Elective paper: Parasitology

1

Background terminology

- **Parasite (**Greek *parásītos* = one who eats at another's table**):**
  - An organism that lives on or within and at the expense (space and nutrition) of another organism.
  - Parasites do not kill their host directly but may weaken it to the point where it is susceptible to secondary infection.

*A **parasitoid** is an organism that lives on or in a host organism and ultimately kills the host. E.g., Order Hymenoptera.*

Endoparasite: Lives within another living organism.
e.g. malarial parasite

Ectoparasite: Lives on the external surface of another living organism. e.g., lice and ticks

2

Background terminology

Host:
The organism in, or on, which the parasite lives.

Definitive (or primary) host:
The organism in which the parasite reaches maturity and, if applicable, *reproduces sexually*.

Intermediate (or secondary) host:
The organism in which some developmental (for e.g., asexual larval) stage of parasite life cycle is completed.

(The Delivery Boy of the Parasitic World)

The definitive host is usually a vertebrate, while intermediate hosts can be either vertebrates or invertebrates.

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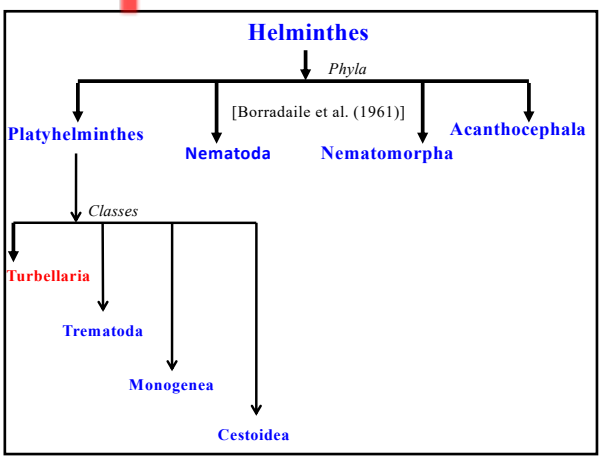

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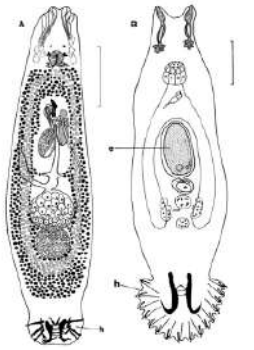
Monogenea: general characters

- Primarily ectoparasites of vertebrates, especially on gills and skin of fish.
- Most are highly *host and site specific*.
- Body plan includes *haptor* whic serves as a holdfast.
- Feeds on blood and/or epitheli cells and mucus of gill tissues.
- All are *hermaphroditic*.
- Most are oviparous; eggs hatch into ciliated infective larva calle *oncomiracidium*.
- They all have the *direct life-cycle*.



Dactylogyrus ***Gyrodactylus***

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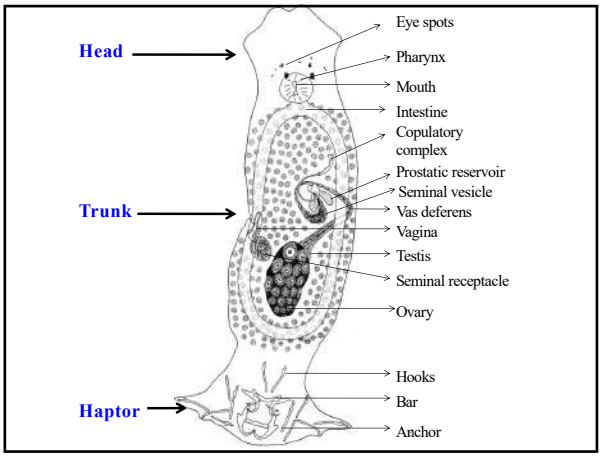

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Host Preference

- In terms of host specificity, monogenean parasites could be distinguished as:
  - specialists (parasitizing one host species or a number of closely related species) and
  - generalists (parasitizing at least two unrelated host species).

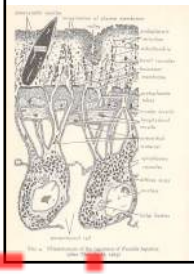
Body form

- Like other flatworms, monogenoids have typical platyhelminth features:
  - dorso-ventrally flattened, acoelomate, bilaterally symmetrical, protonephridial excretory system, no definite anus, no respiratory or circulatory system and are hermaphrodite.
- Size from about 100 microns to 3 cm in length.

7

Tegument

- As in digeneans and cestodes, it was traditionally called a cuticle but it has now been recognized as a ***living tissue***, the tegument.
- Its fundamental structure is similar to that of digenean and cestode tegument, with following differences:



Dorsal ytoplasm: a syncytial stratum laden with various vesicles and mitochondria

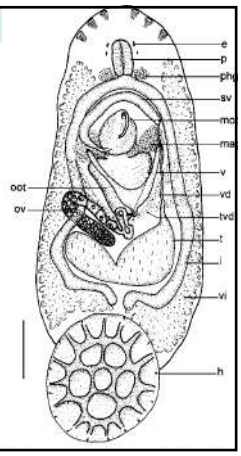
Trabeculae (internuncial processes)

Cytons (perikarya)

8

Digestive system

- Behind the mouth is a muscular and glandular pharynx. This powerful sucking apparatus draws food into the system.
- The intestine divides into two lateral crura, which may or may not join near the posterior end of the body.
- There is no anus.
- feed mainly on **epidermal cells** and secretions, and **blood**.
- May also directly **absorb low–molecular weight organic compounds** supplementing the blood diet.



