ZOOLOGY LECTURE

19.10.2012

Nematodes

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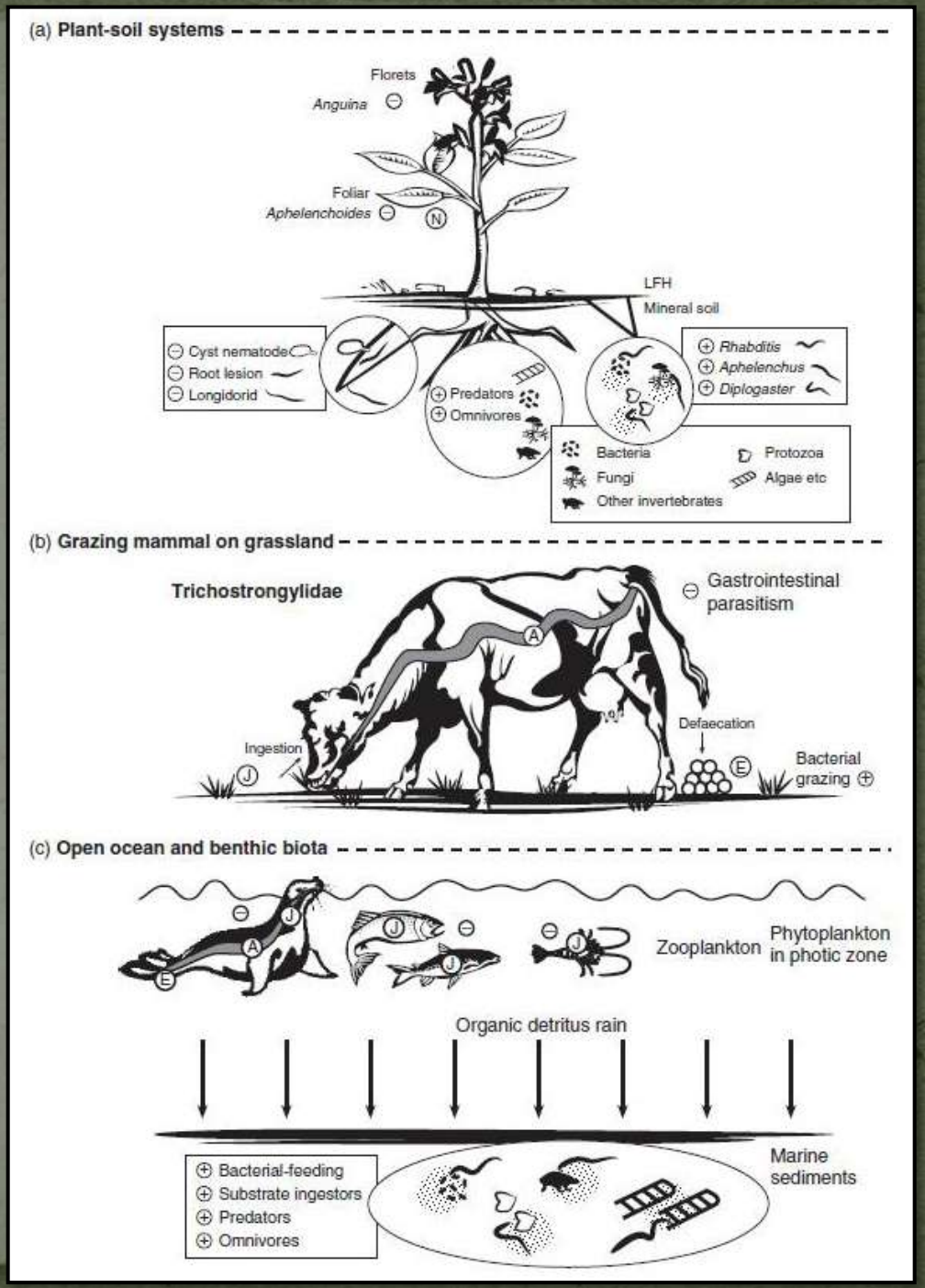
General organisation

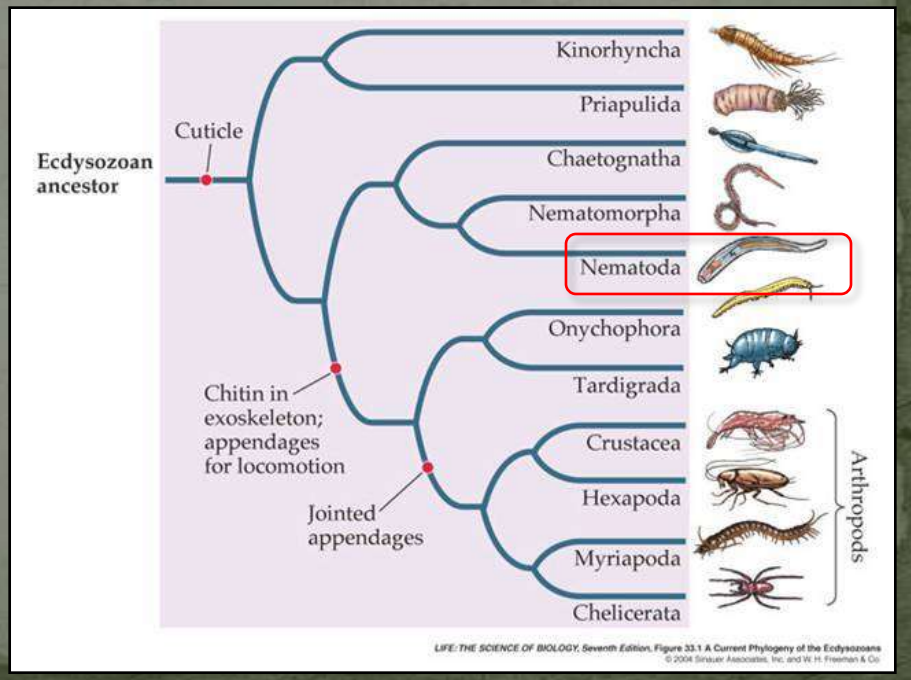
- One of the most diverse group of animals
  - Free-living species
  - Parasitic forms (60 %)
- Ubiquitous in freshwater, marine, and terrestrial environments
- It is very difficult to distinguish nematode species

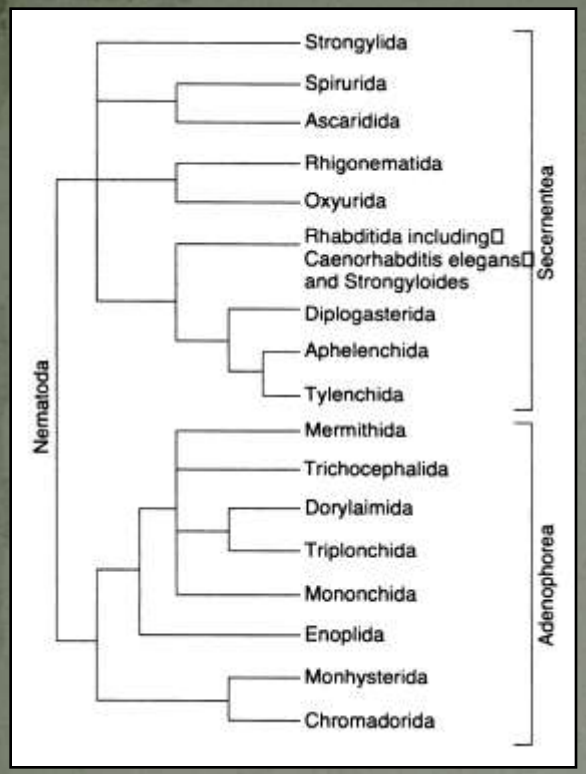


- Fossil nematodes have been found in rocks from as early as the carbon age (345 million years)
- Parasitic forms documented in the Tertiary age (Eocene and Oligocene)

- The relationships of the nematodes and their close relative groups are unresolved

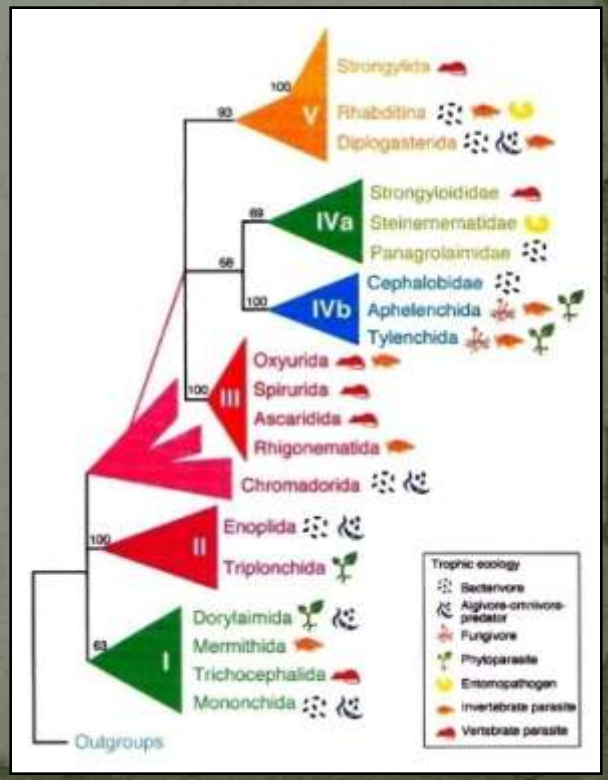
- 1990 – „Ecdysozoa hypothesis“ Nematodes form a clade together with moulting animals





- Nematode systematics is contentious
- Lack of knowledge regarding many nematodes
- Traditionally, they are divided into two classes, the Adenophorea and the Secernentea

- Initial DNA sequence studies suggests the existence of five clades
- The Secernentea are indeed a closely related natural group
- The Adenophorea appear to be a paraphyletic assemblage of nematodes



Importance of free-living nematodes

- Critical ecological roles as decomposers and predators
  - They feed on various materials – algae, fungi, small animals, fecal matter, dead organisms or living tissues
- Marine species are important members of the meiobenthos
  - Important role in the decomposition process
  - Aid in recycling of nutrients in marine environments
  - Sensitive to changes in the environment caused by pollution
- Model organism *Caenorhabditis elegans*
  - Entire genome sequenced
  - Developmental fate of every cell determined
  - Every neuron mapped

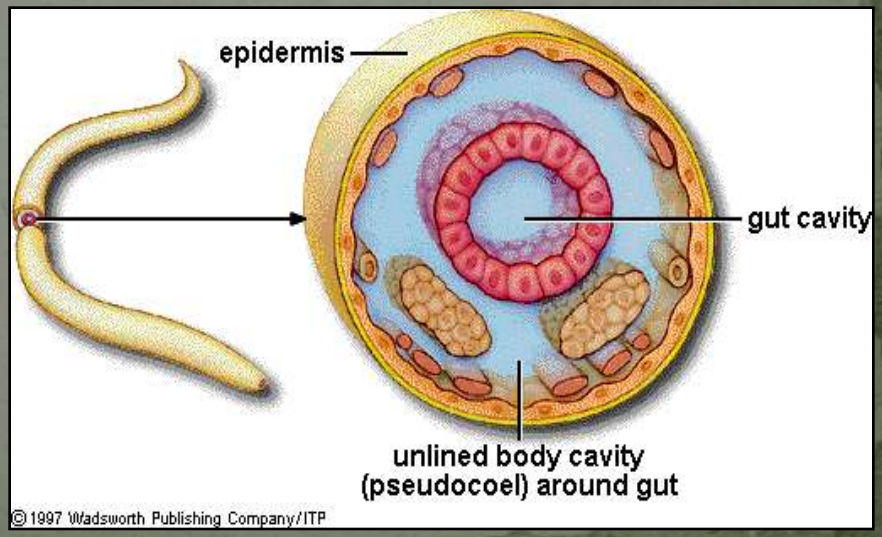
Importance of parasitic nematodes

- Medically important species
  - ☹ Many nematodes cause worldwide economic losses in livestock production
  - ☹ Some of them are implicated in important animal disorders
  - ☹ Some nematodes are causative agents of severe human diseases and are responsible for many deaths worldwide
  - ☺ Some species can be used in the treatment of human syndromes and diseases (IBD)
  - ☺ Enthomopathogenic nematodes parasitize insects which are considered by humans to be beneficial

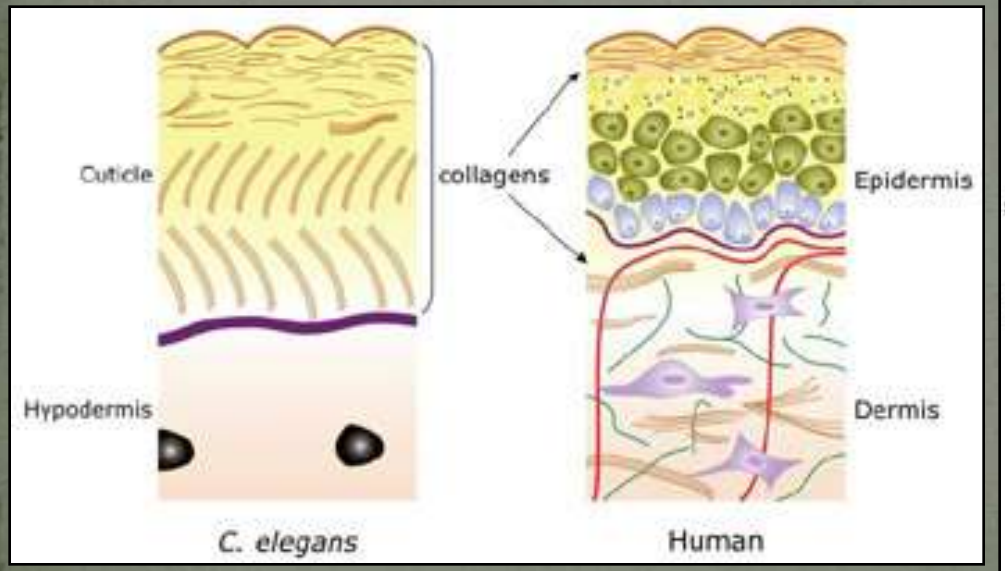
- Plant parasitic nematodes
  - ☹ Several groups cause severe crop losses
  - ☹ Several phytoparasitic nematode species cause damage to roots
  - ☹ Some nematode species transmit plant viruses through their feeding activity
  - ☹ Other nematodes attack bark and forest trees
  - ☺ Predatory nematodes may be beneficial to plant health

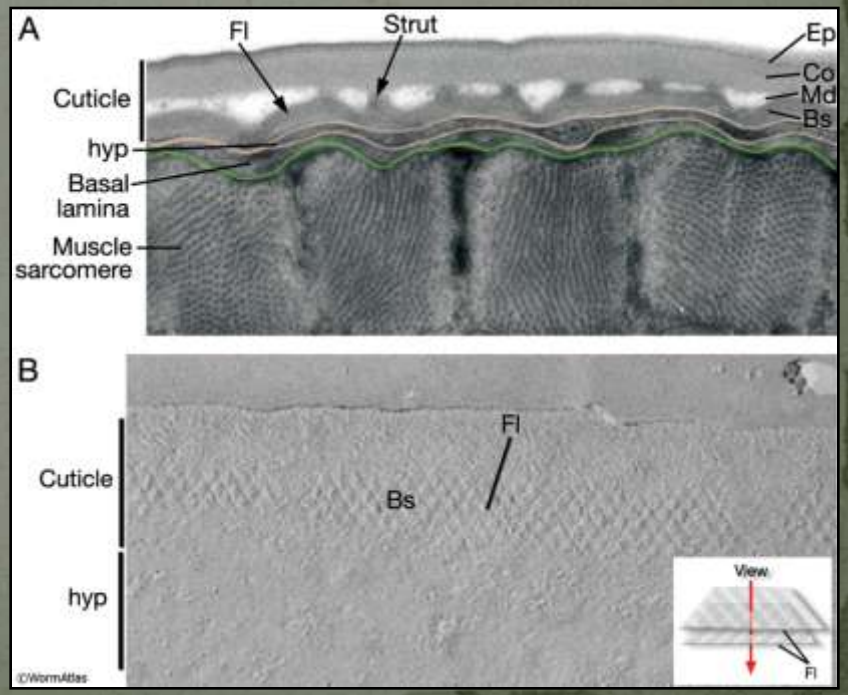
Surface morpholohy

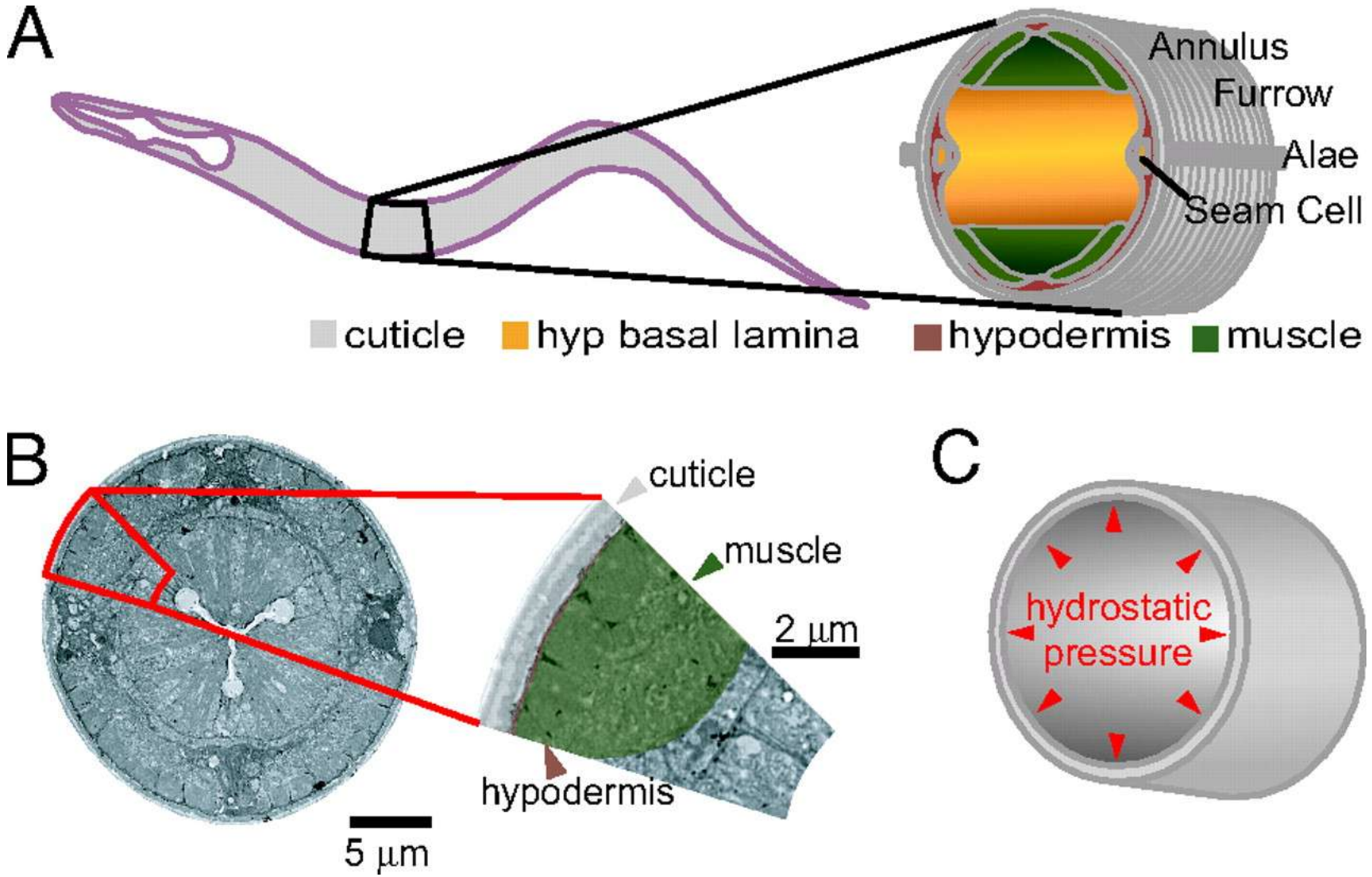
- Most nematodes are reasonably small in size, from 100 μm in length up to 1 metre (female Giant Nematode *Dioctophyme renale*)
- The body is long and narrow, resembling a tiny thread
- Nematodes are round in cross section (roundworms)
- The body cavity is referred to as a pseudocoel, small, mostly filled with an intestine and reproductive organs



- The „skin“ (hypodermis) of a nematode secretes a thick outer noncellular layer (cuticle)
  - Protective function – tough and flexible
  - Permeable to both water and gases, so respiration occurs through it
  - The cuticle is periodically shed during its lifetime, as it grows

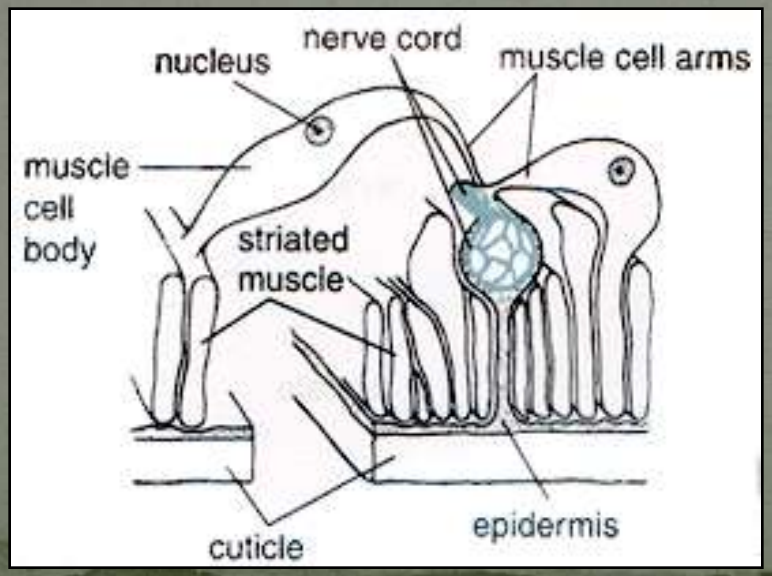


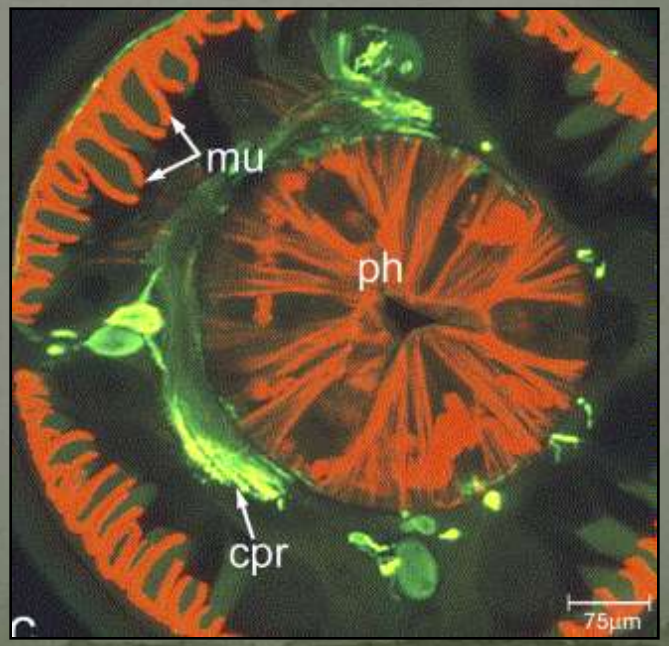



A
Annulus
Furrow
Alae
Seam Cell
cuticle
hyp basal lamina
hypodermis
muscle
B
cuticle
muscle
2 μm
hypodermis
5 μm
C
hydrostatic
pressure

