degenerative inflammations, diarrhea and weight loss**;
- Colic pain – rare;
- Itching of the rectum- **traumatization** and **inflammation** of the skin → hairless spots

Diagnosis

- Coprology – eggs – *intra vitam*
- Detection of adult worms in cecum and colon – *post mortem*

THERAPY

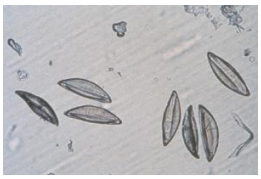
- A single dose - orally of piperazine at a dose of 200 mg/kg, repeated treatment after 14 days.

In addition, benzimidazoles such as:

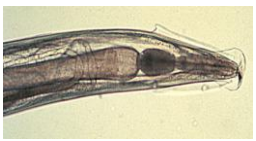
- **Fenbendazol** orally at a dose of 20 mg/kg with a repeat of 10-14 days (or 50 mg/kg for 5 days);
- **Tiabendazol** at a single dose of 100-200, some authors report up to 400 mg/kg (per os), or at a dose of 110 mg/kg followed by 70 mg/kg for 8 days;
- **Mebendazol** single dose (20-50 mg/kg);
- **Oxibendazol** at a dose of 15 mg/kg, repeated after 14 days;
- Of the macrolide preparations, **ivermectin** at a dose of 0.4 mg/kg may be used.

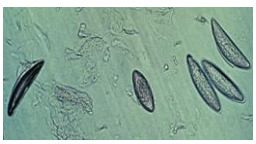
Pinworms of laboratory rodents

- Hamster
  - ***Syphacia mesocriceti***
- Mouse
  - ***Syphacia obvelata***
  - ***Aspicularis tetraptera***



Aspiculuris tetraptera

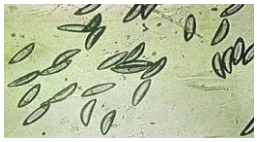




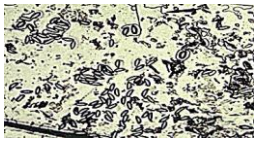
Life cycle - direct

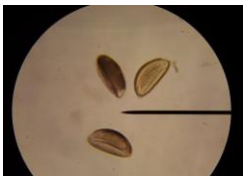
- Post-infectious larvae - large intestine - deep in intestinal crypts
- Adult worms - only in *colon ascendens*
- **Pathogenesis and clinical signs: cattharal enteritidis** (massive infection); slowed growth (moderate infection);
- **Diagnosis:** egg finding; post mortem - finding of adult worms in the caecum and colon;
- **Therapy: piperazine** in drinking water **(4-7 mg/ml)**

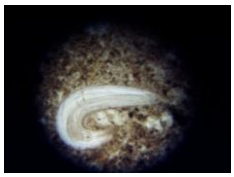
Syphacia obvelata



Syphacia muris – rat and free living rodents







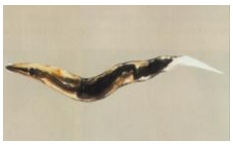
Pinworms of reptiles
Genera: *Pharyngodon*
Tachygonetria

Enterobius vermicularis

- **Definitive Host:** Humans
- **Intermediate Host:** None
- **Distribution:** Cosmopolitan but more common in temperate zones in industrialized countries.
  - Infects approximately 400,000,000 (10%) worldwide
    - Second only to *Ascaris lumbricoides* (1,000,000,000 or 25%)
  - **Most common endoparasite in Europe and U.S.**
    - Incidence between 30-80% in Caucasian children
    - Non-Caucasians seem to be more resistant

Enterobius vermicularis (pinworm)

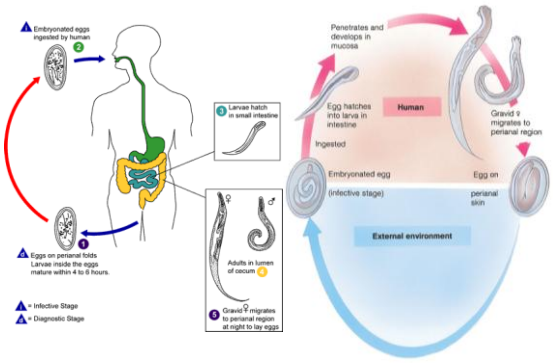
- **Worm - Female: 7-14mm; male: 2-4 mm;**
- **found worldwide in children;**
- **most common helminth infection**
- **eggs ingested - (oral/fecal) or inhaled**
- **adult female lays eggs on perianal skin**