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Muscular systems

- The musculature is found at two places:
  - Haptoral muscles, and
  - Superficial muscles (immediately below the distal cytoplasm of the tegument), arranged in circular, diagonal, and longitudinal layers.

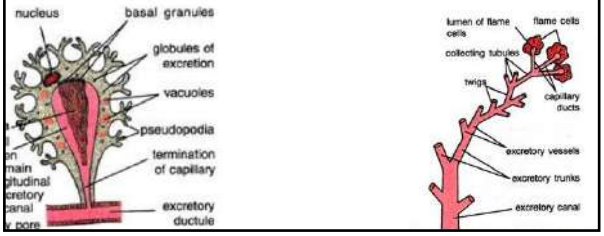
Nervous systems

- The nervous system is a typical flatworm ladder (orthogon) type with cerebral ganglia in the anterior and several nerve trunks coursing posteriorly from them.
  - Fairly wide variety of sense organs such as ***sensillae*** in the tegument and ***pigmented eye spots*** in the anterior body end.

10

Osmoregulatory system

- Typical of the Platyhelminthes, flame cell protonephridia are excretory units.
- A thin-walled capillary leads from this unit to fuse with a succession of ducts leading to **two lateral excretory pores near the worm's anterior end**. Each terminal duct often has a contractile bladder at its distal end.



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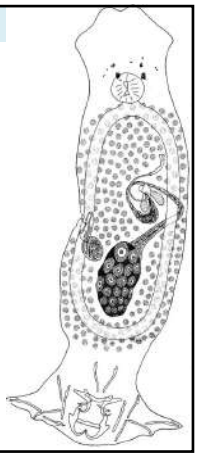
Reproductive system

- Hermaphroditic with cross-fertilization usually taking place.

Male reproductive system

- Testes usually one in number and round to ovoid in shape.
- Each testis has a vas efferens, which expands (or fuses with others) to become a vas deferens, which may in turn lead into an ejaculatory duct opening into a sclerotised or muscular copulatory organ or penis.
- A simple, saclike seminal vesicle and prostatic glands are usually present.



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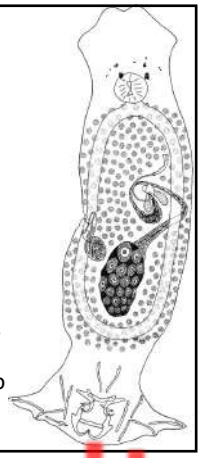
Female reproductive system

- The ovary is usually single in number and round or oval to elongated or lobed in shape.
- The oviduct leaves the ovary and courses toward the ootype, receiving vitelline, vaginal, and genitointestinal ducts along the way.
- More specifically, the oviduct extends from the ovary to a confluence with the vitelline duct (canal); the remainder is often referred to as the female sex duct.
- A seminal receptacle is present, either as a simple swelling of the oviduct or as a special sac with a separate duct to the oviduct.



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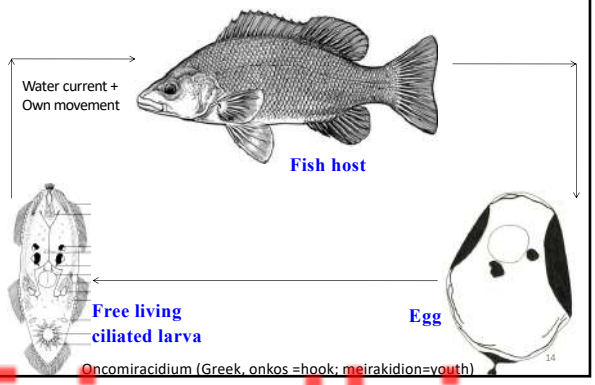
Direct life cycle (host to host transfer)



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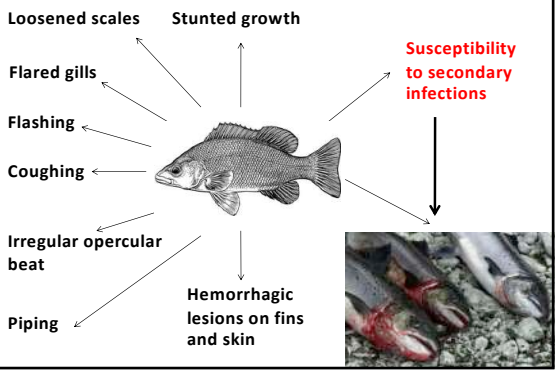
Clinical signs and disease pathology …..



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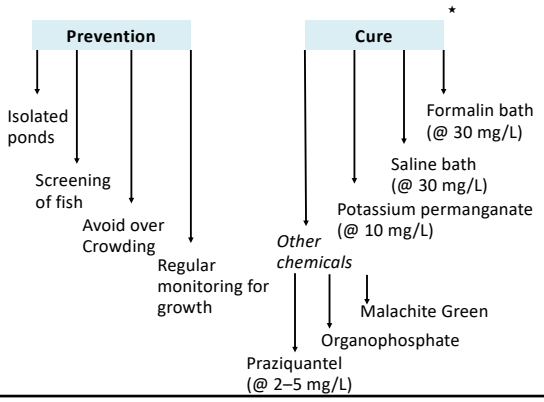
Control Measures



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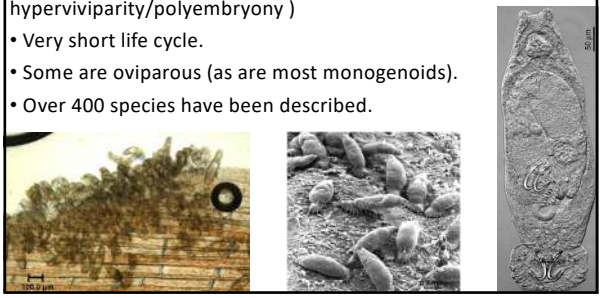
17

Gyrodactyus

- von Nordmann (1832) the embryo in utero as "stomach hooks".
- Retain fully grown daughters in utero until they themselves contain developing embryos. Also known as hyperviviparity/polyembryony)
- Very short life cycle.
- Some are oviparous (as are most monogenoids).
- Over 400 species have been described.