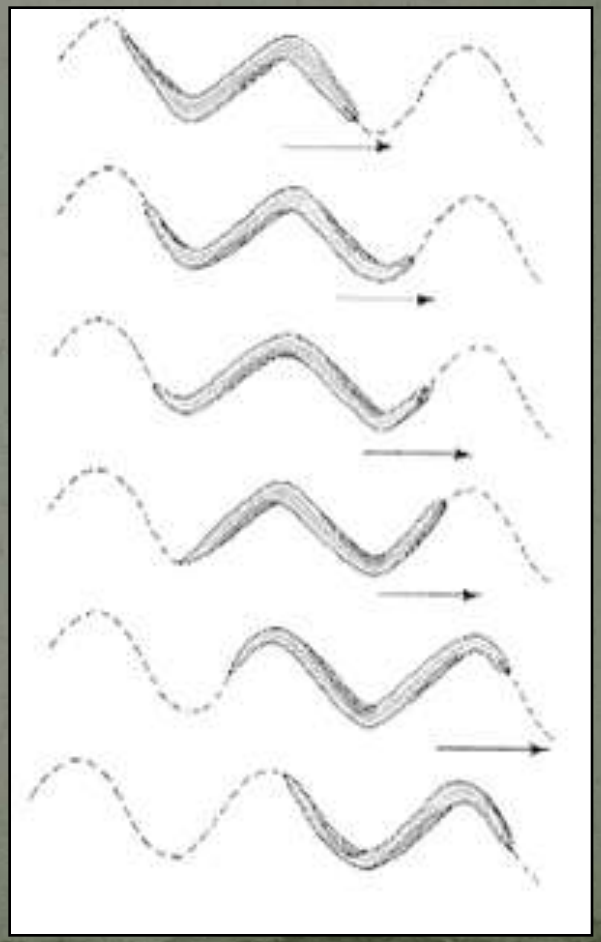
Nematode locomotion

- No cilia or flagellae are present
- Long muscles lie just underneath the hypodermis
  - They are aligned longitudinally along the inside of the body
  - The muscles are activated by two nerves on both the dorsal and ventral side



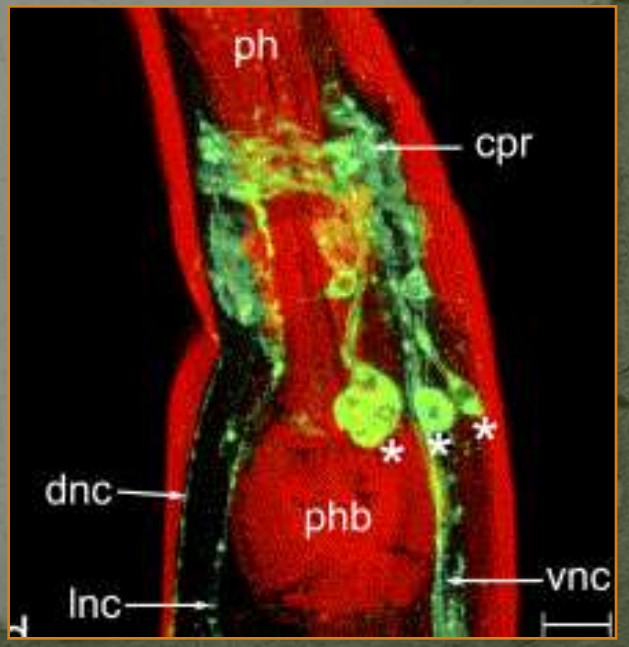


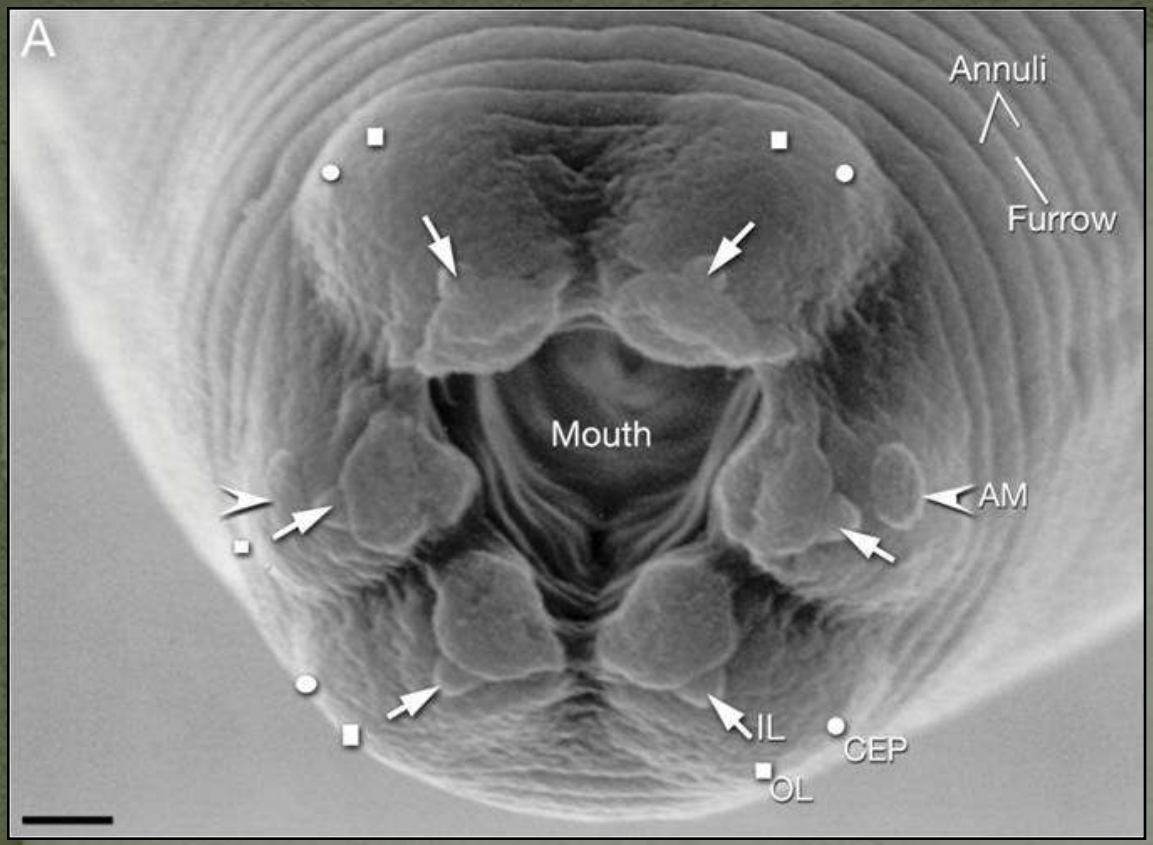
- Characteristic whip-like wriggle locomotion called undulatory propulsion (wave-like motions)
  - The combination of dorsal/ventral contractions of the body
  - The muscles are able to contract/relax accordingly by use of the pressure changes throughout the fluid skeletal space of the pseudocoel

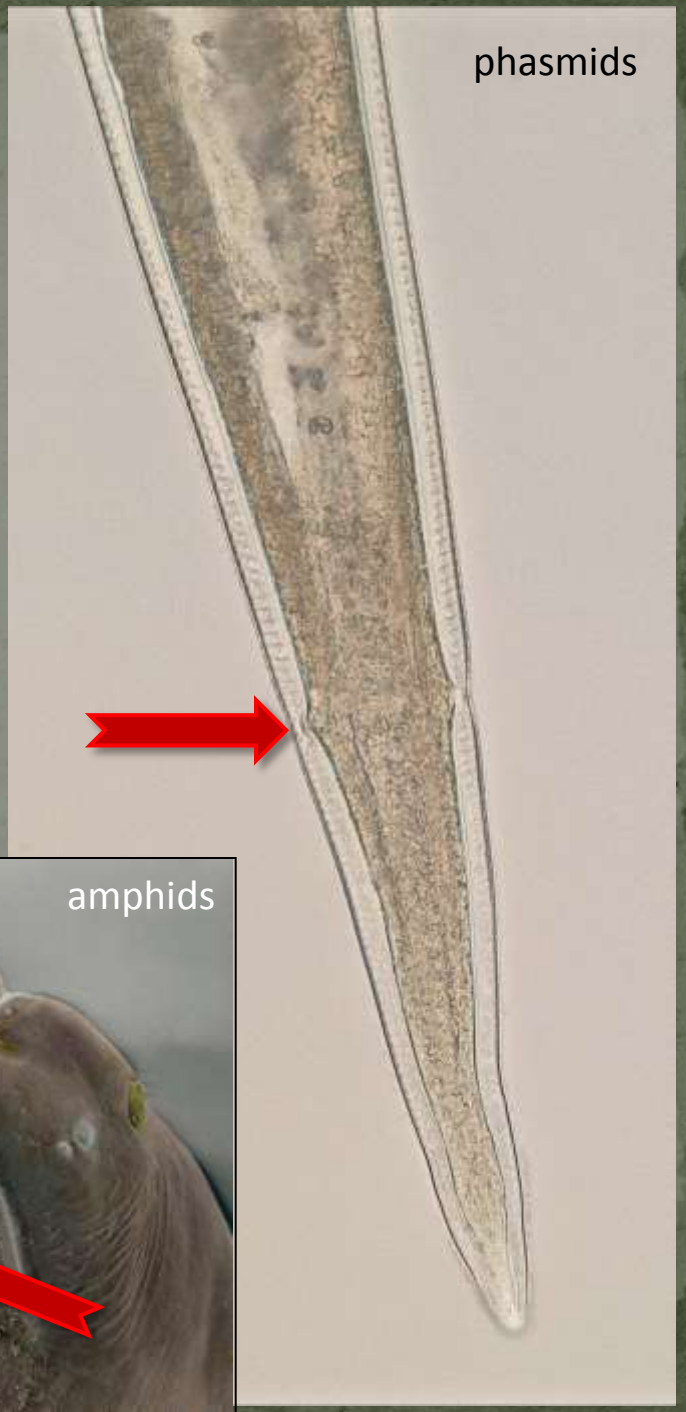


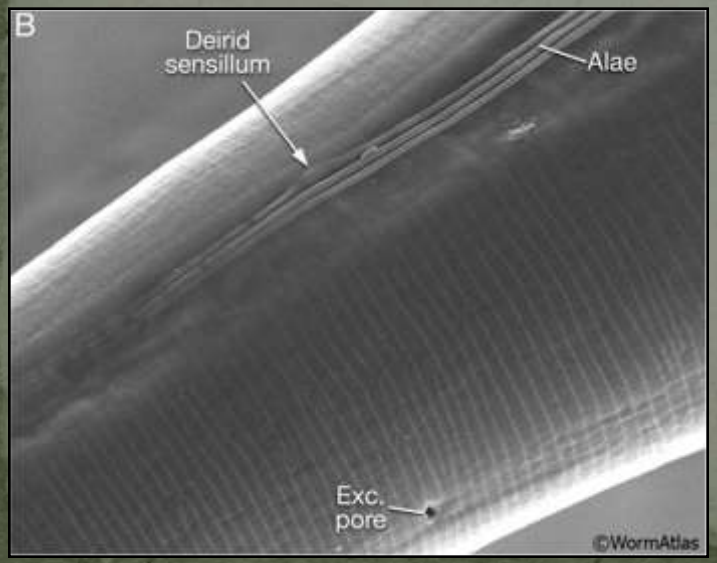
Nervous system

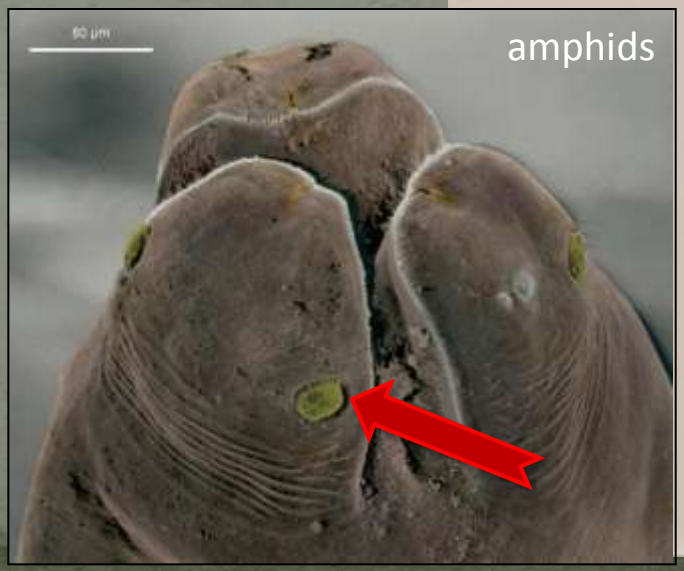
- Comprised of a circum-pharyngeal nerve ring
  - 4 nerve ganglia from which 6 longitudinal nerves extend down through the body to the various parts of the gut and the reproductive organs
  - 6 shorter nerves which extend forward from the circum-pharyngeal ganglia towards the mouth
- A few tiny sense organs
  - amphids on the head, near the labia
  - deirids close to nerve ring
  - phasmids on tail end, used for determination