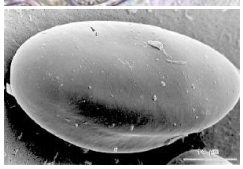
Enterobius vermicularis

- **Transmission:** Eggs are infective stage. They are light and can float. 3 modes:
  - **Hand to mouth (fecal/oral contamination)**
    - Eggs are picked up on the fingers and transferred to mouth
  - **Inhalation**
    - Eggs float and are inhaled, trapped by mucus membrane, then swallowed
  - **Reinfection**
    - Eggs hatch and larvae crawl back through anus
- **Location in definitive host:** Large intestines from caecum to anus.

Life cycle



Pathology and Symptoms



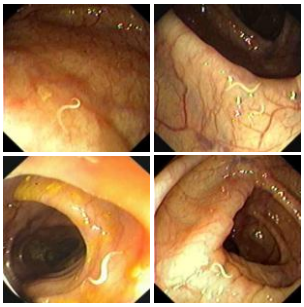
Pinworm Neurosis

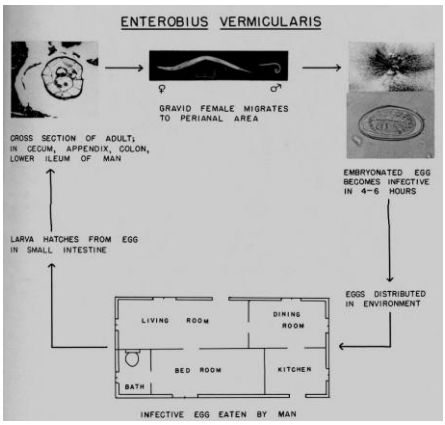
- More of a mental condition than a medical one.
- Female lays 15,000 eggs
- The eggs get into everything
  - Bedding
  - Clothing
  - Curtains and drapery
  - Stuffed animals
- People spend time and money trying to eliminate the eggs from the house.

- sleep disturbance
- decresed appetite and weight loss
- vaginal irritation or discomfort in young girls
- wearing away of the skin or infection around anus from constant scratching

Complications:

- salpingitis
- worms may enter the peritoneal cavity through the genital tract
- Vaginitis
- emotional disturbance
- reinfestation

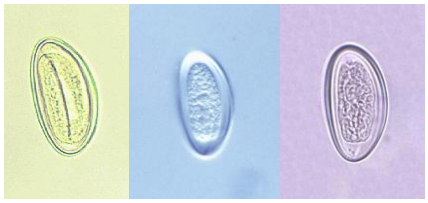




Enterobius vermicularis

- **Diagnosis:** **Two preferred techniques**:
  - Scotch tape technique
    - Early morning, pat the area around the anus with a piece of Scotch tape (or any other transparent tape)
    - Place tape on microscope slide with a drop of acetone.
    - Examine slide for eggs
  - Flashlight technique
    - Shine a flashlight on the anus during the middle of the night
    - You can see the adult females crawling out to lay eggs.
- **Treatment:** **Mebendazole (Vermox).** Must treat entire family and repeat after 10 days. Bedding, towels, and clothing should be washed in hot water.
  - **Pyrantel pamoate**
  - **Pyrvinium pamoate**

Enterobius vermicularis – Dg.



Control of spread

- Maintain excellent personal hygiene, particularly washing hands after going to the bathroom and before eating or preparing food.
- Keep nails short and discourage scratching or nail-biting.
- Daily morning showers;
- Frequent change of underclothing, night clothes, and bed sheets (take care not to disperse eggs into the air by shaking linen) are also important.
- Clean/vacuum the house daily for several days after treatment of cases.