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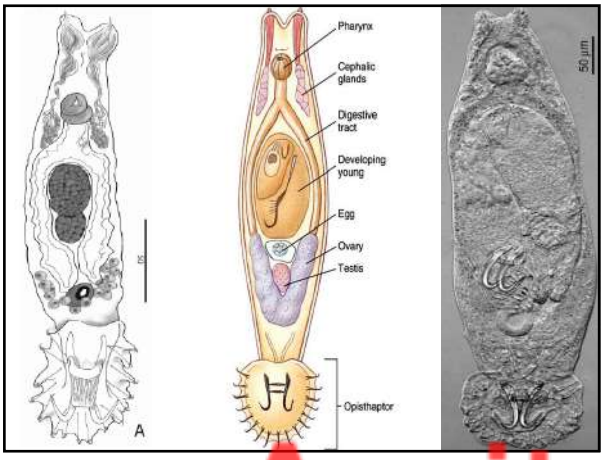

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Gyrodactylus salaris individual giving birth to a pregnant daughter as large as itself.

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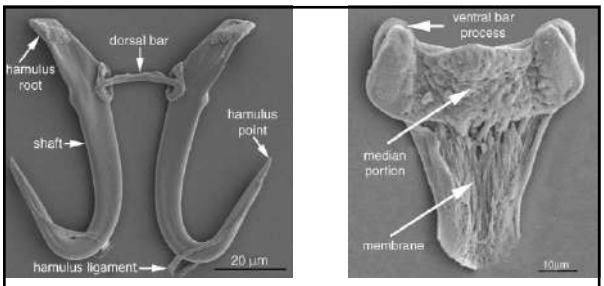

A haptor armed with 16 marginal hooks and 2 large anchor

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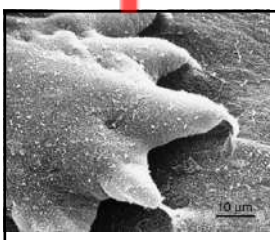
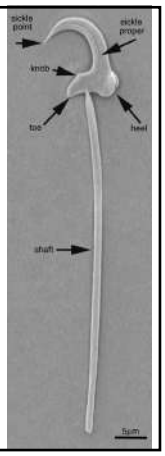


Feeds mostly on the mucus and epithelial cells of the skin's surface - occasionally on blood - it attaches to the host by means of a complex hook and anchor arrangement and it is this attachment which damages tissues and causes great irritation to the fish. The fish shows obvious signs of irritation and the damaged areas can develop into significant skin ulcers and fin erosions, often with secondary bacterial and fungal infections.



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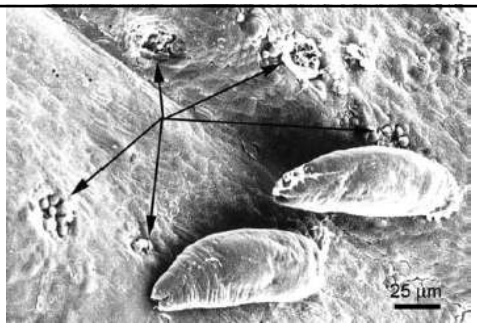

Scanning electron micrograph demonstrating the wounds (see arrows) on the epidermis of an Atlantic salmon parr caused by the feeding activity of *Gyrodactylus salaris*

23

***Gyrodactylus salaris* on Atlantic salmon (*Salmo salar*)**

Salmo salar

Gyrodactylus salaris

- Norway has recorded over 41 of their river systems being infected
- Economic losses ran in excess of US $500 million.

24

***Gyrodactylus salaris* on Atlantic salmon (*Salmo salar*)**

- Norway suffered huge losses of wild salmon populations because of the translocation of *Gyrodactylus salaris* along with resistant Atlantic salmon into their natural environment from Sweden. Epidemics of the organism occurred when it was transferred to areas where it is not naturally found and salmon exposed to the parasite for the first time had no evolved immunity (unlike those fish in the Baltic rivers which appear to be tolerant). This resulted in heavy losses of the susceptible fish and populations of salmon have been eliminated from more than twenty Norwegian rivers with the probable inevitable loss of some strain characteristics of those populations. The resulting economic losses ran in excess of US $500 million. Apparently, Norwegian stocks of salmon lacked endogenous resistance to the parasite.