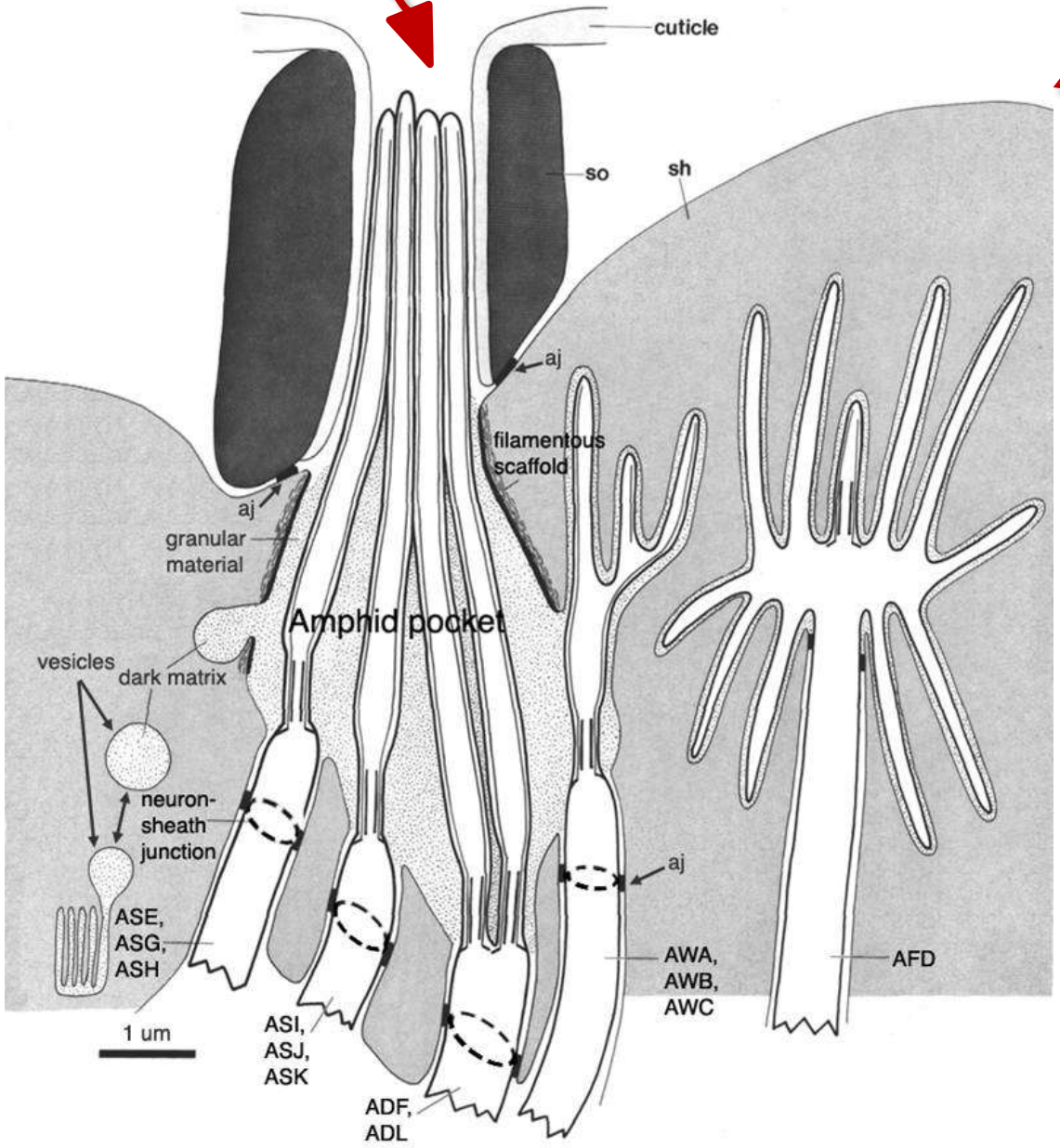

A
Annuli
Furrow
Mouth
AM
IL
CEP
OL

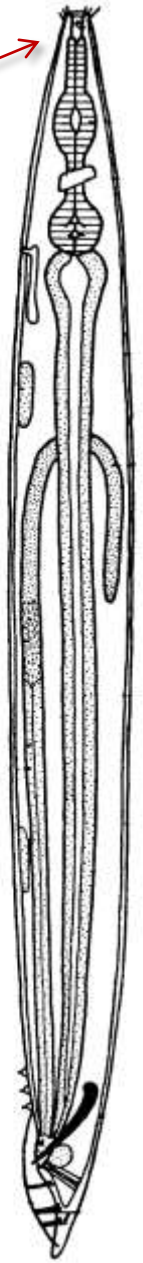

phasmids


B
Deirid sensillum
Alae
Exc. pore
©WormAtlas


amphids

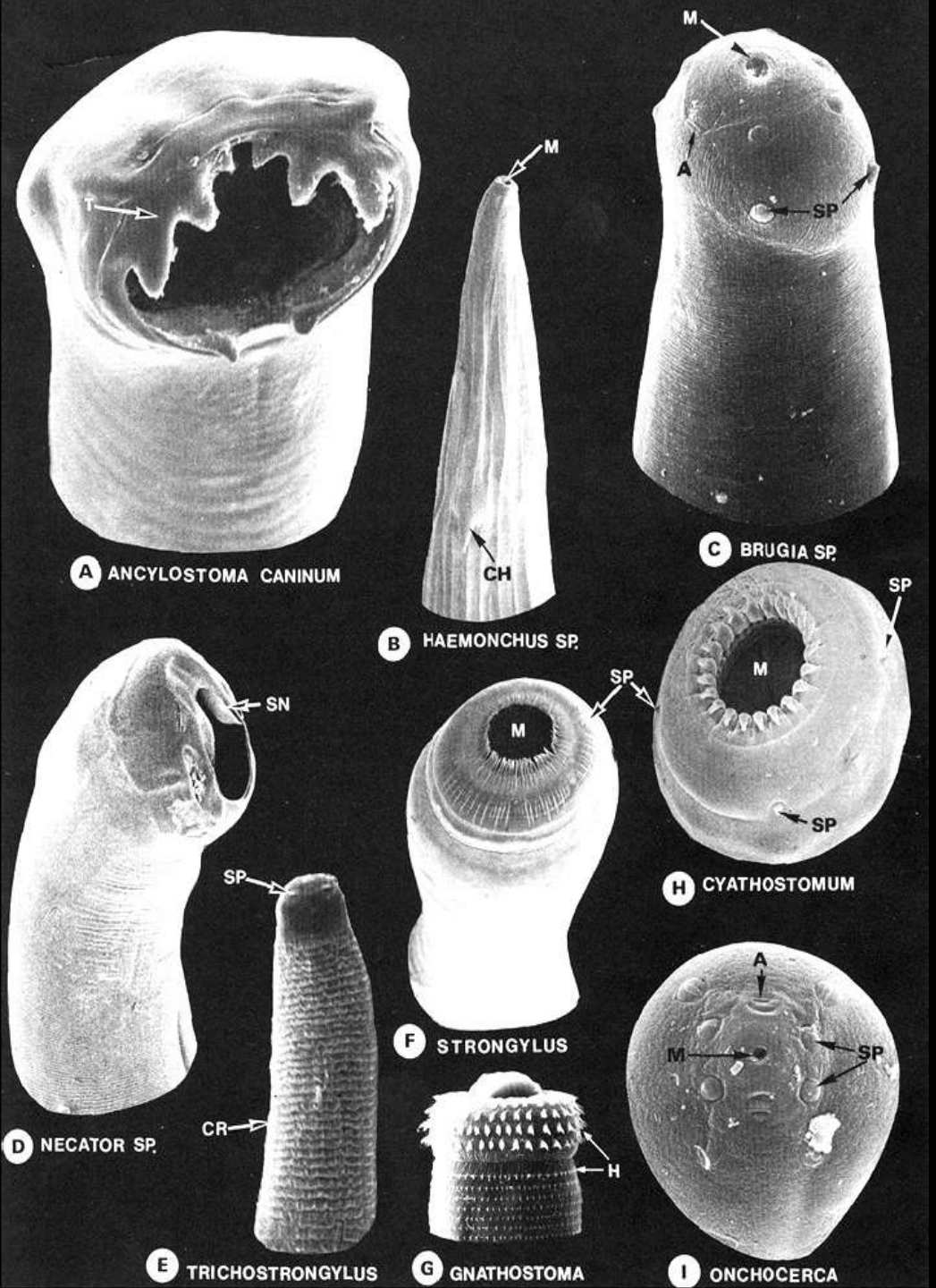
Amphid structure

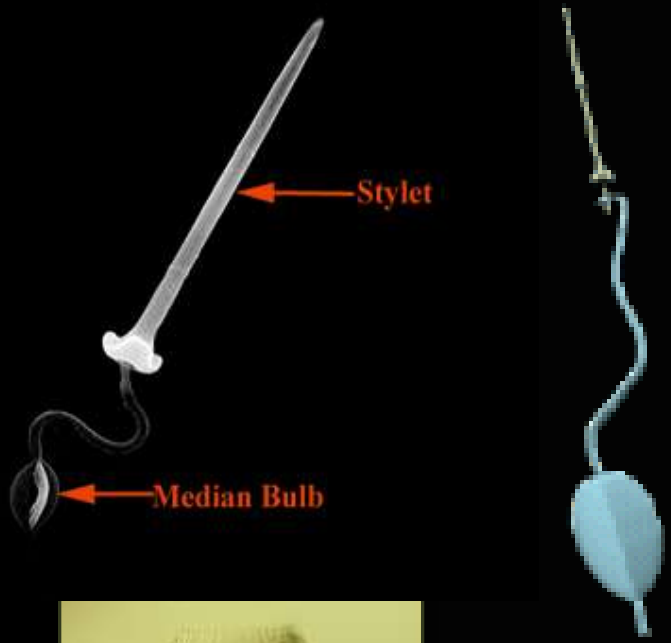


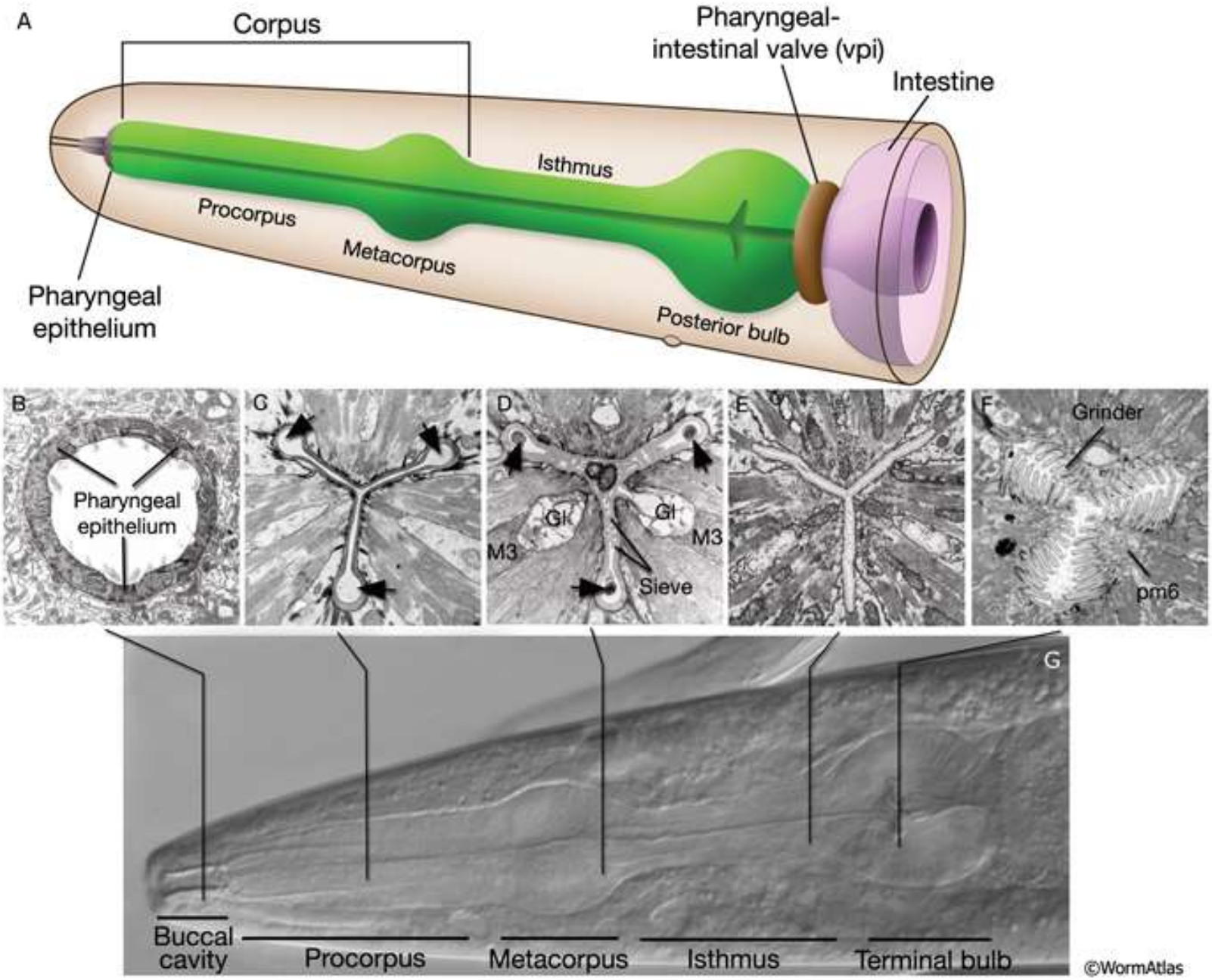


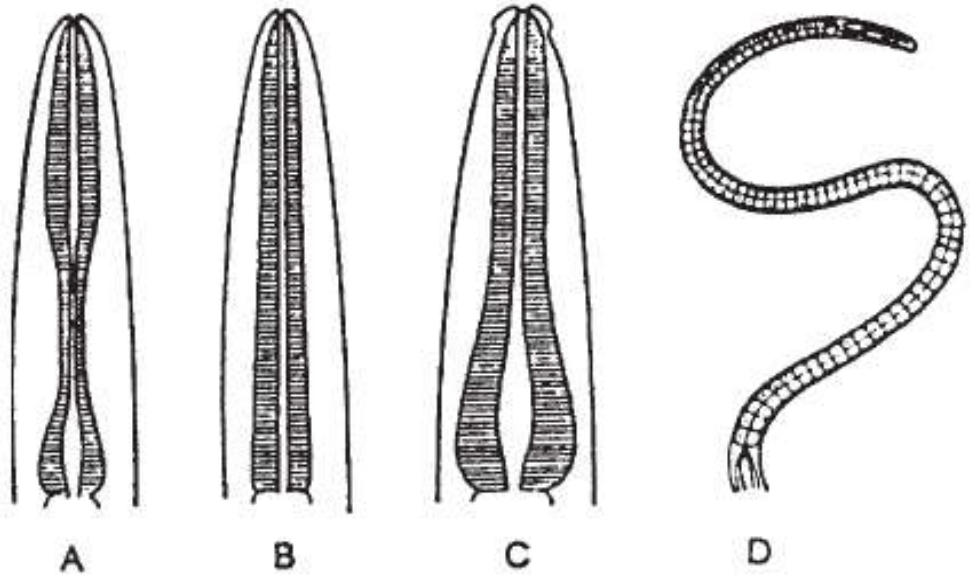
Feeding

- Mouth located at the anterior end (head)
- According to feeding behaviour there are specific structures which facilitate food intake (labias, buccal capsule, teeth, stylet)
- Muscular pharynx (throat) which is triangular in cross section, food is pulled in and crushed
  - There are 4 types of pharynx according to feeding behaviour
  - Pharynx is an efficient pump and forces food into the intestines
- Digestion is rapid and faeces are expelled under pressure


A ANCYLOSTOMA CANINUM
M
CH
B HAEMONCHUS SP.
M
A
SP
C BRUGIA SP.
SN
D NECATOR SP.
SP
CR
E TRICHOSTRONGYLUS
M
SP
F STRONGYLUS
M
SP
SP
H CYATHOSTOMUM
H
G GNATHOSTOMA
A
M
SP
I ONCHOCERCA

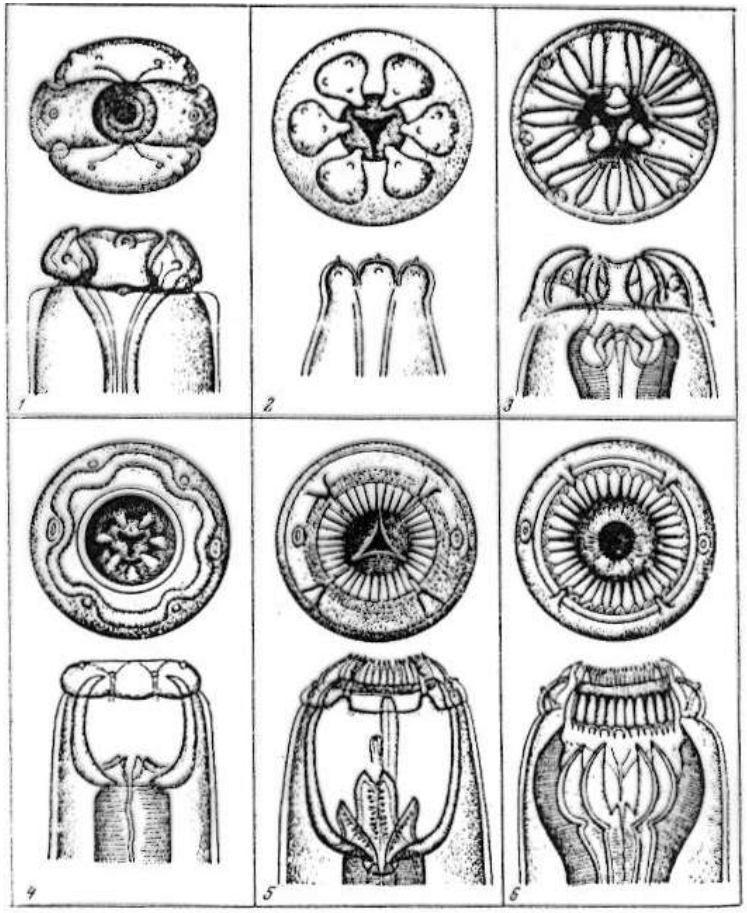

Stylet
Median Bulb

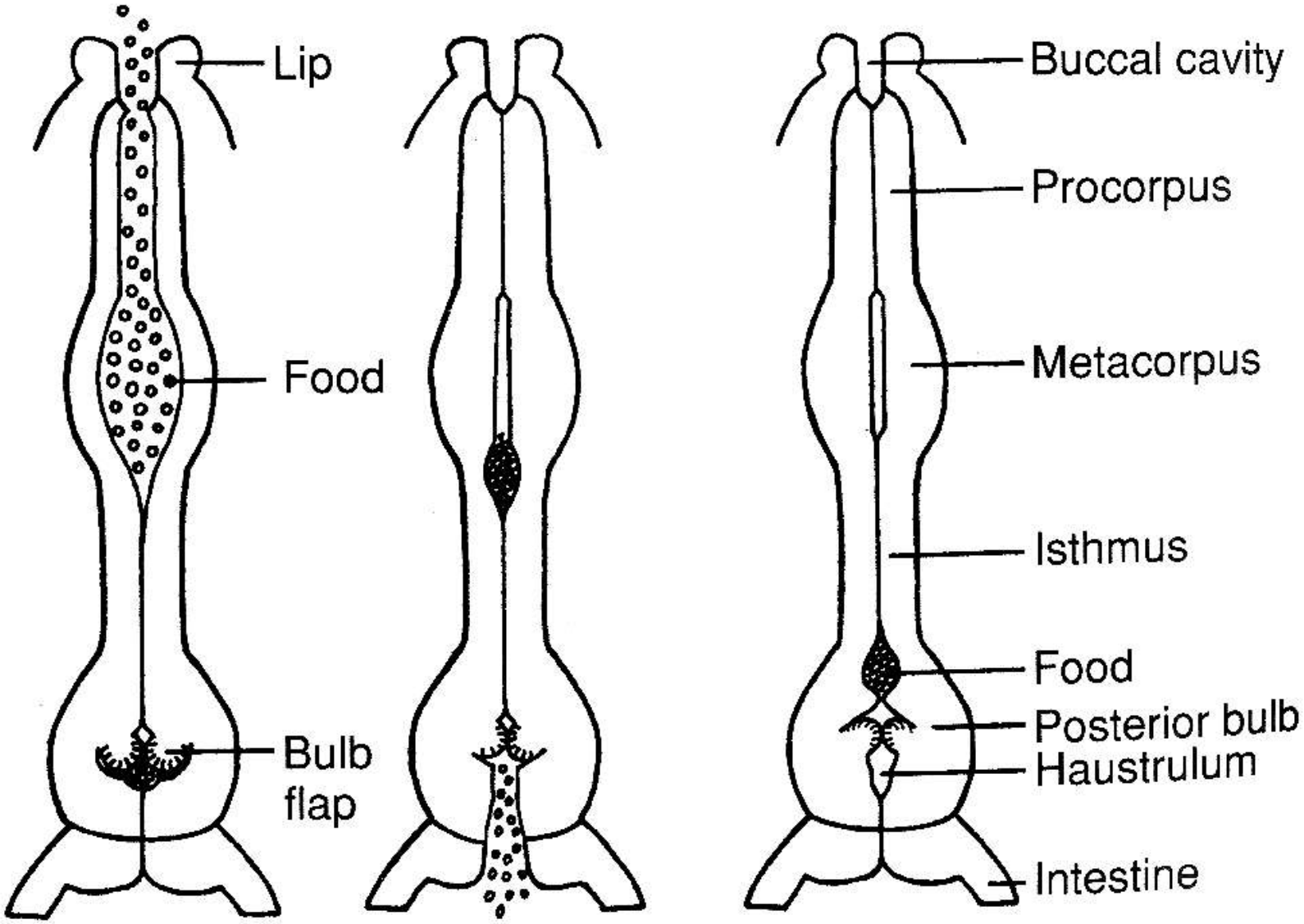

A
Corpus
Pharyngeal-
intestinal valve (vpi)
Intestine
Isthmus
Procorpus
Metacorpus
Pharyngeal
epithelium
Posterior bulb
B
Pharyngeal
epithelium
C
D
Gl
Gl
M3
M3
Sieve
E
F
Grinder
pm6
G
Buccal
cavity
Procorpus
Metacorpus
Isthmus
Terminal bulb
©WormAtlas

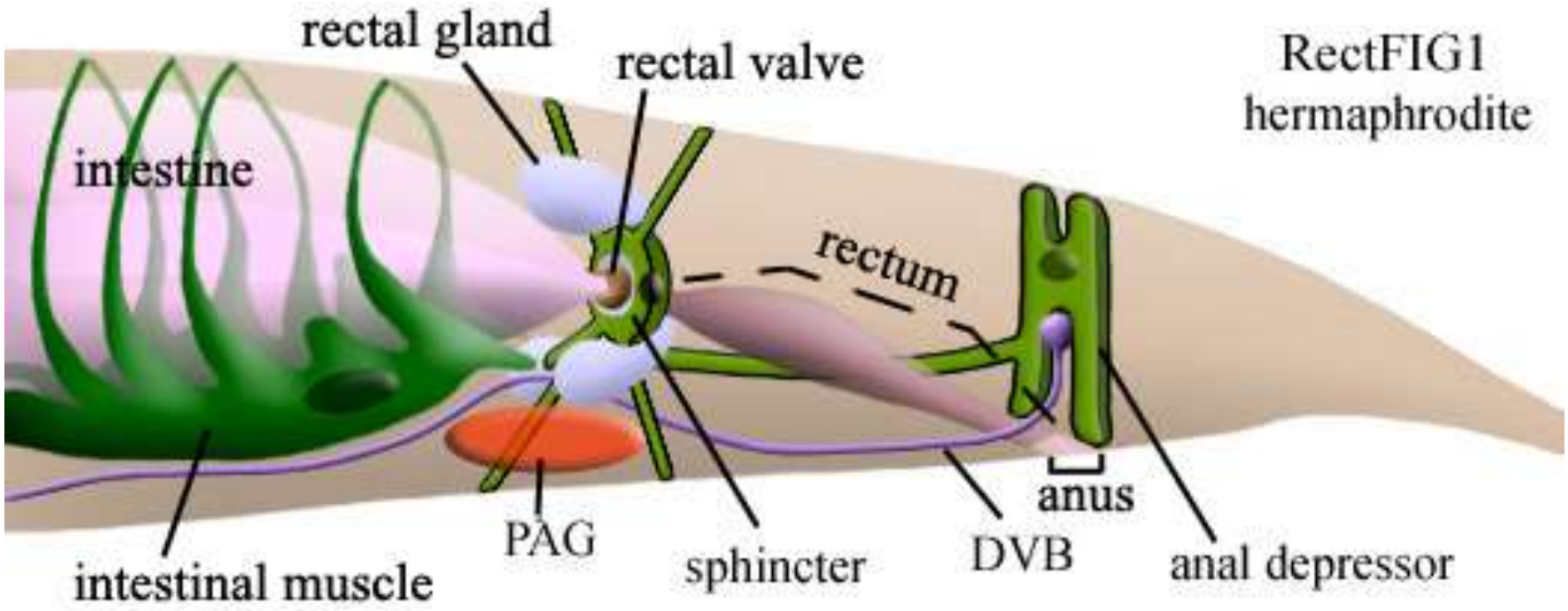


Types of esophagus:

A. Rhabdiform
B. Strongyliform (filariform)
C. Oxyuroideal
D. Stichosome

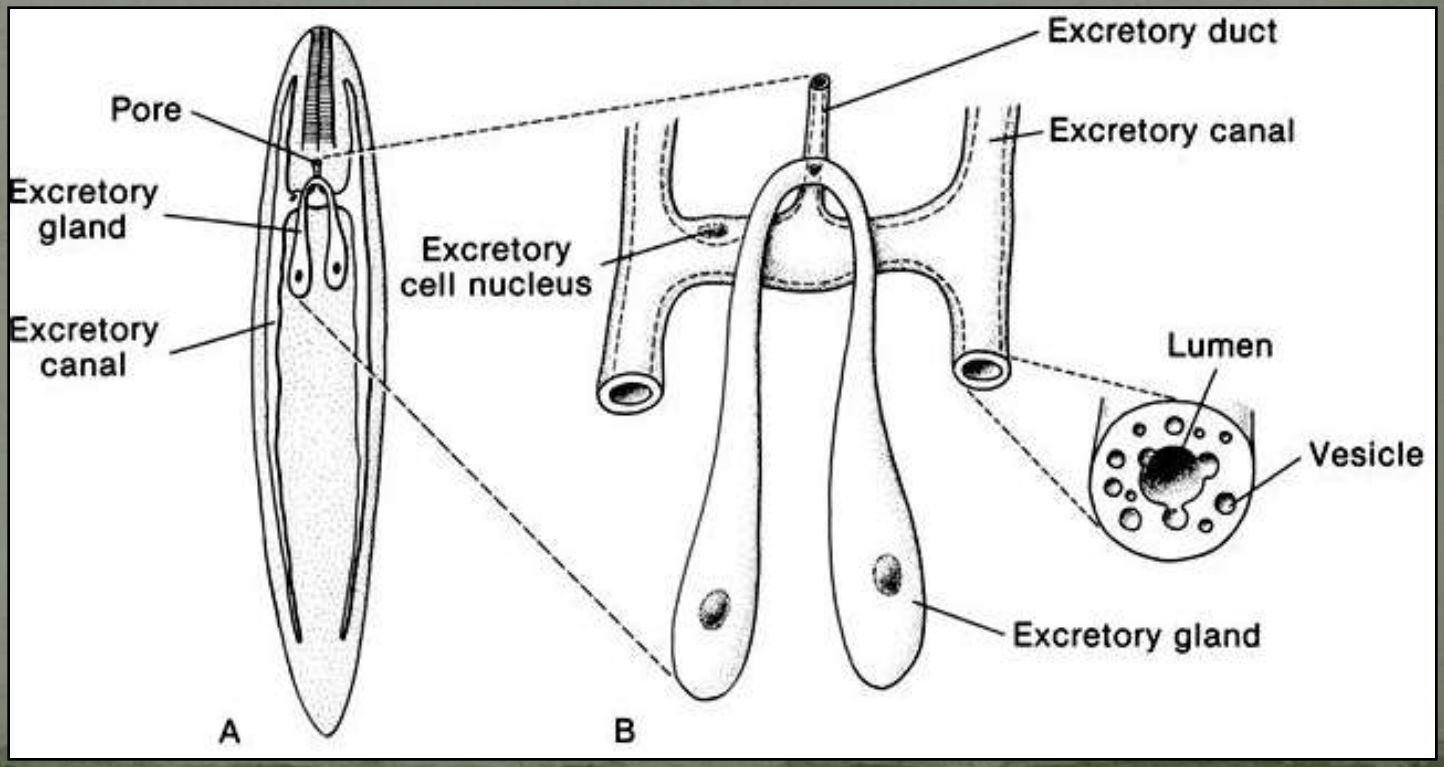


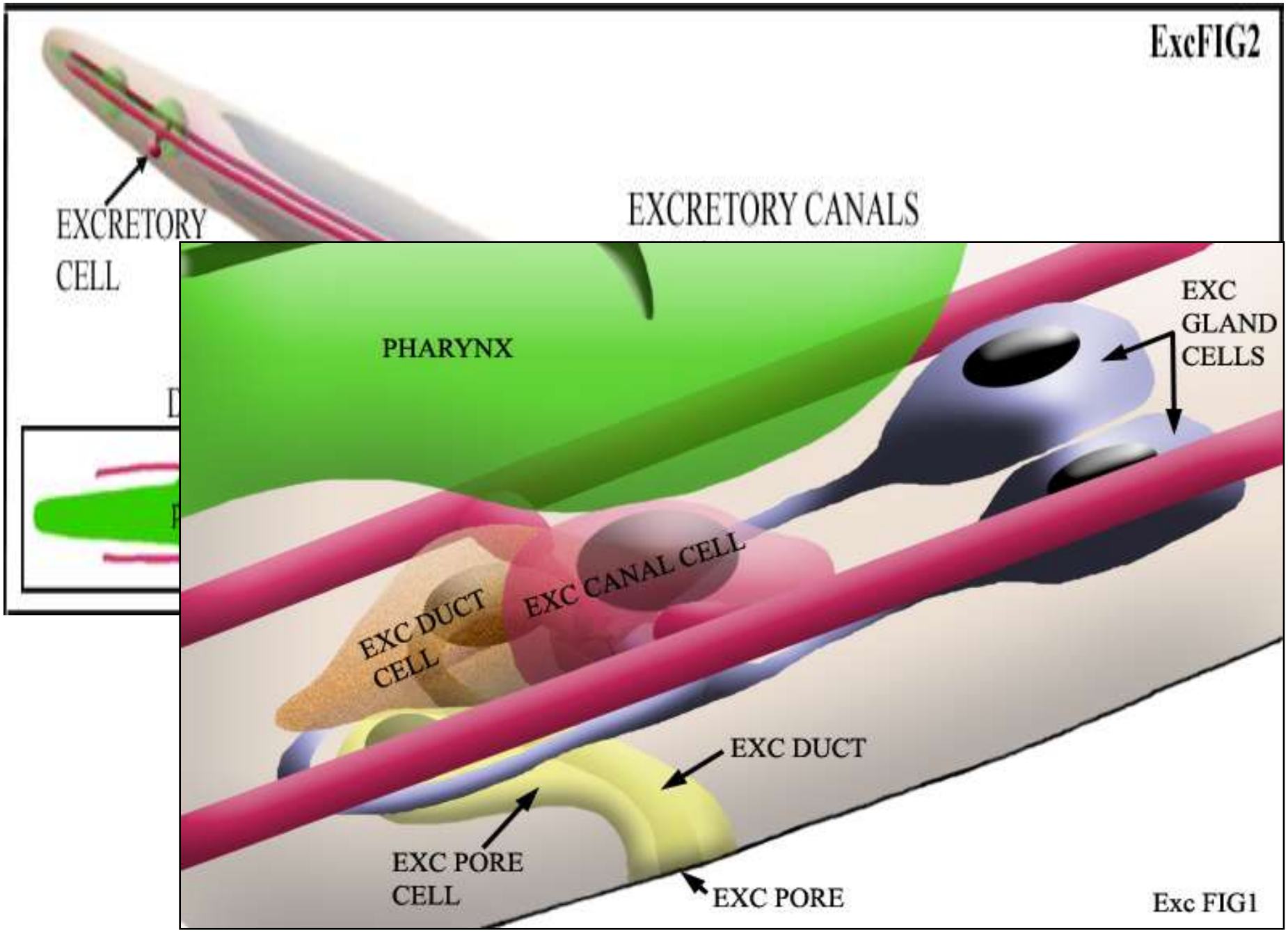

Lip
Food
Bulb
flap
Buccal cavity
Procorpus
Metacorpus
Isthmus
Food
Posterior bulb
Haustrulum
Intestine


rectal gland
rectal valve
RectFIG1
hermaphrodite
intestine
rectum
anus
PAG
sphincter
DVB
anal depressor
intestinal muscle