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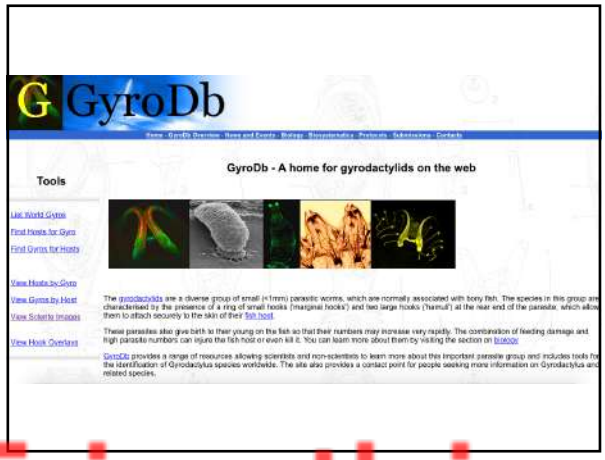

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27

Diplozoon

- Oviparous, blood-feeding ectoparasites of freshwater, mainly cyprinid, fish.
- Comprise seven genera: *Diplozoon*, *Eudiplozoon, Paradiplozoon*, *Sindiplozoon*, *Inustiatus, Neodiplozoon, Afrodiplozoon.*

28

- Unique in their pairing strategy, in which two sexually immature stages, known as **diporpae**, fuse together with subsequent rearrangement and interconnection of their reproductive and nervous systems
- After fusion, the two individuals grow together and survive only as a pair fused in permanent copula.
- Such a reproductive strategy, in which two independent heterogenic individuals fuse into a single hermaphrodite organism without the need to search for mating partner, represents a high specialization to the parasitic life and is found only in the Monogenoidea.

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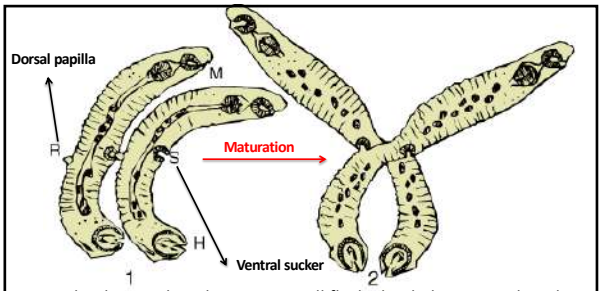

During the diporpa larval stages a small fleshy knob, known as dorsal papilla, appears on the dorsal surface of the worms. Fusion begins when two diporpae moving on the host gills come into a contact and grasp one another's dorsal papillae via their ventral suckers. Fusion triggers their maturation to adult stage, and the vas deferens from two individuals grows through the body junction to the other making cross-fertilization possible

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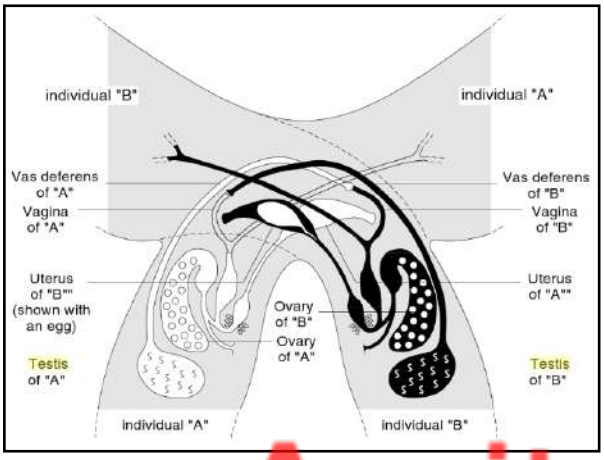

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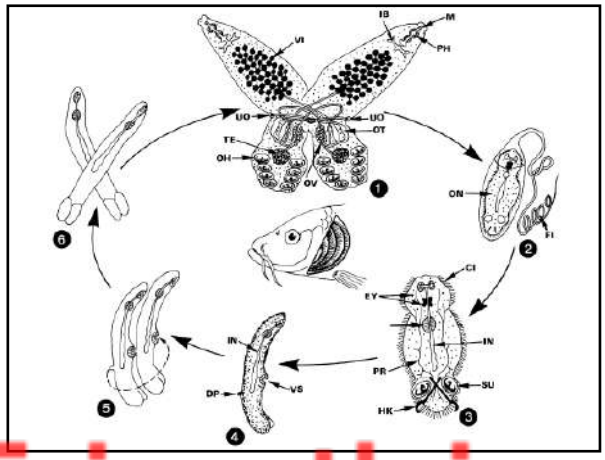

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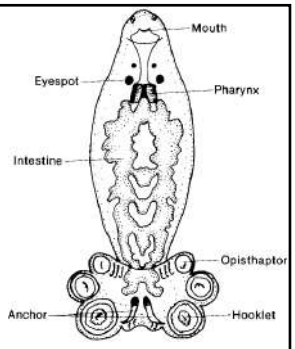
33

Polystoma integerrimum

- Inhabits the urinary bladder of the adult frogs/toads and gills of the tadpole
  - Other species in the bladde of turtles.
- Reproductive cycles of frog and parasite are in sync. due to hormones that appear in the frog's urine (gonadotropins).



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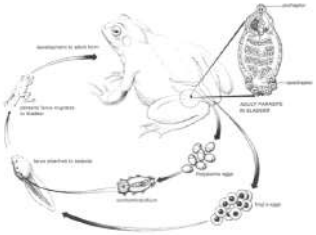
- Gonadotropins that are produced by the host during spawning season trigger the worms to lay eggs in the frog's bladder.



- When the frog goes to breed in water the parasite's eggs are also voided in the frog's spawning area.
- Eggs hatch in the water, yielding an oncomiracidium in 20-50 days.
- The oncomiracidia will either continue to the normal adult stage or to the neotenic adult stage depending upon where the tadpole is at in its life cycle.

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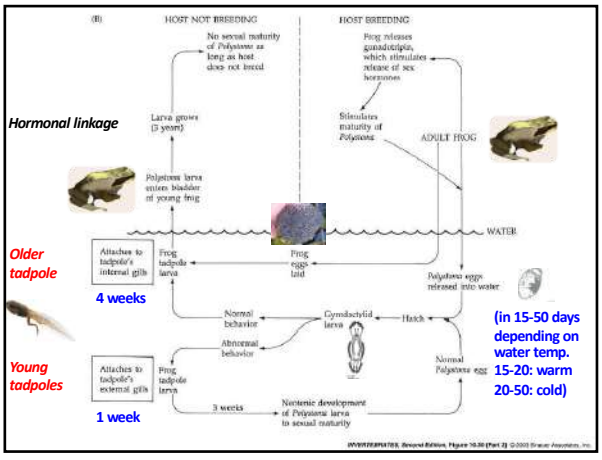

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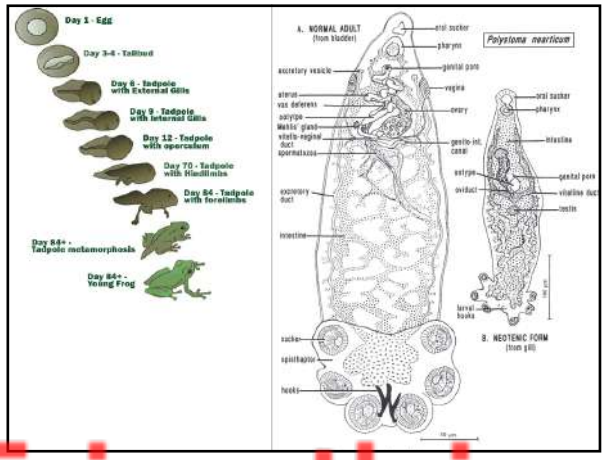
Neotenic life cycle	Normal life cycle
• The oncomiracidia attaches to the external gills of the tadpole. • These larvae cue in on hormones of the frog that are involved in the metamophosis. • Specifically, they undergo accelerated development of their reproductive organs and become neotonic. • Eggs are produced by the parasite within 20-25 days and begin to hatch within 15-20 days (*Rapid life cycle*). • When the tadpole begins to mature and resorbs its gills, the parasite larvae will move onto the normal life cycle stage.	• *Polystoma* larvae leave the internal gills and crawl over the ventral side of tadpole body to reach the cloacal opening. • Through this opening they enter the bladder of the host. • Larvae slowly develop for 4-5 years before production of eggs occur during spawning season (*Slow life cycle*). • The cycle repeats itself.

37



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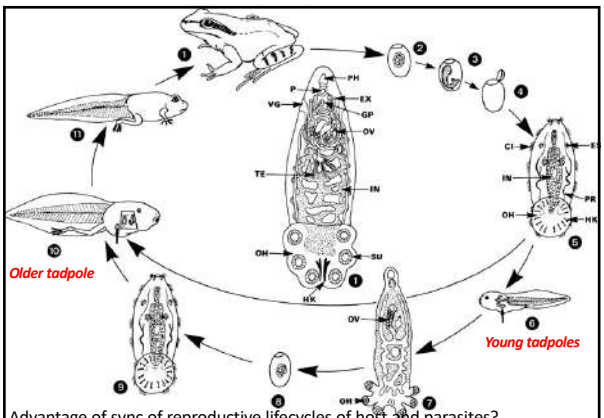


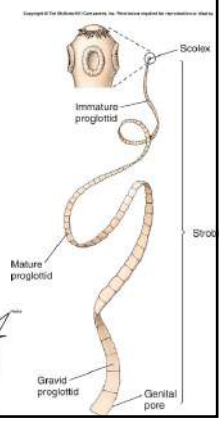
Advantage of sync of reproductive lifecycles of host and parasites?
Ensures that there is a steady supply of hosts for the oncomiracidia hatchings.

39

40

Cestoidea: general characteristics

- Endoparasitic (*intestinal*) flatworms, commonly known as *tapeworms* due to their long, flat and ribbon-like forms.
- Body *segmented*: scolex, neck, and strobilla (consisting of proglottids of varying stages of maturity).
- *Digestive tract absent* (nutrients are taken up through the tegument).
- No sense organs
- Embryos with hooks
- All are *hermaphroditic*.



41

T. solium: habit and habitat

- Adult in the small intestine of man; larval stages (*Cysticercus cellulose*) in the tissues of (usually) pig or man
- Distribution is cosmopolitan, especially found in those parts of the world where pig is domesticated.

External morphology

- Body 1 to 5 meters long (Can get to 9+ meters long)
- Dorsal and ventral surface indistinguishable (surface closer to testis is dorsal and closer to ovary is ventral).

42

External morphology

• Neck is the region of growth as the segments are budded off and pushed backwards.

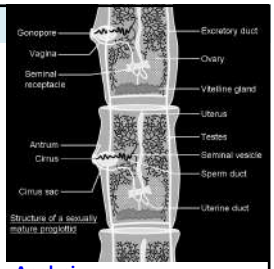
• A segmented strobila consists of up to 1000 segments (proglottids) arranged in a linear fashion.

• Strobila includes following three kinds of proglottids:

1) Immature proglottids

2) Mature proglottids

3) Gravid proglottids



Apolysis:

Passive separation of the gravid proglottids, in chains of 5 to 6 at a time, from the posterior end of strobila. It serves twofold purposes:

1. Transfer the developing embryos to the exterior, and
2. Limits the body size.

43

Digestive system

- Alimentary canal absent (WHY ?)

  1. it absorbs pre-digested food available in host's small intestine through its general body surface.

  2. it would have rendered the process of apolysis impossible.