Excretory system

- Excretion of metabolic waste is via two simple ducts (excretory canals)
- Excretory gland cells present, no nephridia or flame cells

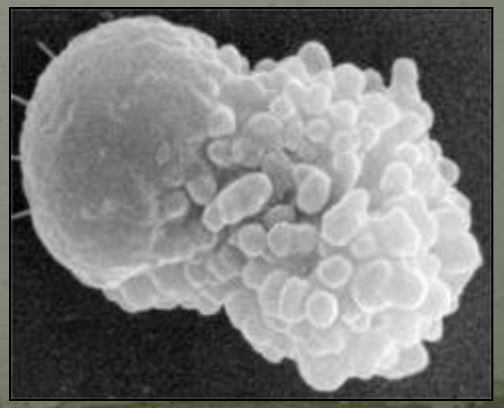



ExcFIG2
EXCRETORY CELL
EXCRETORY CANALS
PHARYNX
EXC GLAND CELLS
EXC DUCT CELL
EXC CANAL CELL
EXC DUCT
EXC PORE CELL
EXC PORE
Exc FIG1

Reproduction

- Reproduction is usually sexual
- Gonochorists with marked sexual dimorphism

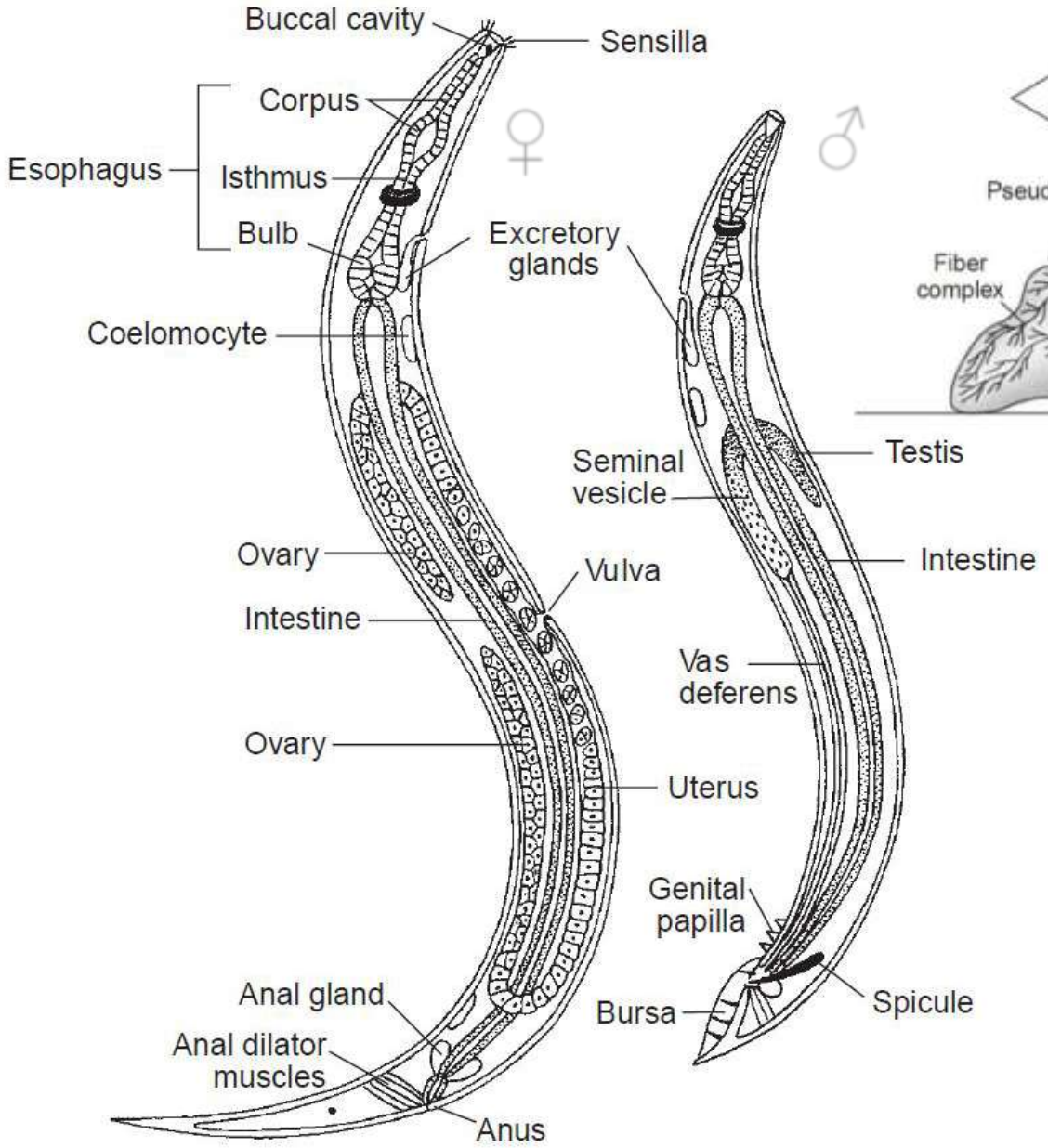
- Males are usually smaller than females and often have a characteristically bent tail end
  - Accessory copulatory organs mostly present: bursa copulathrix, spicules, genital papillae, gubernaculum and telamon
  - The sperm are unique
    - They lack flagellae and move by pseudopodia
    - The only eukaryotic cells without actin

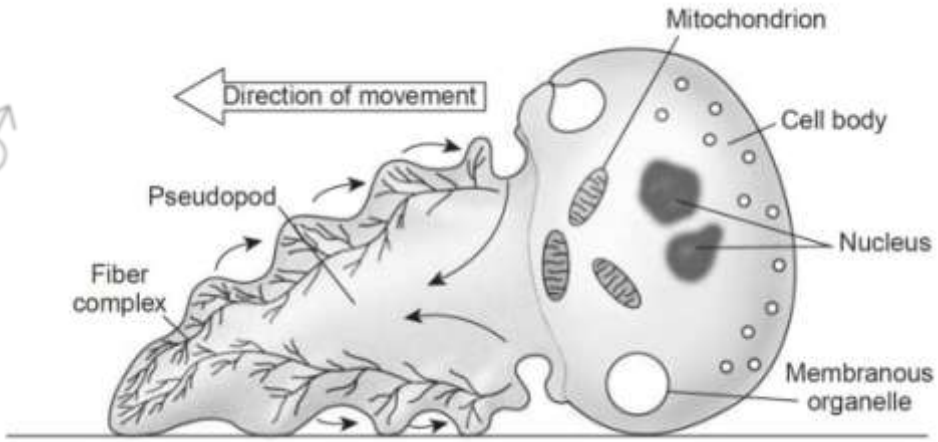


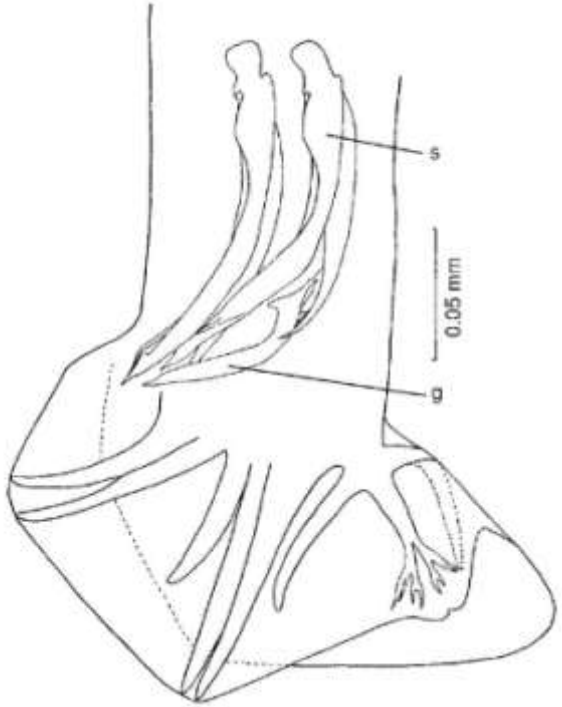
- Females are mostly oviparous, eggs may be embryonated or unembryonated when passed by the female
- The vagina opens into a vulva mostly in the first third or half of the body

- Nematodes possess a wide range of reproduction modes: hermaphroditic species, parthenogenesis, amphimixis, traumatic insemination, ovovipary or vivipary

Nematode morphology





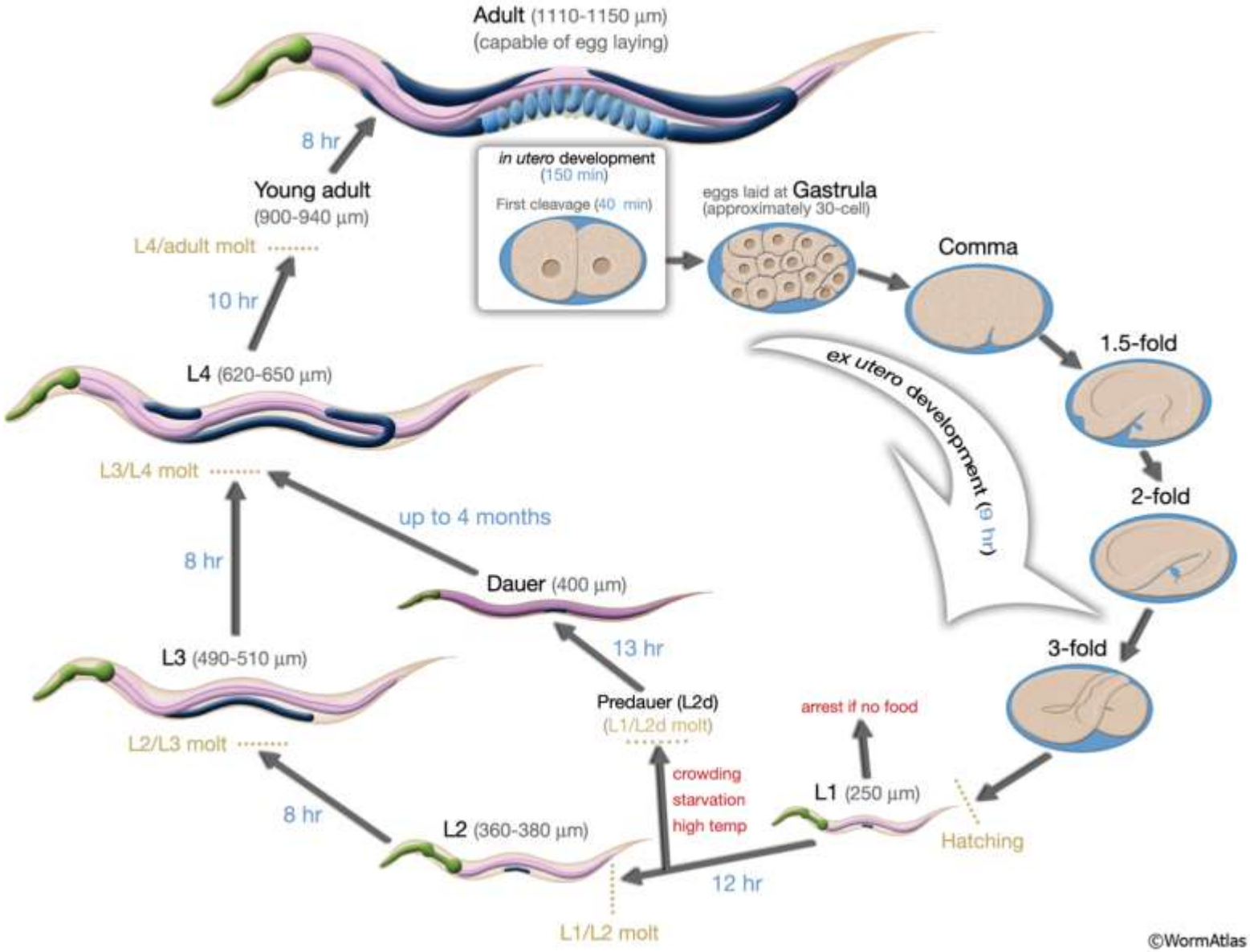


Development

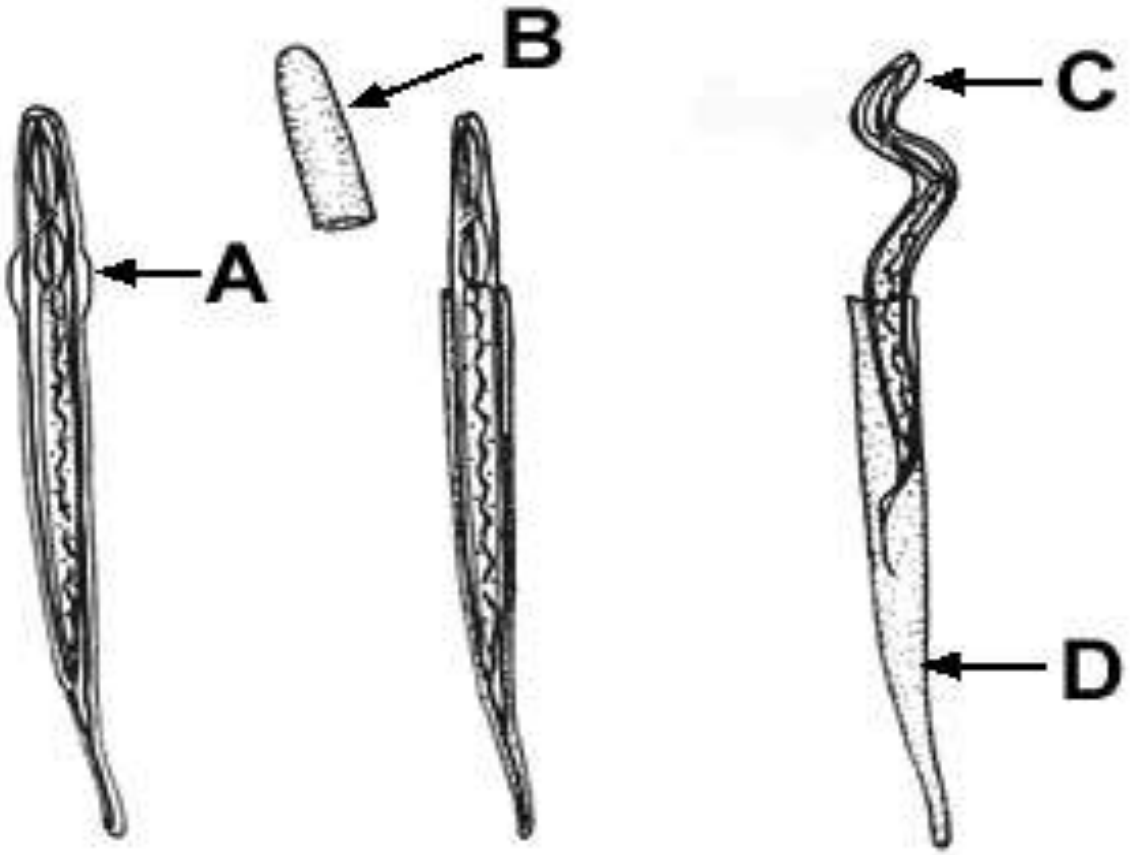
- Usually direct life cycles, indirect development in some species
- The egg hatches into the larva
- 4 larval stages L_1, L_2, L_3, L_4
- 4^{th} larval stage molt into adult nematode

- Developmental adaptation: arrested development of trichostrongylid nematodes, dauer larva in free-living soil nematodes