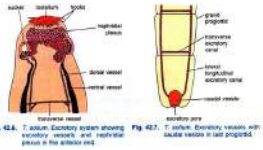
Respiratory system

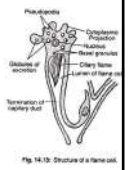
- Mainly anaerobic
- Glycogen, the principal reserve food, undergoes glycolysis producing fatty acid, lactic acid and carbon di oxide.
- Fatty acids on catabolism produce energy.

44

Excretory system

- It consists of 1) Lateral longitudinal canals, 2) Secondary canals, 3) Capillaries, and 4) Flame cells.





Nervous system

- Not known satisfactorily.
- Specialised sense organs are not necessary..

45

Reproductive system

- *T. solium* is hermaphroditic.
- Protandrous (male reproductive organs differentiate before the female).
- Replication more usually by self fertilisation (because there is usually a single tapeworm) when strobila bent into fold.

Life cycle and development

- Life cycle is digenetic: man and pig.
- Zygote turns into capsule into ootype and then passes into uterus.
- Uterus develops lateral branches to accommodate more capsules.

46

Life cycle

- Eggs or gravid proglottids are passed with faeces; the eggs can survive for days to months in the environment.
- Cattle (*T. saginata*) and pigs (*T. solium* and *T. asiatica*) become infected by ingesting vegetation contaminated with eggs or gravid proglottids. In the animal's intestine, the eggs hatch into oncospheres, which invade the intestinal wall, and migrate to the striated muscles, where they develop into cysticerci. A cysticercus can survive for several years in the animal.
- Humans become infected by ingesting raw or undercooked infected meat. In the human intestine, the cysticercus develops over 2 months into an adult tapeworm, which can survive for years.
- The adult tapeworms attach to the small intestine by their scolex and produce proglottids which mature, become gravid, detach from the tapeworm, and migrate to the anus or are passed in the stool (approximately 6 per day). The eggs contained in the gravid proglottids are released after the proglottids are passed with the faeces.

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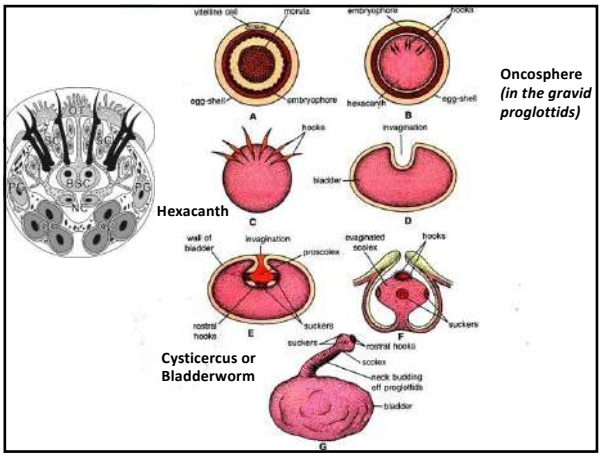

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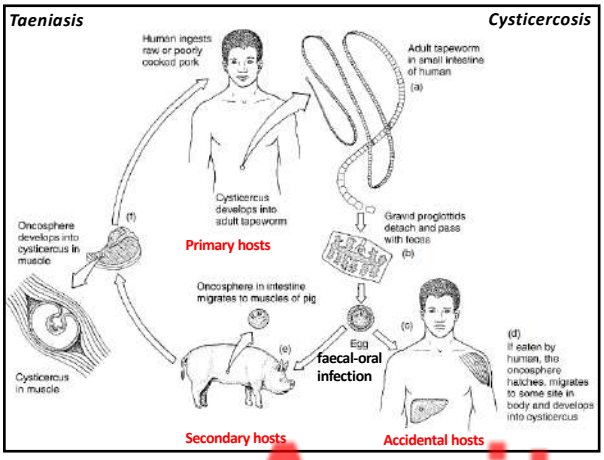

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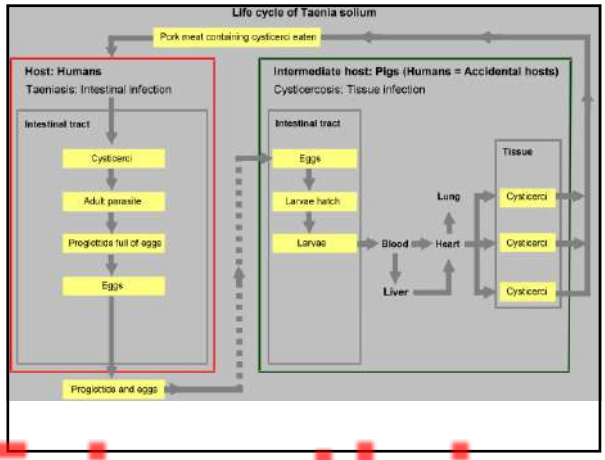

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Pathology and symptoms

Taeniasis

- Due to presence of the adult worm in small intestine of human
- Usually asymptomatic, most common one usually includes abdominal discomfort and intestinal irritation.

Cysticercosis

- Due to infection of the larval forms (cysticercus), which invade the CNS (neurocysticerosis) and rarely in other organs, for e.g., subcutaneous tissue, muscle, eye (ocular cysticercosis) and heart.
- Symptoms includes chronic headaches, blindness, seizures (epilepsy if they are recurrent), hydrocephalus, meningitis, dementia, and symptoms caused by lesions occupying spaces of the central nervous system.