Nematode development

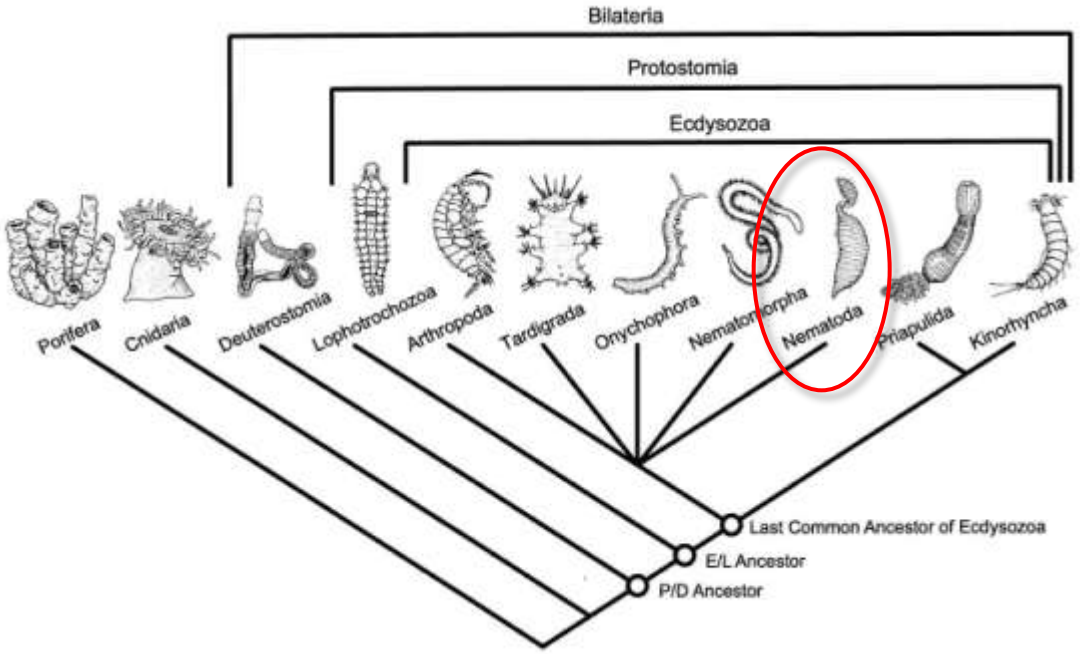


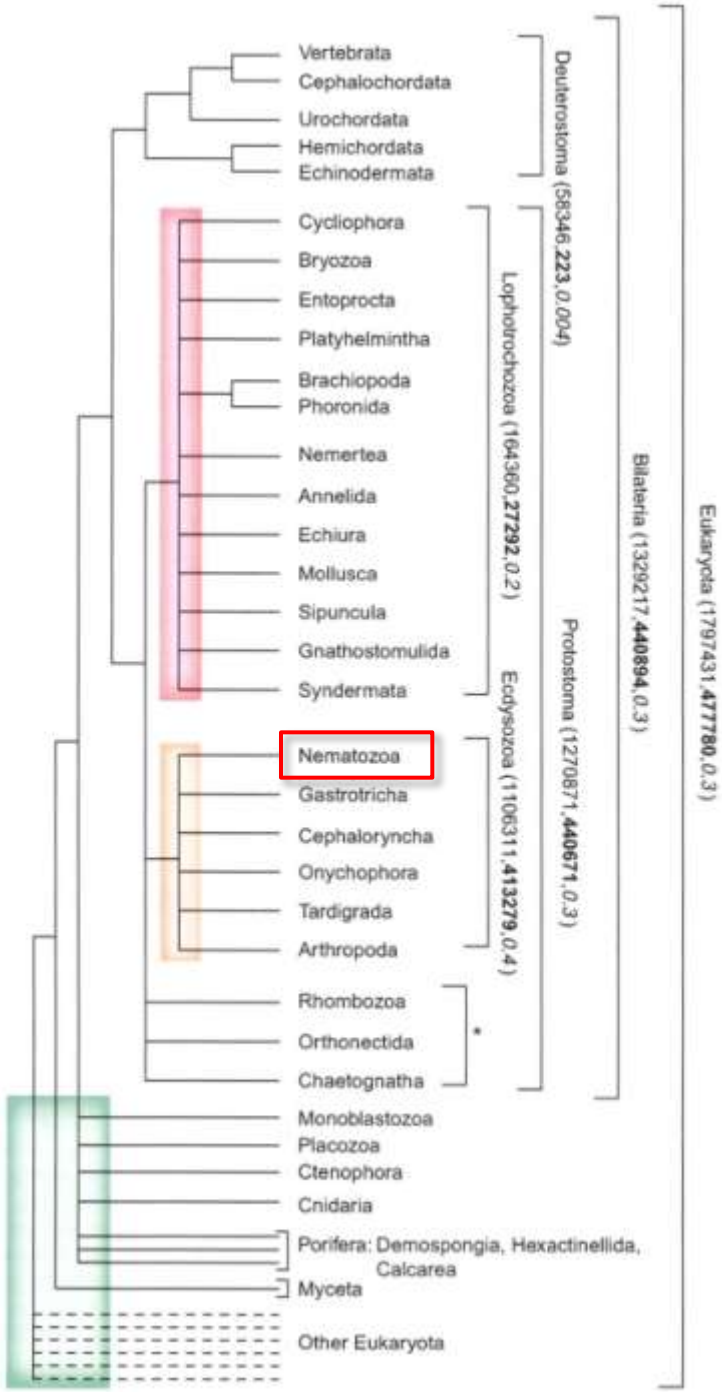
Exsheathment



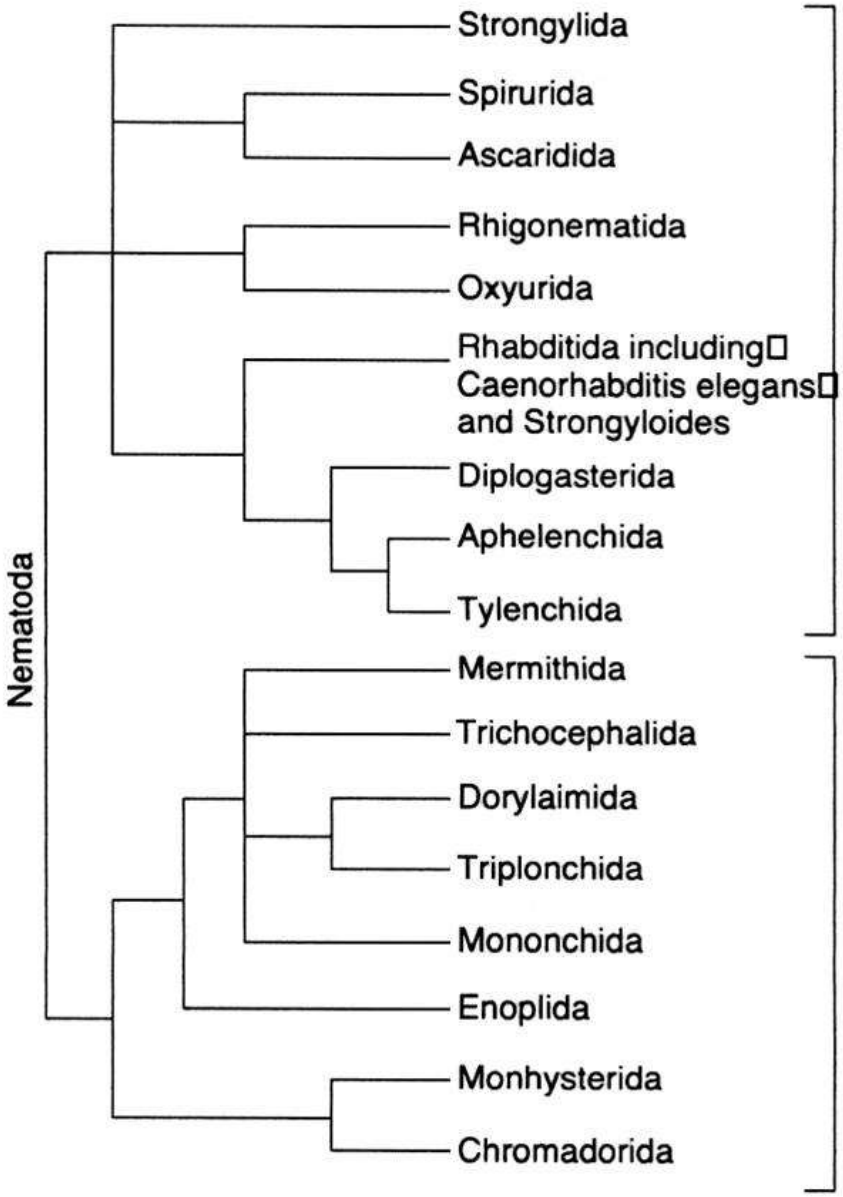
Nematode systematics

Phylogenetic relationships within metazoans



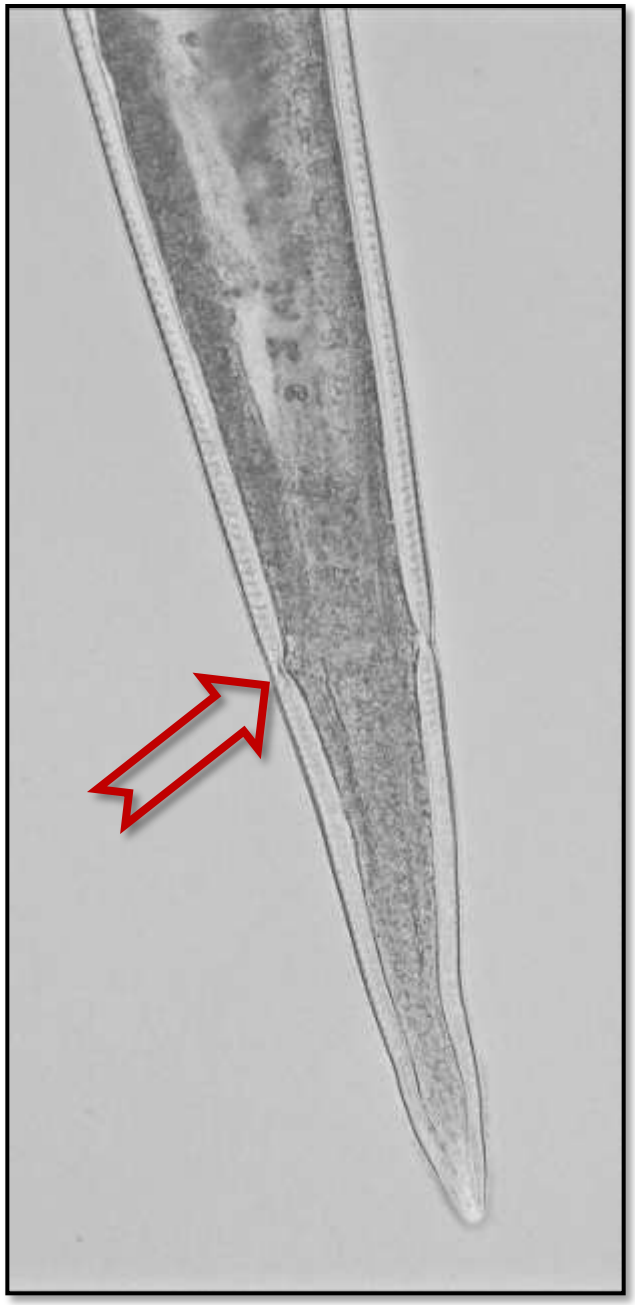


Sense organs – phasmids

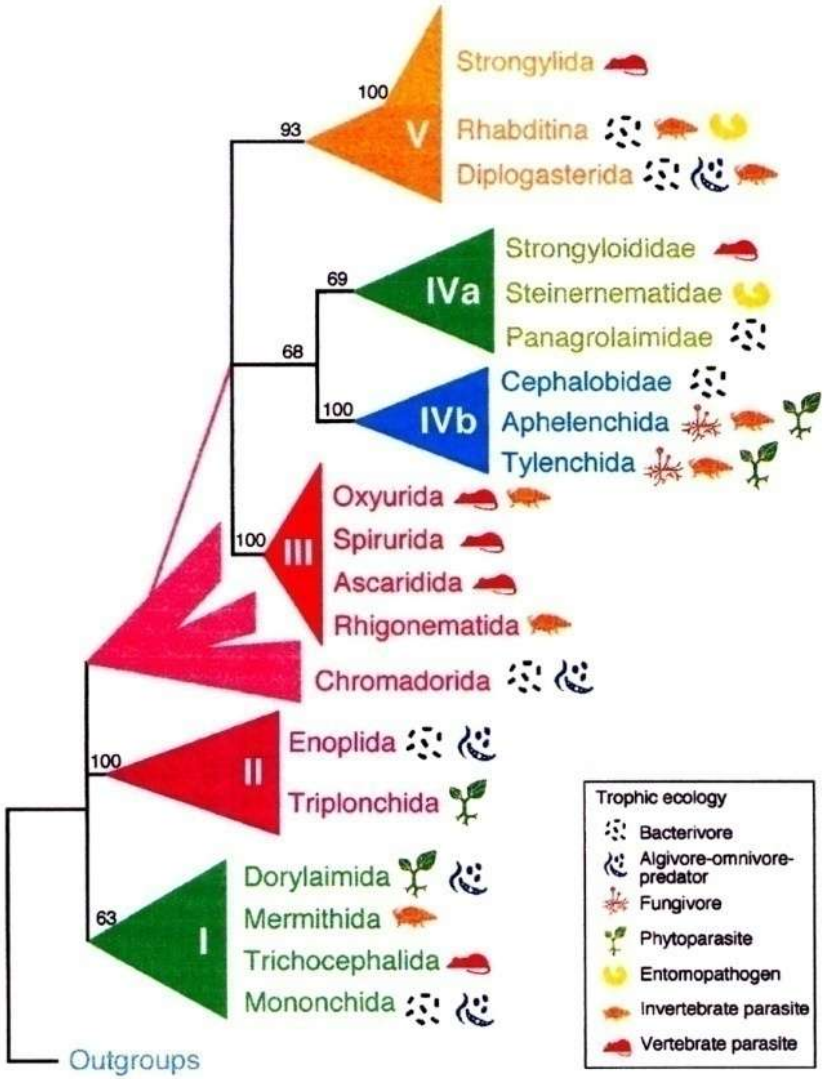


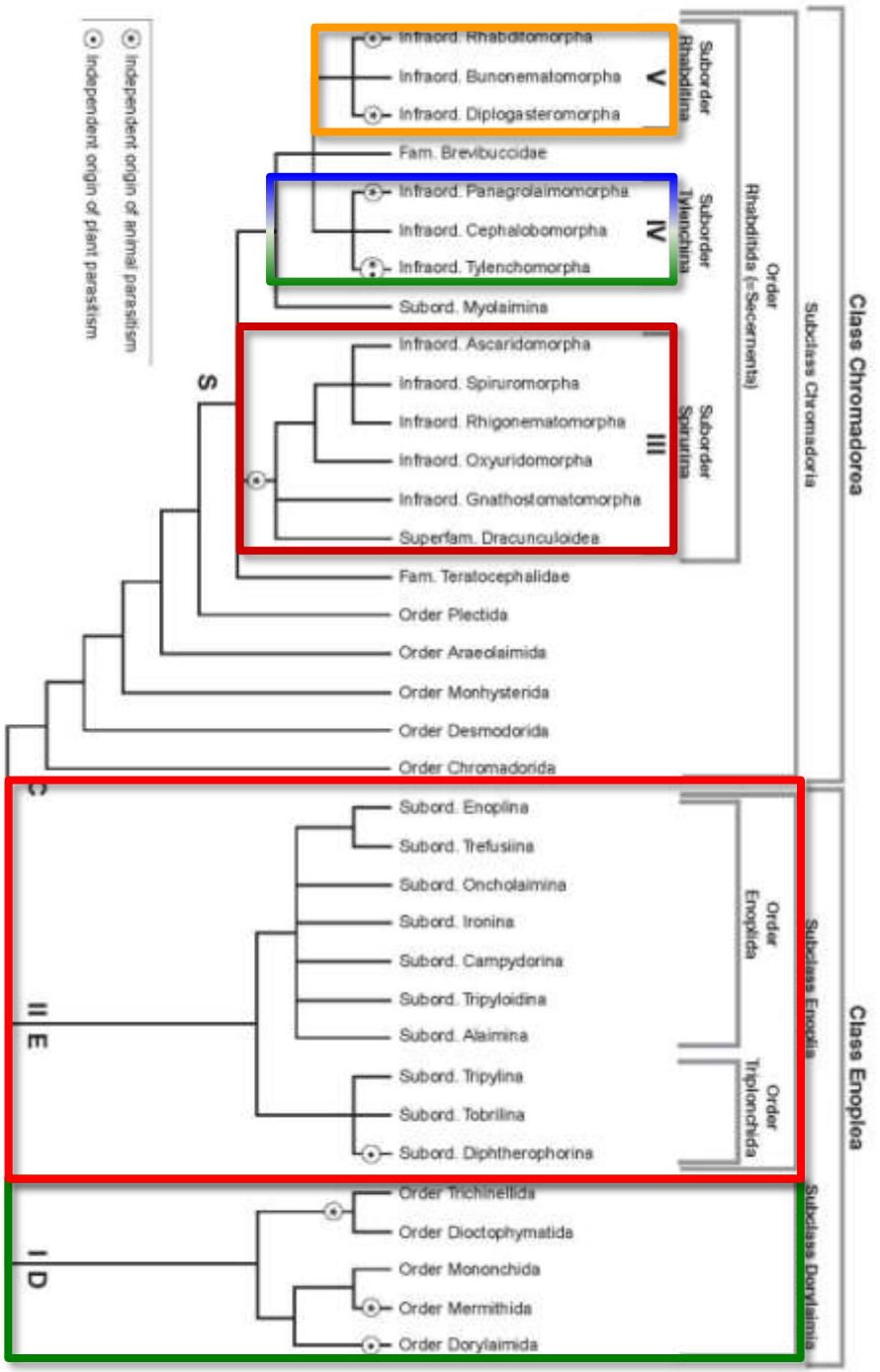
Secernentea
= Phasmidea

Adenophorea
= Aphasmidea

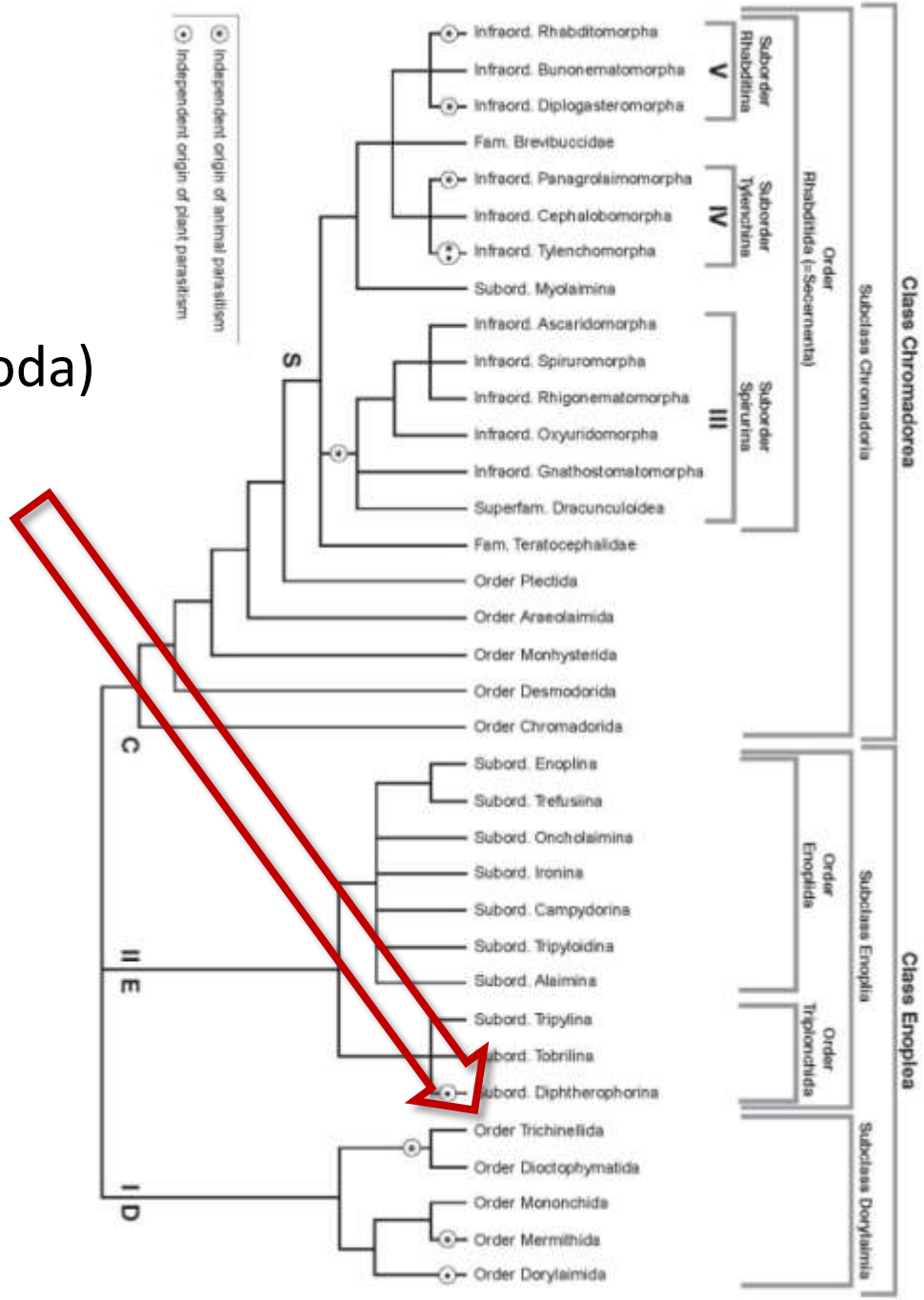


„New“ phylogenetics relationships within nematodes





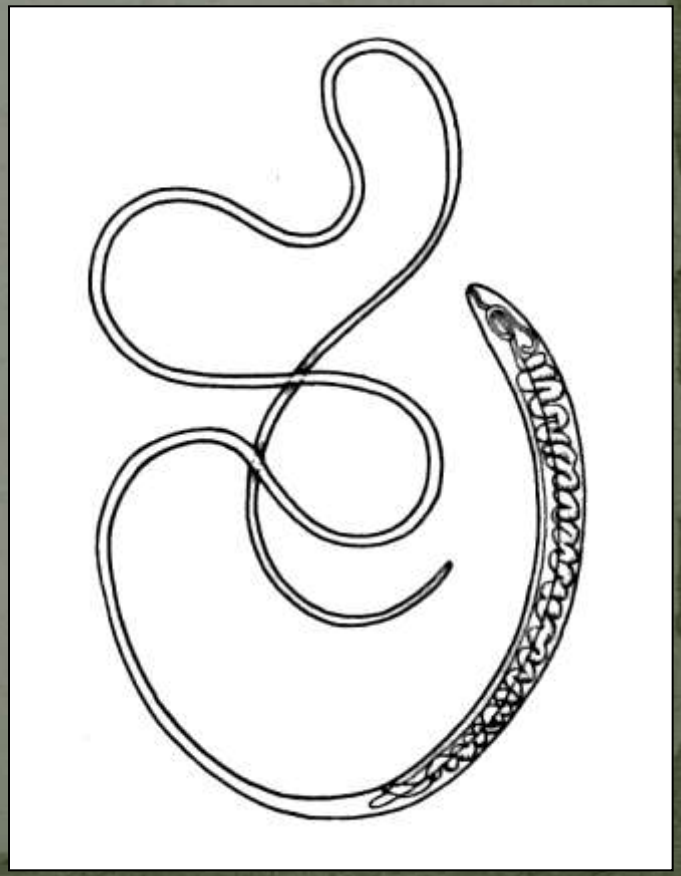
Kingdom: animals (Animalia)
Phylum: nematodes (Nematoda)
Class: Enoplea
Subclass: Dorylaimia



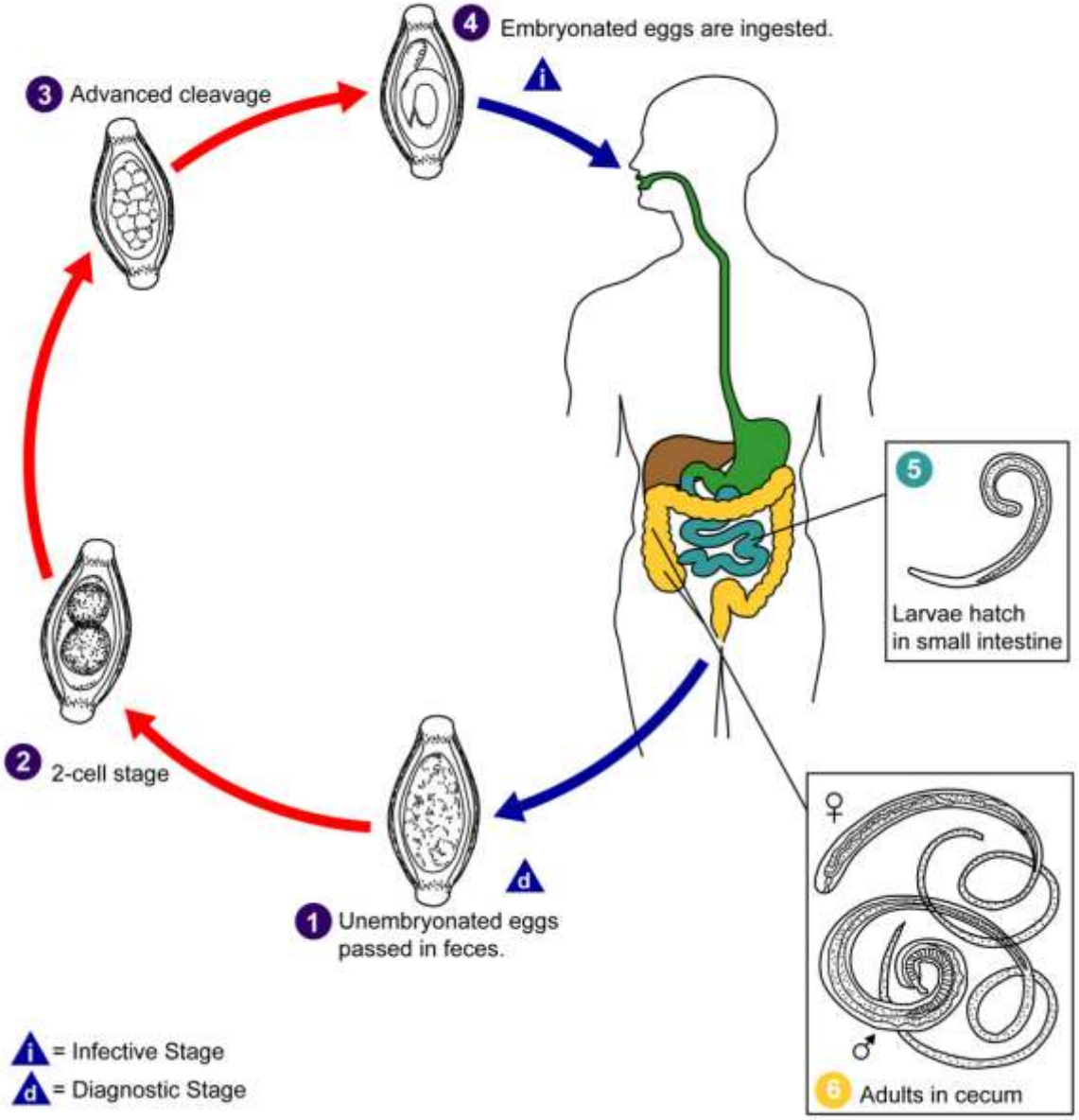
Whipworms

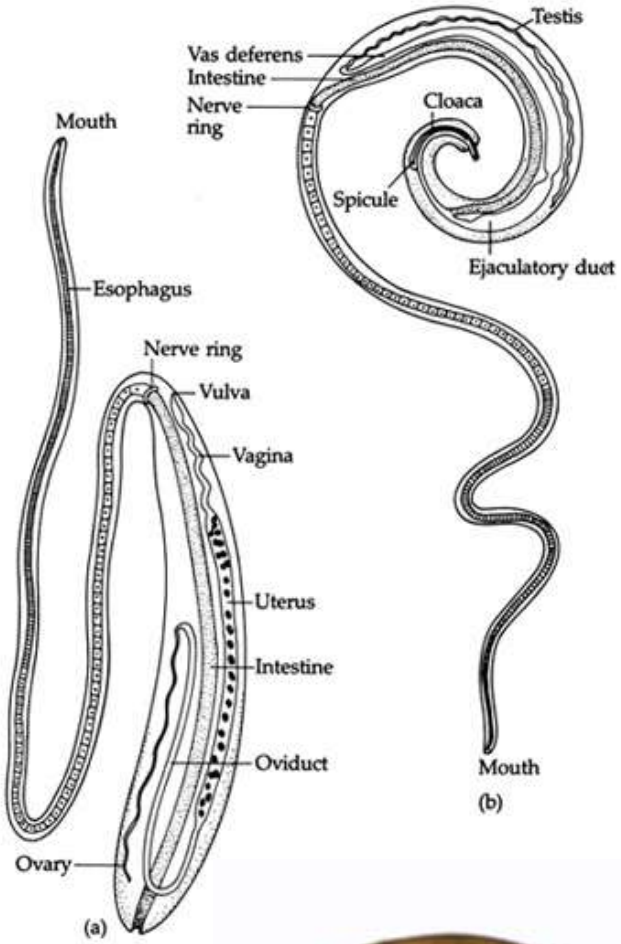
- There is one human whipworm (*Trichuris trichiura*) and some species infecting animals – dog whipworm (*Trichuris vulpis*), swine whipworm (*Trichuris suis*) and *Trichuris ovis* in sheep

  - Narrow anterior end with shorter and thicker posterior anus
  - They attach to the host large intestine mucosa through their slender anterior end and feed on tissue secretions instead of blood
  - Their characteristic eggs are barrel-shaped, brown, and have bipolar protuberances
  - Infection occurs through ingestion of eggs with L_1 larva



Whipworms Life cycle and Morphology

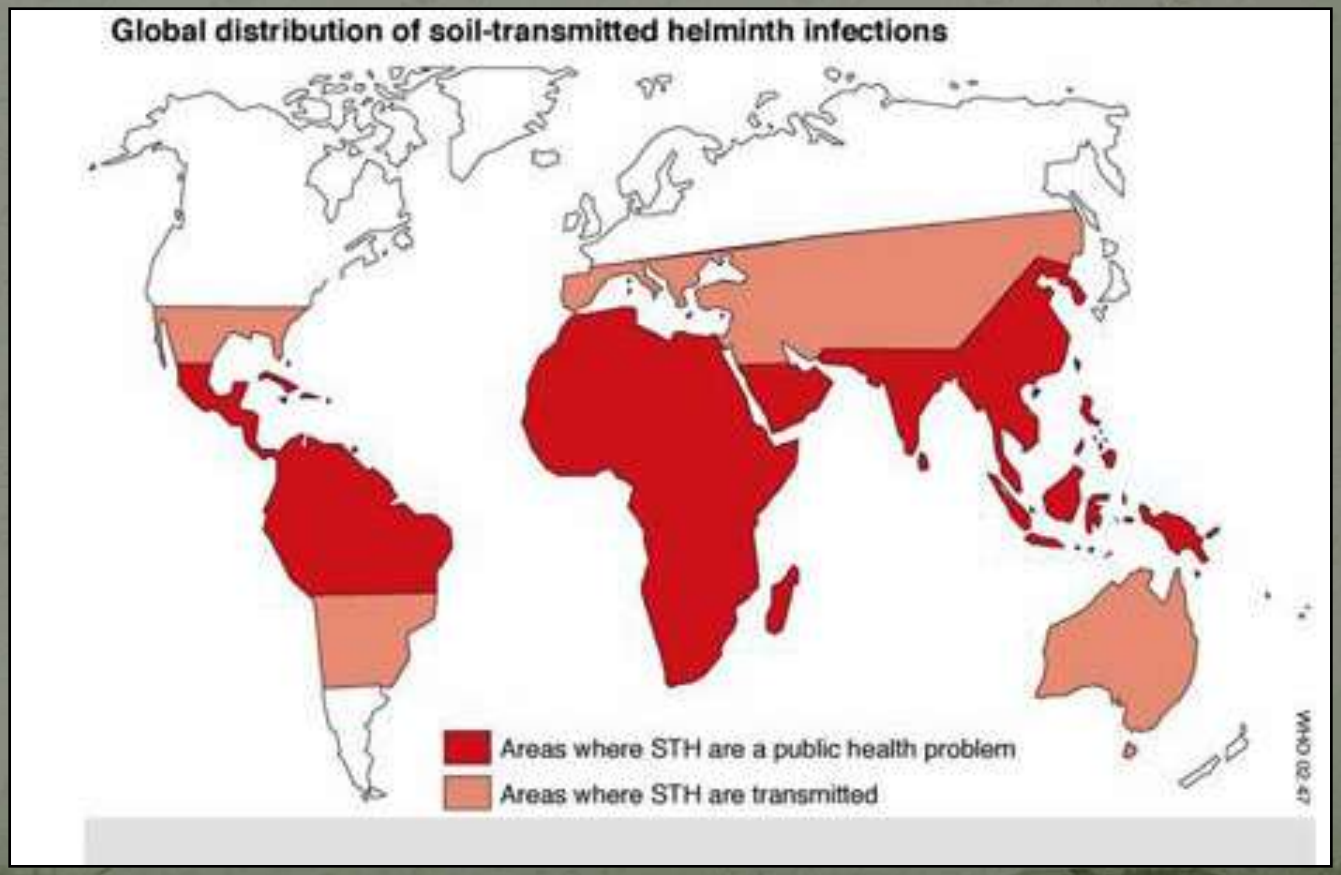




syncytium – SEM

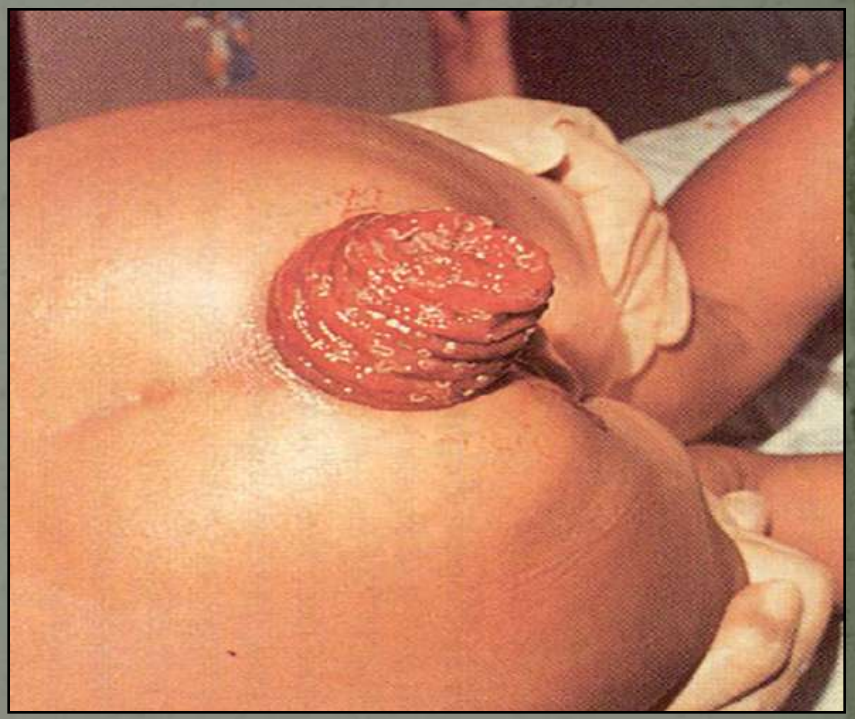

whipworm eggs

- Soil-transmitted helminths
  - *Ascaris, Trichuris, Ancylostoma, Necator*
  - WHO estimates 795 million human *Trichuris* infections, especially in sub-Saharan Africa, the Americas, and east Asia



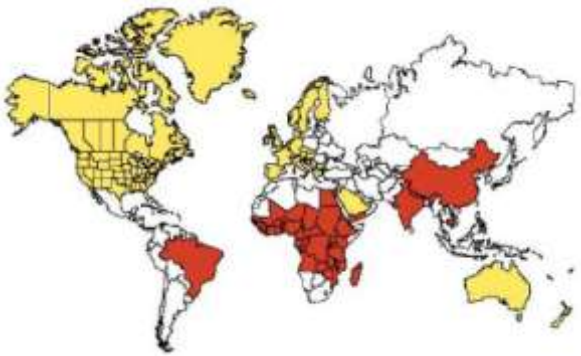
- Intestinal manifestations of trichuriasis:

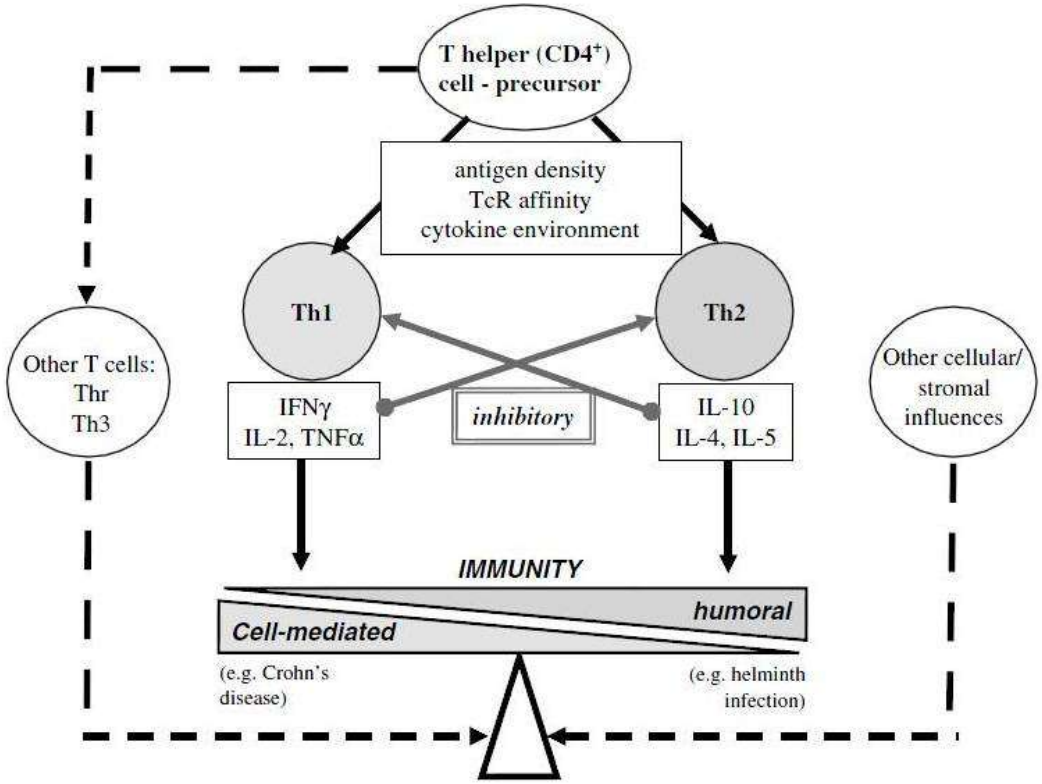
  asymptomatic or abdominal pain, diarrhoea, in severe infestations bloody diarrhea, rectal prolapse is possible in severe cases



- Whipworms can serve as a therapeutic agent for some life style diseases

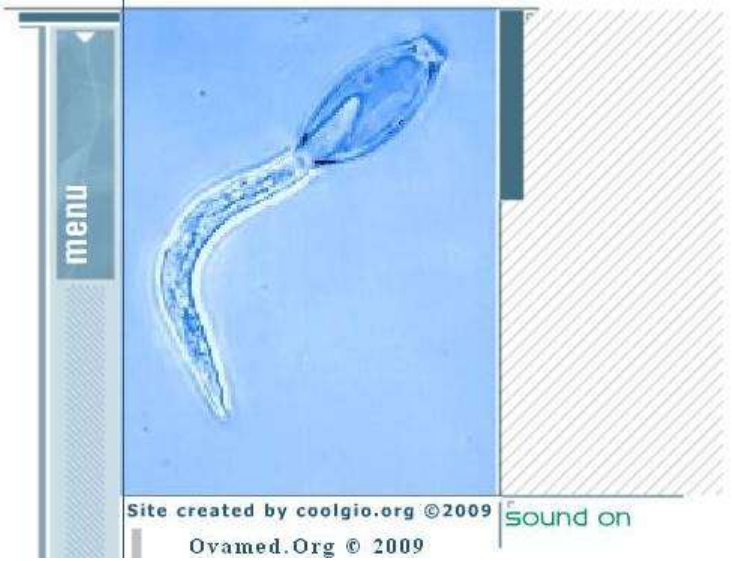
- nematodes are able to improve the health status of IBD patients (Crohn´s disease, ulcerative colitis)





OVAMED GmbH

better medicine through biology



Dose	Unit cost	Annual cost
TSO300	80.00 €	2080 €
TSO500	150.00 €	3900 €
TSO1000	220.00 €	5720 €
TSO2500	300.00 €	7800 €

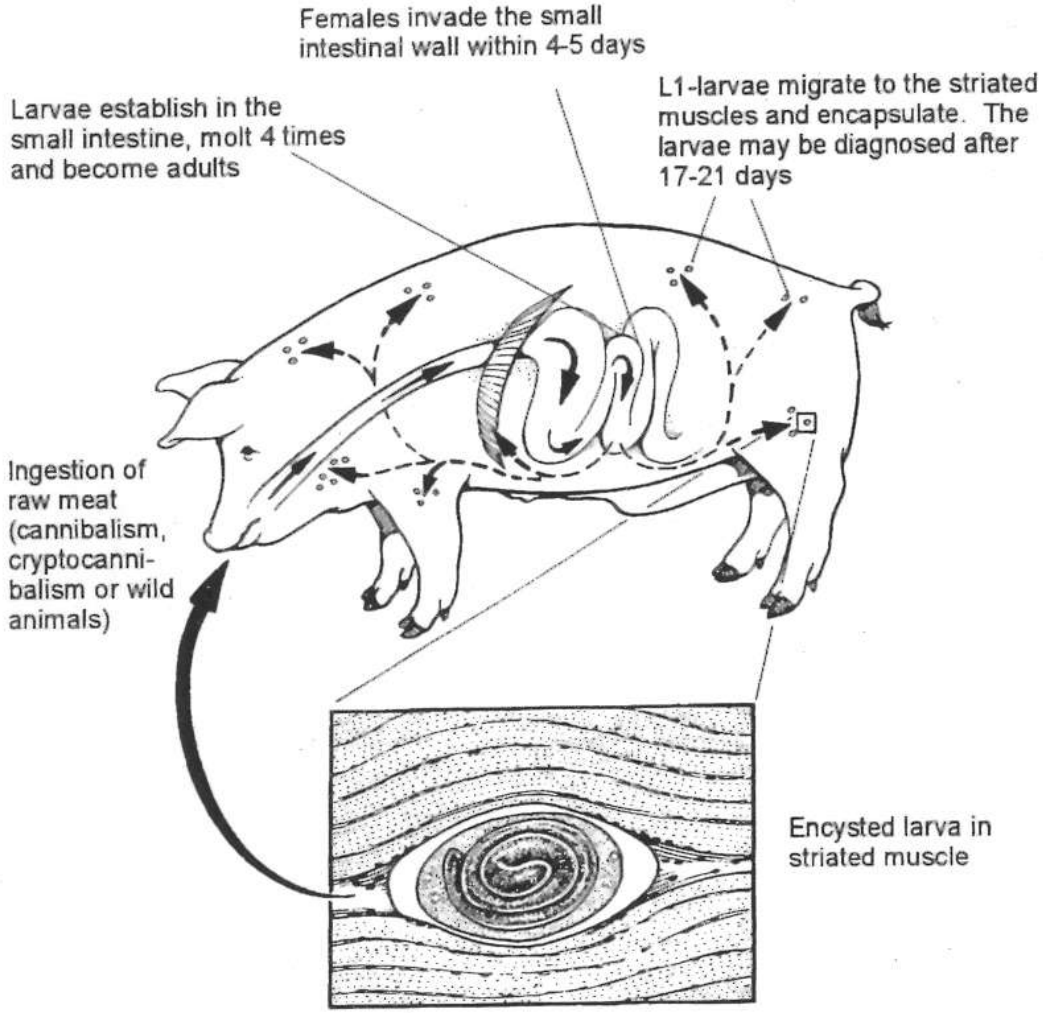
Trichinella

- Eight species are currently recognized: *T. nativa* (arktic area), *T. nelsoni* (Afrika, hyena), *T. britovi* (mild climate, sylvatic life cycle), *T. pseudospiralis* (birds), *T. murrelli* (USA, carnivora), *T. papuae* (human, pig), *T. zimbabwensis*

- *Trichinella spiralis* is the most important species
- ♂ 1,0 – 1,8 mm, ♀ 1,3 – 3,7 mm

- Trichinelosis reported in more than 150 different hosts (omnivors, carnivors, rodents, human)
- The L_1 larva live in the modified skeletal muscle (nurse) cell
- Direct life cycle without an intermediate host and no exogenous stage