51

Diagnosis and control

Taeniasis

- Perianal swab: to find egg at perianal region
- Stool exam: to find gravid proglottids in stool
- ELISA test

Cysticercosis

- Biopsy of a subcutaneous nodule.
- X-ray/CT/MRI (for cerebral cysticercosis)
- Fundoscopic examination (for ocular cysticercosis)

Treatment

- Paziquantel: for intestinal stages (adult)
- Albendazole: for tissue stages (cysticercus)
  - To readily eliminate the segments from the bowel, a purgative may be given 1-2 hours after anthelminthic treatment.
  - Neurosurgical intervention may be necessary

52

Control

1, 2, 3, and 4. Health education (*T. solium* is virtually extinct in Europe and the USA).

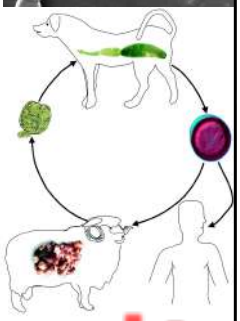
5. Avoid to consume raw meat. (Since cysticerci do not survive temperatures above 50°C).

53

54

Echinococcus granulosus

- Small worms (2-6mm long) with a scolex and only three segments.
- **Dog tapeworm or Hydatid worm** (cyst containing watery fluid)
- **Primary host:** Canids (dogs, wolves etc.)
  - **Site of infection:** Small intestine
- **Secondary host:** Sheep and cattle (**accidentally men**)



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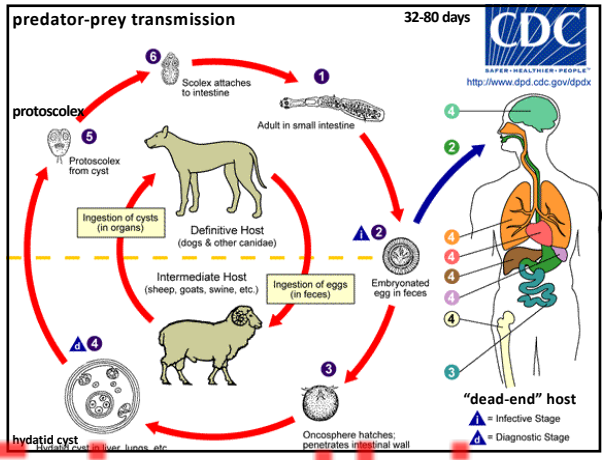
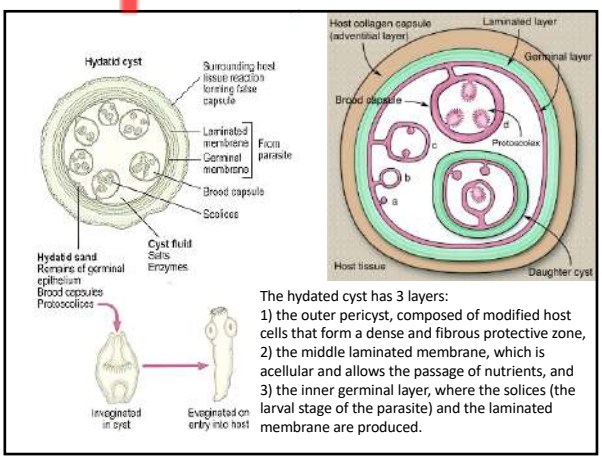


56

Life cycle

- Tapeworm eggs are passed in the faeces of an infected dog and may subsequently be ingested by grazing sheep; they hatch into embryos in the intestine, penetrate the intestinal lining, and are then picked up and carried by blood throughout the body to major filtering organs (mainly liver and/or lungs).
- After the developing embryos localize in a specific organ or site, they transform and develop into larval echinococcal cysts in which numerous tiny tapeworm heads (called protoscolices) are produced via asexual reproduction. These protoscolices are infective to dogs that may ingest viscera containing echinococcal cysts (with protoscolices inside), mainly because of the habit in endemic countries of feeding dogs viscera of home-slaughtered sheep or other livestock.
- Protoscolices attach to the dog's intestinal lining and, in approximately 40-50 days, grow and develop into mature adult tapeworms, once again capable of producing infective eggs to be passed to the outside environment with the dog's feces.

57



The hydated cyst has 3 layers:
1) the outer pericyst, composed of modified host cells that form a dense and fibrous protective zone,
2) the middle laminated membrane, which is acellular and allows the passage of nutrients, and
3) the inner germinal layer, where the solices (the larval stage of the parasite) and the laminated membrane are produced.

58

Symptoms

- The adult stages are benign and do not cause disease in dogs, as the worms do not invade or feed on host tissues.
- Humans are accidental intermediate hosts
  - The symptoms, comparable to those of a slowly growing tumor, depend upon the location of the cyst.

Abdominal cysts	: increasing discomfort.
Liver cysts	: obstructive jaundice, abdominal distension.
Peribronchial cysts	: (coughing up blood), dyspnoea (difficulty in breathing), chest pain.
Brain cysts	: intracranial pressure and Jacksonian epilepsy (a simple partial seizure).
Kidney cysts	: renal dysfunction.

  - Contents of cyst released (due to rupture) may produce fatal anaphylactic responses.

59

Diagnosis

- A slow-growing tumor accompanied by eosinophilia.
- Intradermal (Casoni) test with hydatid fluid is useful.
- Ultrasonography imaging (for pulmonary cysts and calcified cysts) is a technique of choice.
- Antibodies against hydatid fluid antigens have been detected by ELISA.