Trichinella spiralis Life cycle



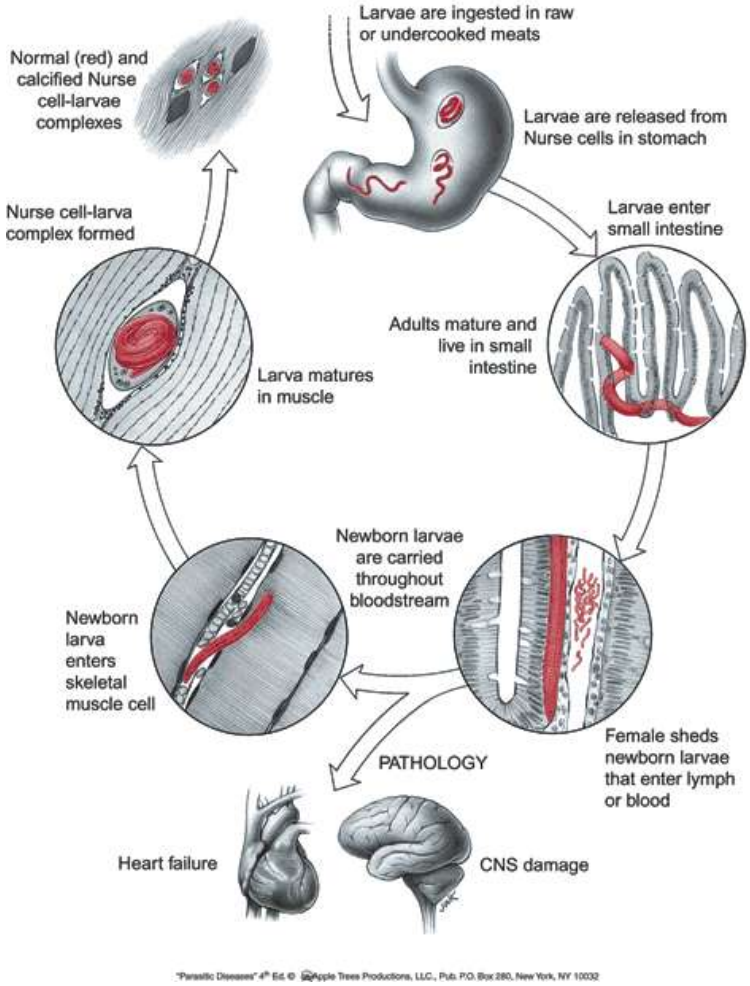
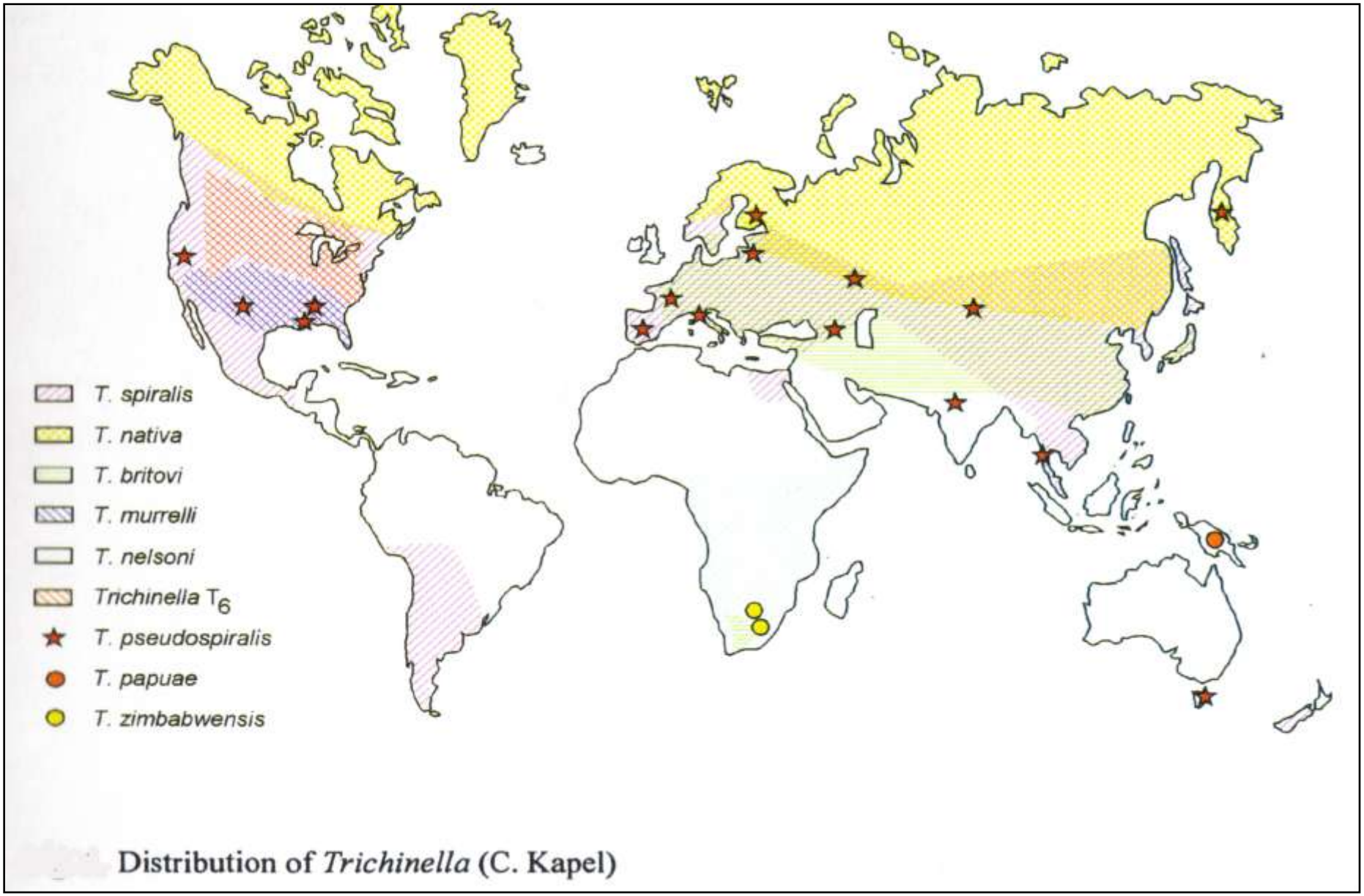
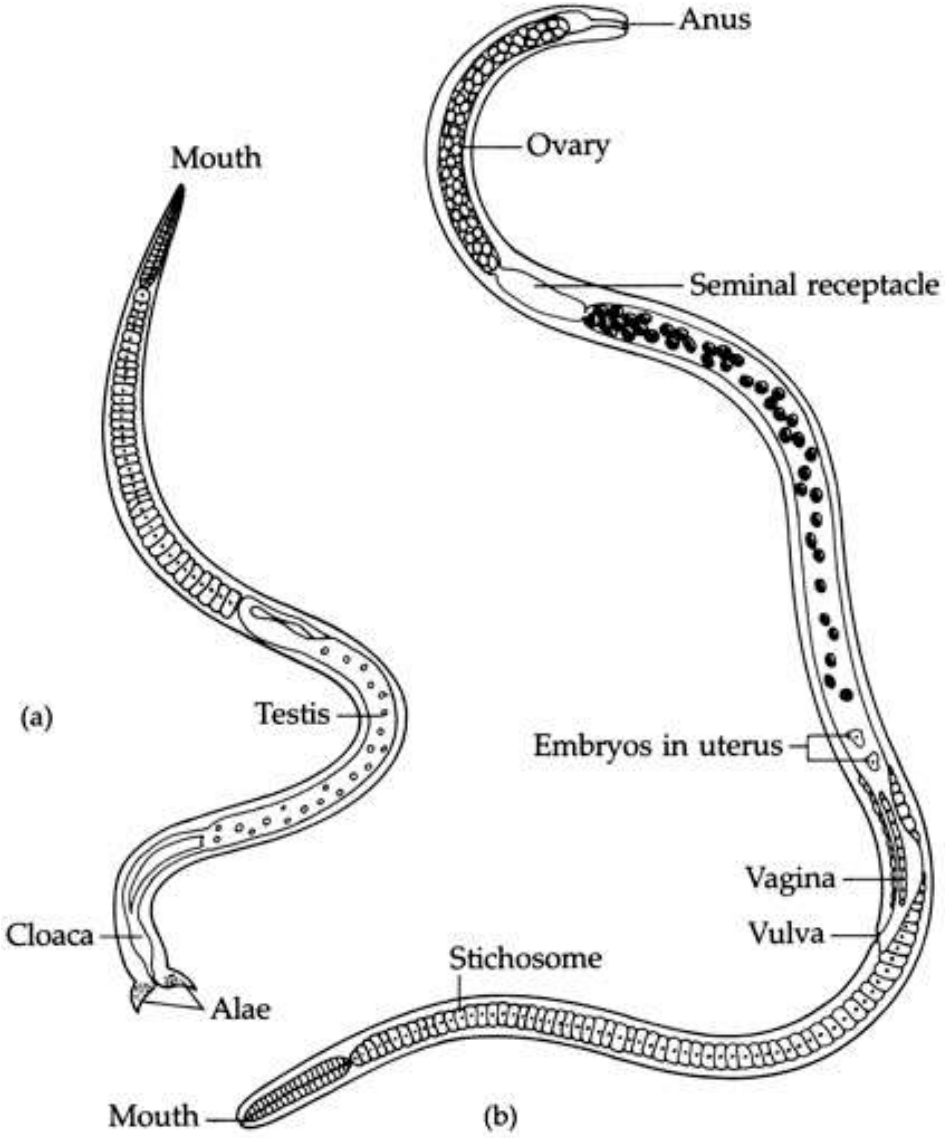


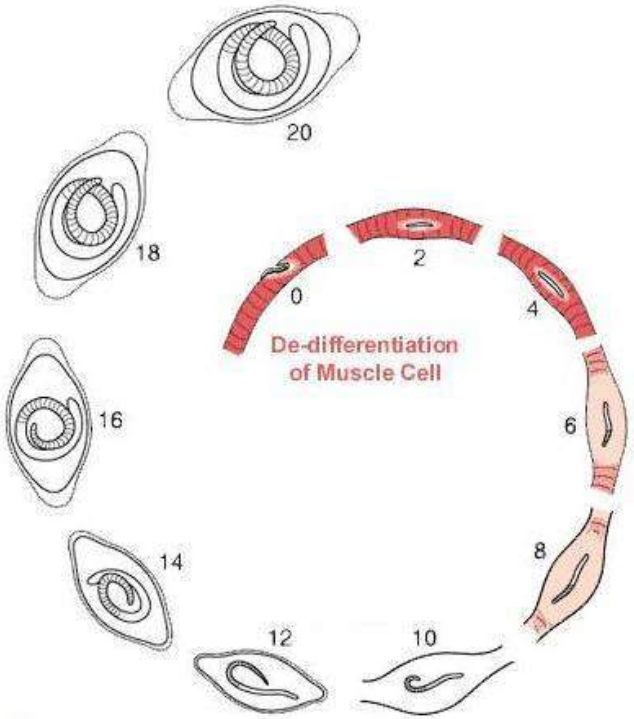
Illustration by Wm P Hamilton CMI

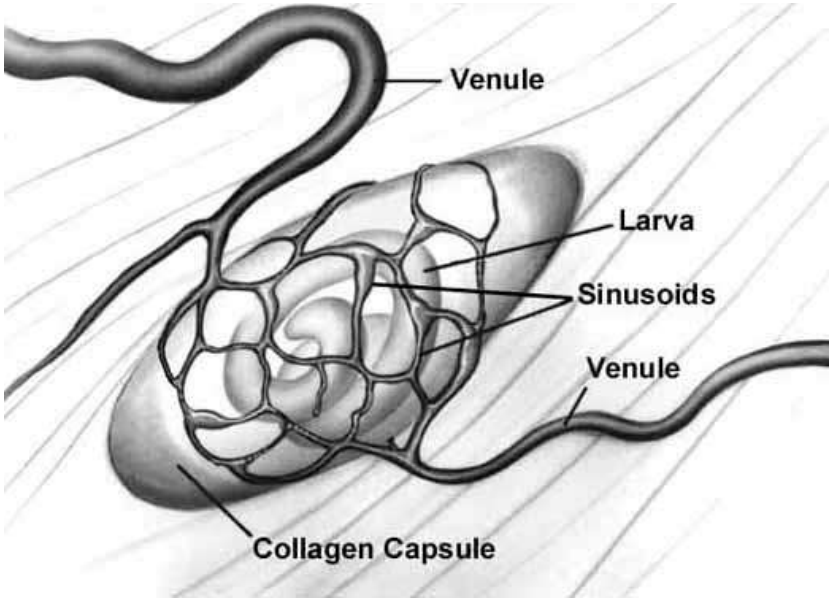


Distribution of *Trichinella* (C. Kapel)

Trichinella sp. morphology





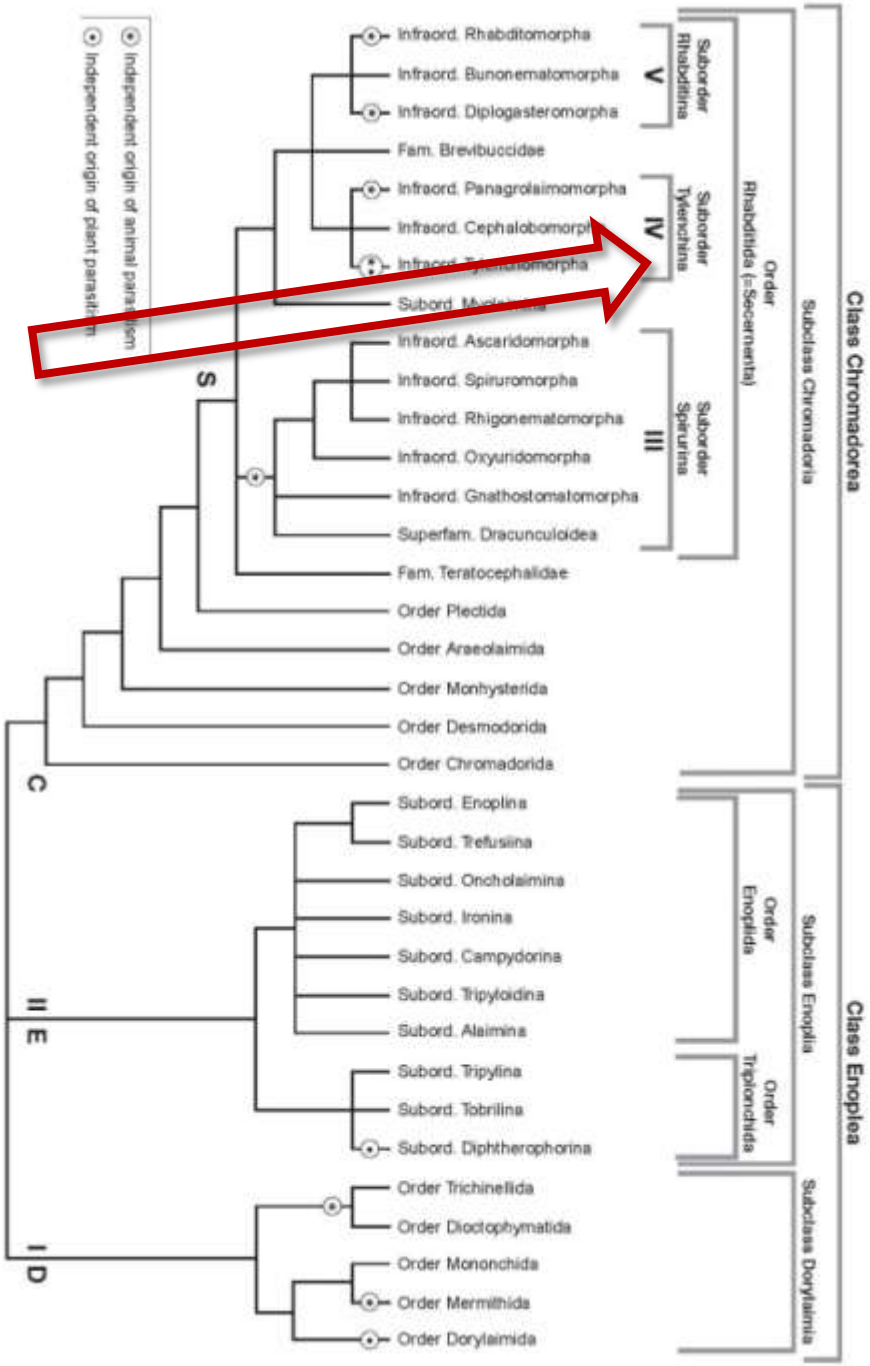



Encysted larva in the muscle

- Domestic swine can be exposed to the parasite by:
  - Feeding on animal waste products or other feed contaminated with *Trichinella* larvae
  - Exposure to infected wildlife animals (rodents)
  - Cannibalism within an infected herd

- *Trichinella* is more pathogenic in man than in swine
  - Human infection is caused by eating raw or undercooked meat of infected animals
  - The larvae have a predilection for the diaphragm and jaw muscles in pigs
  - In man, intestinal adult worms cause nausea, fever, produce stiffness and pain, myalgia, malaise and edema

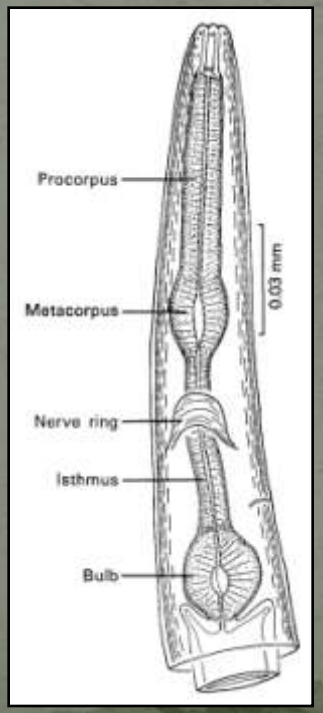
Kingdom: animals (Animalia)
Phylum: nematodes (Nematoda)
Class: Chromadorea
Superfamily: Strongyloidoidea



- Usually free-living microbivorous nematodes live in soil, only some species are parasitic

- Members of this group have direct life cycles
- Alternating life cycle strategy – free-living and parasitic population

- Rhabditiform type pharynx,
  with the exception of parasitic forms
  which have a firaliform pharynx



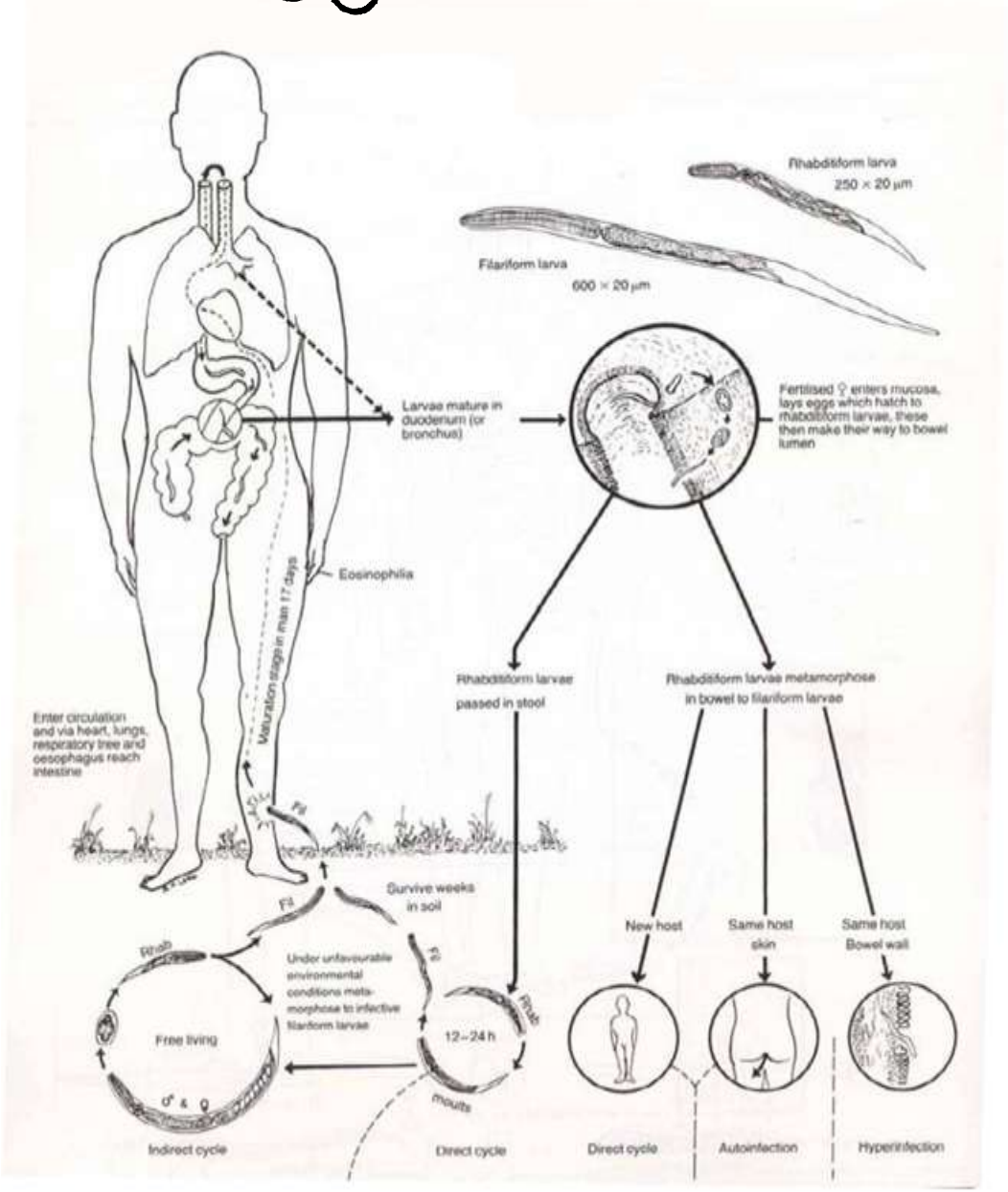
Strongyloides stercoralis

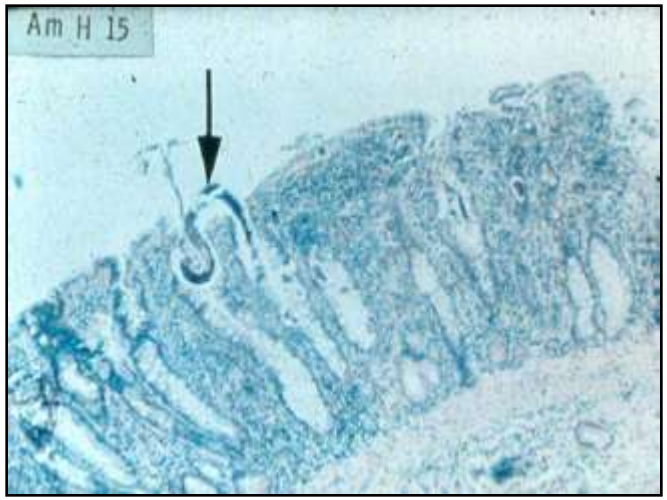
- Males grow to about 0.9 mm in length, they have the spicules and gubernaculum, females can be from 2.0 to 2.5 mm
- Both genders possess a tiny buccal capsule and cylindrical esophagus without a posterior bulb

- Parasitic and free-living worm populations
  - Parthenogenetic females are parasitic only
  - In the free-living stage, the pharynx of both sexes are rhabditiform

- Direct development, thin-walled eggs with L_1 larva inside, infectious L_3 larva