Treatment and control

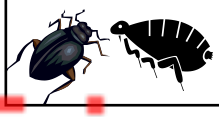
- Chemotherapy usually involves albendazole alone or in combination with praziquantel.
- Surgical removal of intact cyst, whenever possible, is considered an optimal treatment
  - For cystic echinococcosis, there is an average of 2.2% post-operative death rate for surgical patients (WHO 2015).
- Preventive measure involve avoiding contact with infected dogs and cats and elimination of their infection

60

61

Hymenolepis nana

- Hymenolepididae only two species of this family can infect humans: *Hymenolepis nana* and *Hymenolepis diminuta*
- **Dwarf tapeworm** (Gr. nanos = dwarf) (smallest human tapeworm: 2 to 4 cm long having about 200 proglottids)
- One of the most common human cestode.
- **Definitive hosts** - man, rodents.
- **Site of infection:** Intestine
- **Secondary host:** ABSENT (only cestode)
  (can use insects such as fleas or beetles)

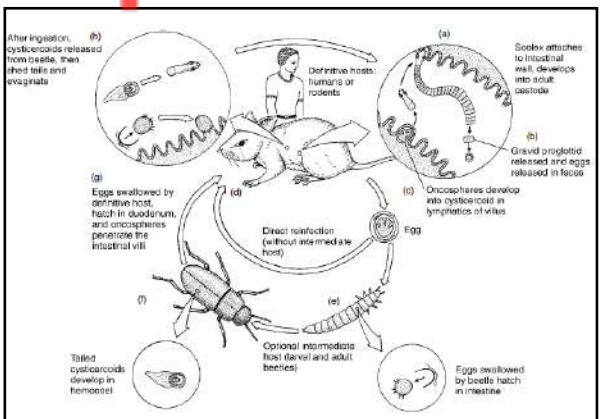


62

Life cycle

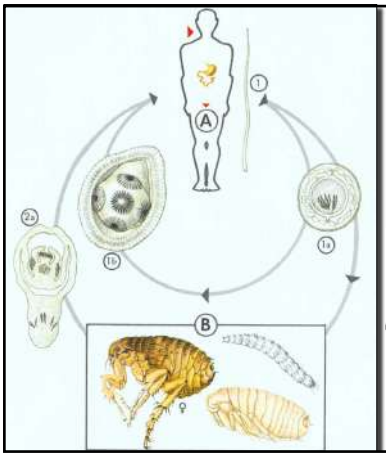
- The eggs of *H. nana* are expelled out with the stool of an infected human. *H. nana* has 3 possible modes of infection:
- **1) Faecal–oral (hand-to-mouth) transmission:** This is a usual mode of transmission releasing the embryonated eggs in the doudenum.
- **2) Indirect 2-host cycle:** Alternatively, the eggs may get ingested by an arthropod intermediate host (various species of beetles and fleas) where they develop into **cysticercoid larvae,** which then can infect humans (or rodents) upon ingestion.
- **3) internal autoinfection:** Most of the time, some proglottids disintegrate themselves in the small intestine releasing the eggs.
- Once in the intestine, the eggs hatch into hexacanth embryo, which penetrates the mucosa and come to lie in lymph channels of the intestinal villi. Here, each develop into a cysticercoid larva within 4 to 6 days. The cysticercoid then re–enter the intestinal lumen, and travel to the ileum where it evaginates its scolex and reattaches itself to the intestinal mucosa. Within 2 weeks, it develops into a full adult worm producing gravid proglottids. If an intact cysticercoid is ingested, it attaches directly to the small intestinal wall and matures into an adult worm. The life span of adult worms is 4 to 6 weeks, but internal autoinfection allows the infection to persist for years. Besides humans, the house mouse is another possible definitive (and reservoir) host.

63

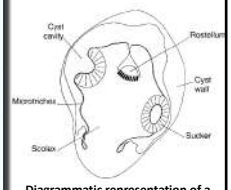


Modification of ancestral two-host cycle

64



Cysticercoid: A cestode larva develops from the onchosphere in many Cyclophyllidea. It usually possesses a tail-like appendage and a well-formed scolex, which is withdrawn in upright position (and not invaginated) into a greatly reduced cystic cavity almost devoid of fluid.



Diagrammatic representation of a longitudinal section through a cysticercoid from a mouse villus.

65

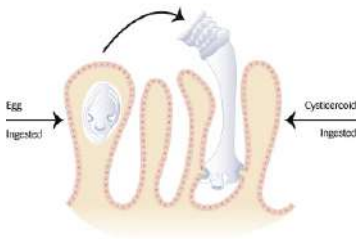


Fig. 2. Illustration showing direct development of adult *Hymenolepis nana* following ingestion of cysticercoid or indirect with mucosal development of cysticercoid following ingestion of egg.

66

Symptoms

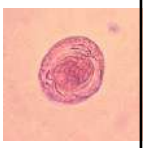
- Usually asymptomatic in adults but prolonged or heavy infections, especially in children, can cause severe symptoms.
- The worms eat the intestinal food and cause *inflammation* of the intestinal mucosa. The inflamed tissue will have a *reduced ability to absorb nutrients*.
- **Hymenolepiasis:** Some usual symptoms are: diarrhoea (can be bloody), headache, increased appetite or loss of appetite, insomnia, muscle spasms, nausea, nervousness, seizures, stomach ache, vomiting, weakness, and weight loss.

67

Diagnosis

- By identifying tapeworm eggs in stool.
- Egg colourless, thin outer membrane, and thick outer membrane with *polar filaments*.

Treatment and control



- The nature of the life cycle (i.e., no essential intermediate host and a high likelihood of autoinfection) renders prevention difficult.
- Usually treated with *praziquantel* which causes the tapeworm (both adults and larvae) to dissolve.
- A single dose of praziquantel has an efficacy of 96%. If praziquantel is not available, niclosamide or albendazole can be used instead.

68