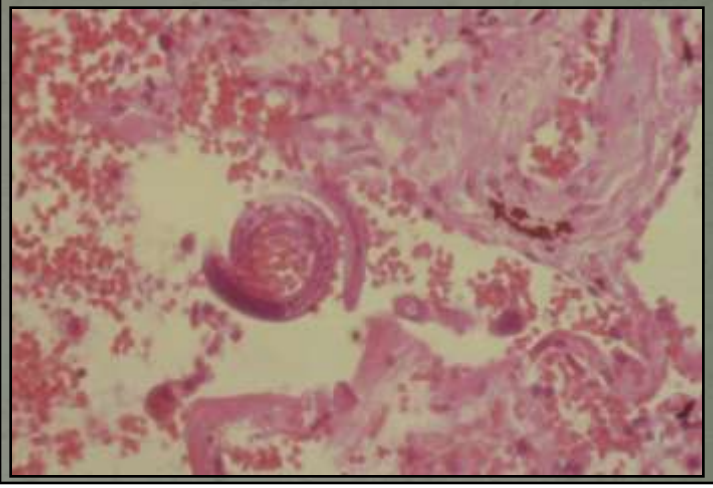
Strongyloides stercoralis Life Cycle

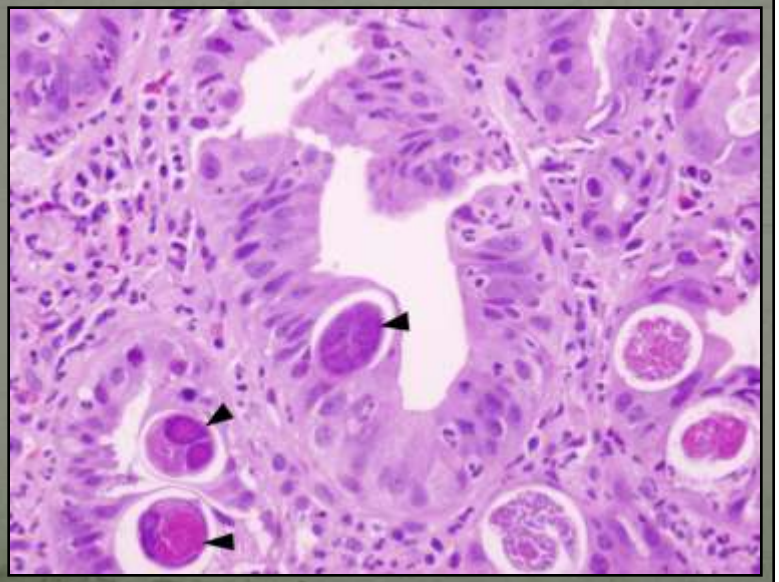


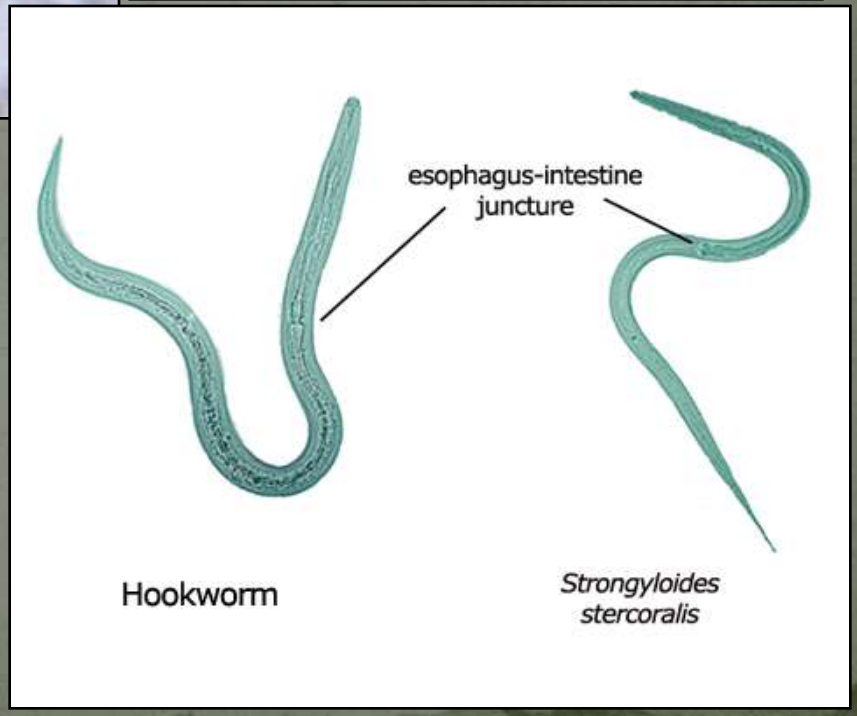


eggs with larvae

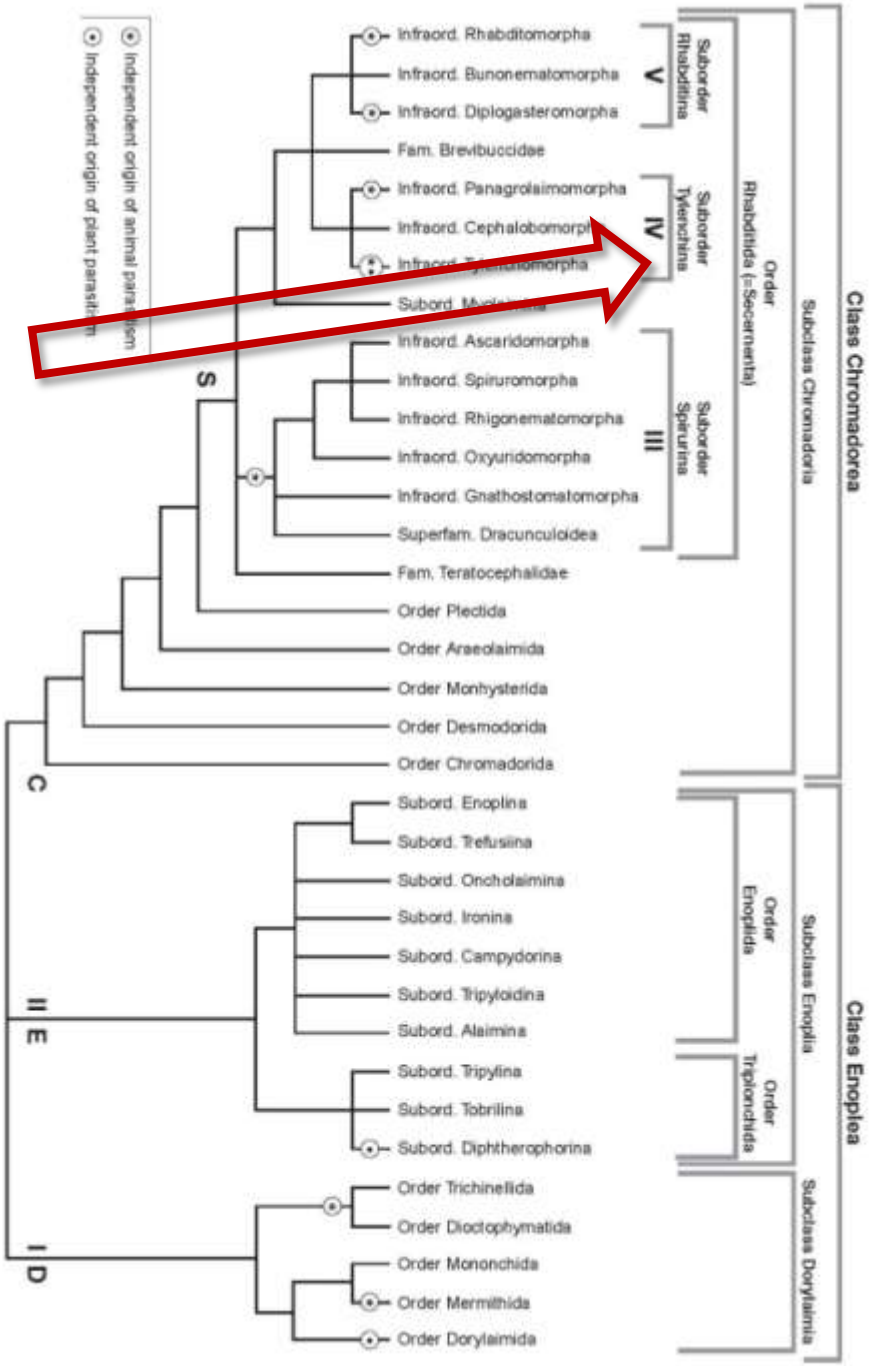
- Causes of infection: peroral (ingestion), percutaneous, autoinfection
  - Many people infected are usually asymptomatic
  - Symptoms include dermatitis: swelling, itching, larva currens, and mild hemorrhage at the site where the skin has been penetrated
  - In severe cases, edema may result in obstruction of the intestinal tract as well as loss of peristaltic contractions
- Strongyloidiasis in immunocompetent individuals is usually a serious disease (opportunistic agent)






esophagus-intestine
juncture
Hookworm
Strongyloides
stercoralis

Kingdom: animals (Animalia)
Phylum: nematodes (Nematoda)
Class: Chromadorea
Suborder: Tylenchina



- The largest and most economically important group of plant-parasitic nematodes
  - They exploit all plant organs including flowers and seeds, mostly they attack roots
  - Great economic importance as parasites of agricultural crops and forest trees
- Entomopathogenic forms (parasites of insects and mites haemocoel) also included

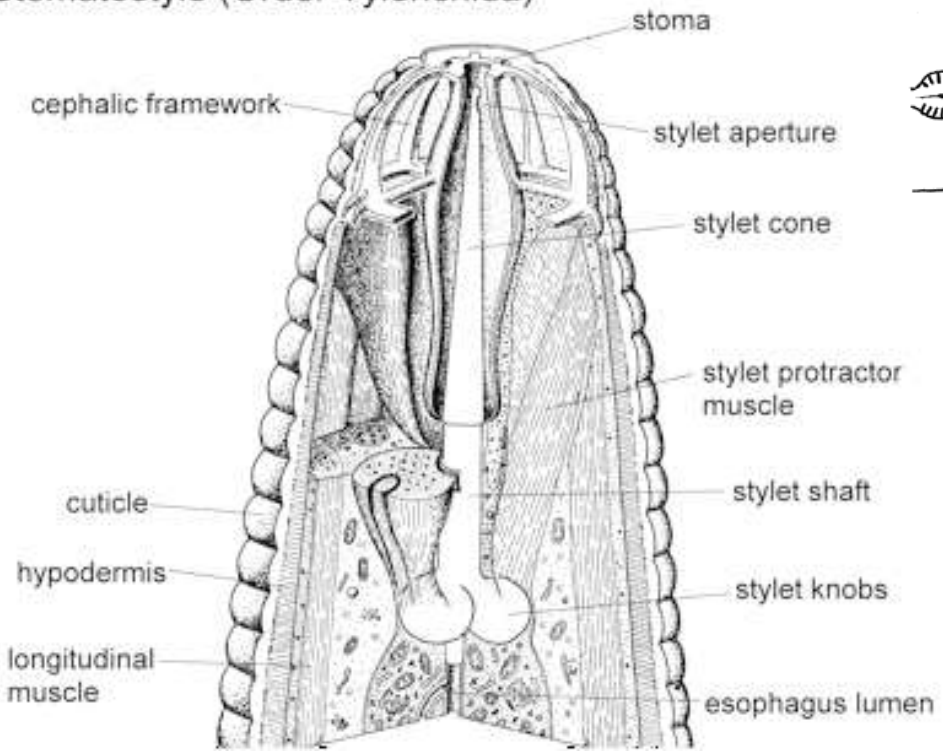
- Stomatal stylet and substylet orifice of the dorsal oesophageal gland

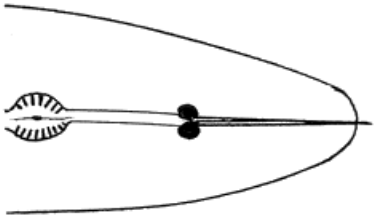
- Male accessory genital structures include a pair of spicules, a gubernaculum, a bursa and genital papillae
- Tylenchs are oviparous but number of entomopathogenic genera have ovoviviparous species

Life cycle strategies

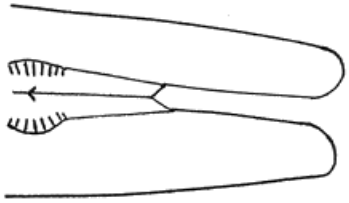
- Migratory ectoparasites
  - Motile nematodes, which feed on the external surface cells of roots
  - The most common type of life cycle strategy among all plant-parasitic nematodes (pin, ring, mint and stubby-root nematodes)
- Migratory endoparasites
  - Motile nematodes, which may feed on external surfaces of roots but generally burrow into the root to feed on internal root cells (root-lesion nematodes)
- Sedentary endoparasites
  - Invade root tissues soon after hatching and then establish a permanent, stationary feeding location (cyst nematodes and root-knot nematodes)

Stomatostyle (Order Tylenchida)

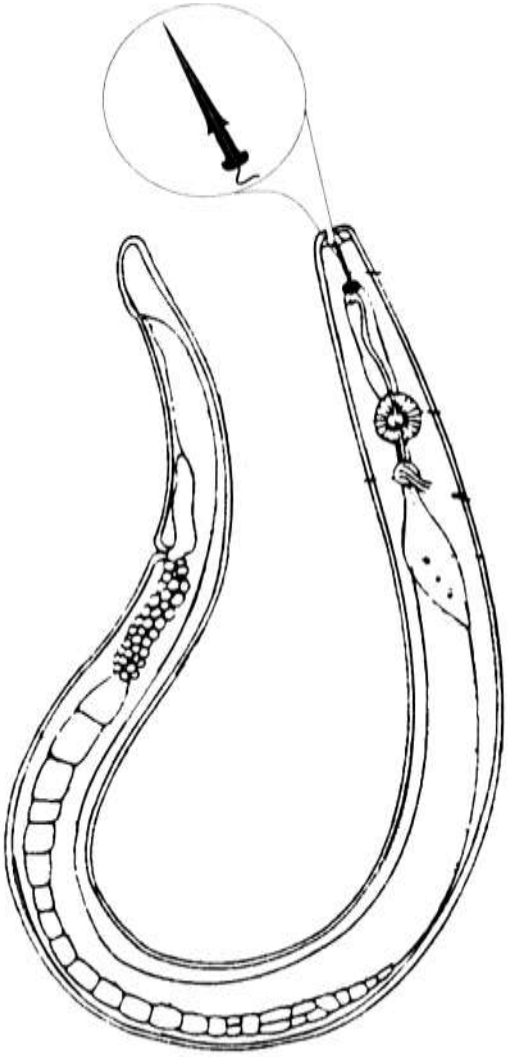


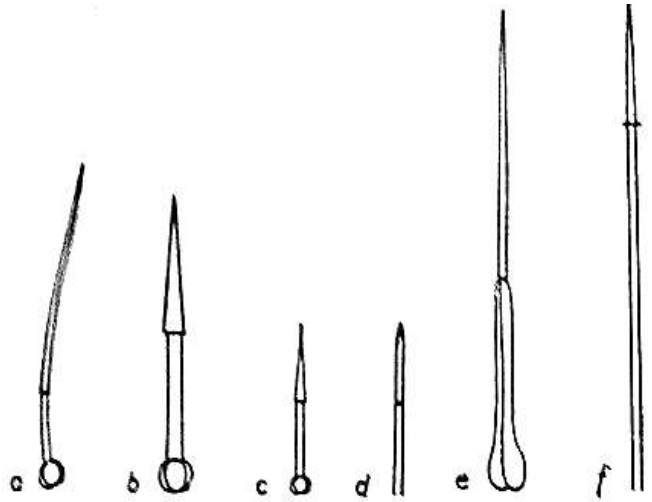


Herbivore Mouthpart



Bacterivore Mouthpart

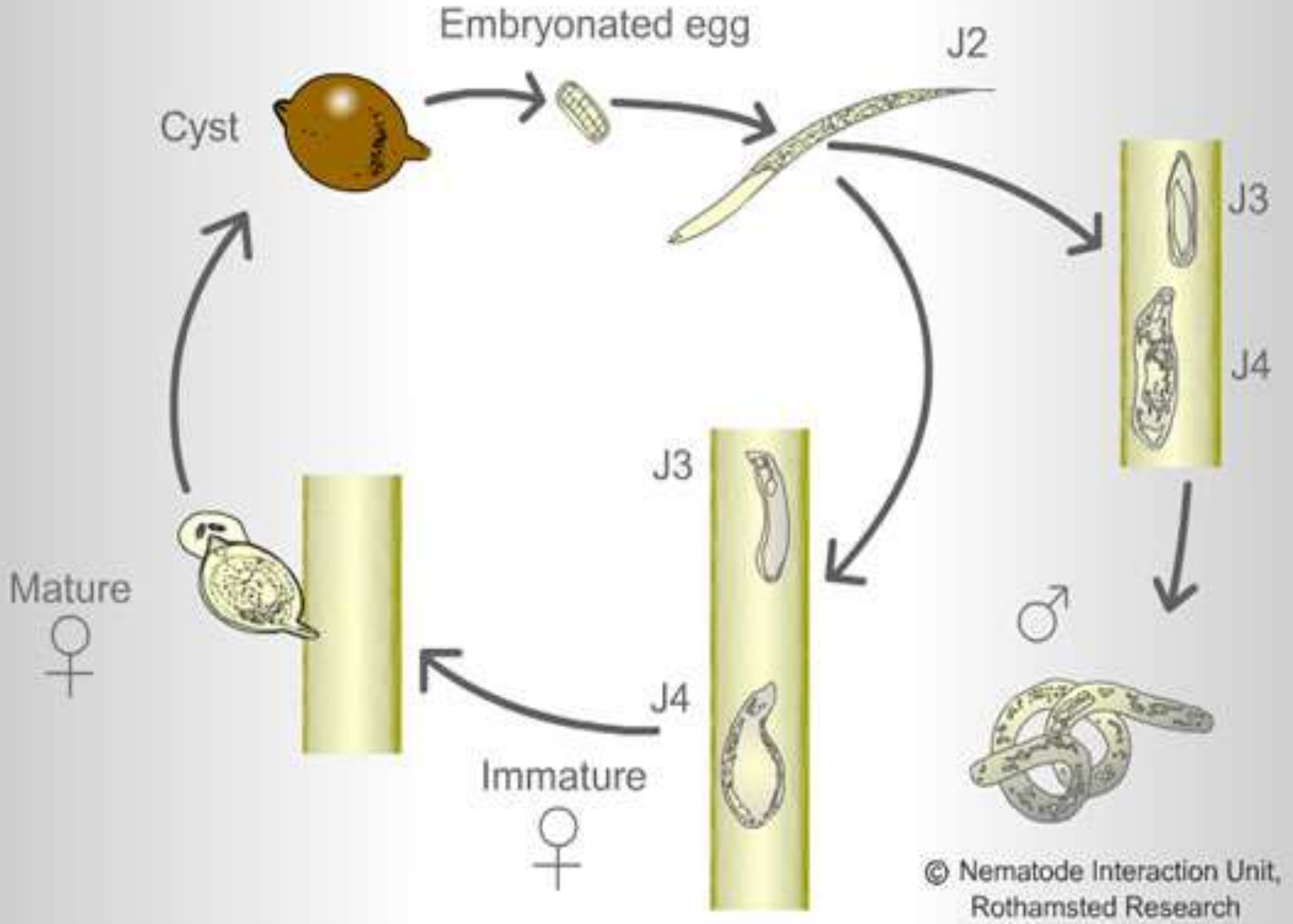


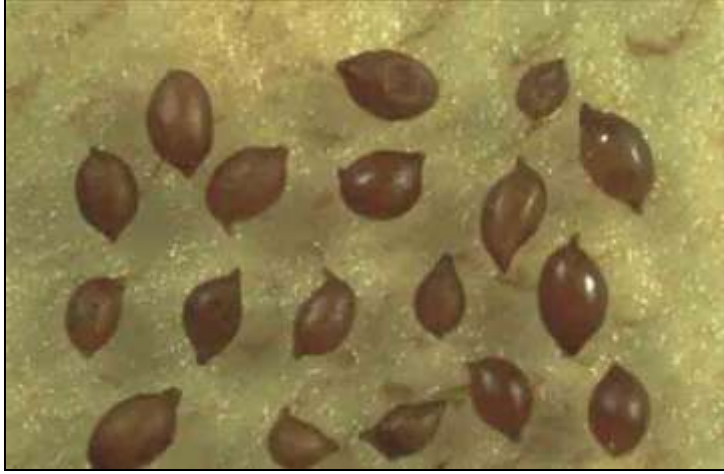


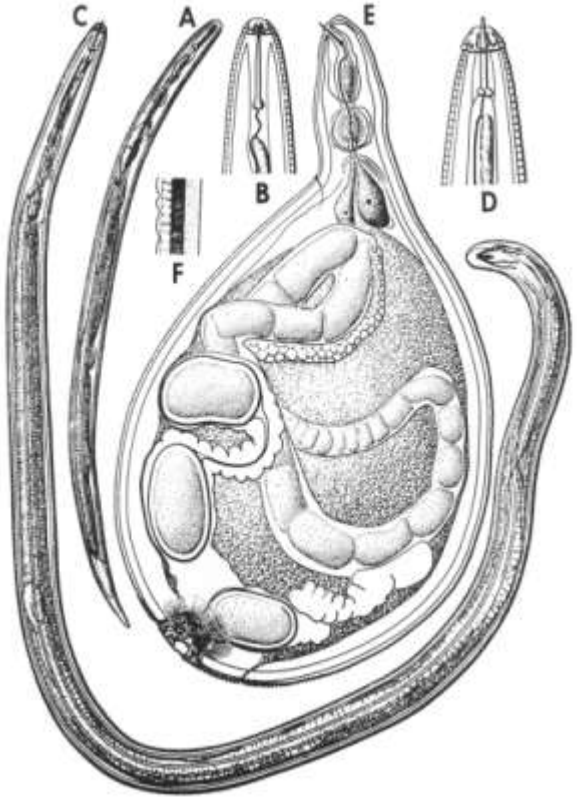
Cyst-forming nematodes

- Upon death the female body forms a resistant structure that protects eggs from hostile edaphic factors
- Second-stage juvenile (J_2) emerges from the egg as the infective preparasitic stage that penetrates host roots
- J_2 stimulates plant cells to develope a syncytium, the feeding site for all juvenile stages and adult females
- In many species adult, non-feeding males develop
- Lemon- and round-shaped cysts
  - Soybean cyst nematode *Heterodera* sp.
  - Golden nematode *Globodera rostochiensis* primarily infecting potatoes and tomatoes

Life Cycle of *Heterodera schachtii*






C
A
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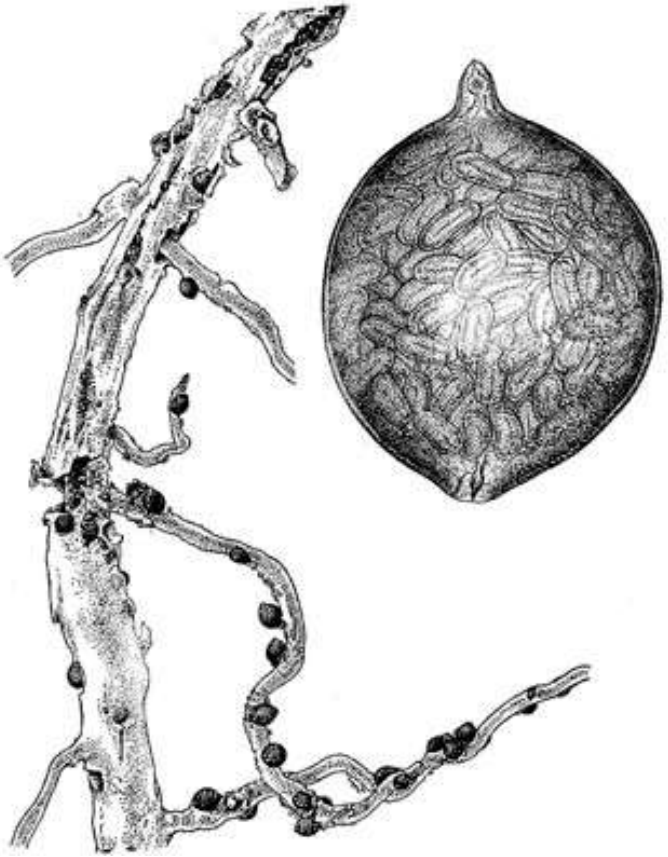
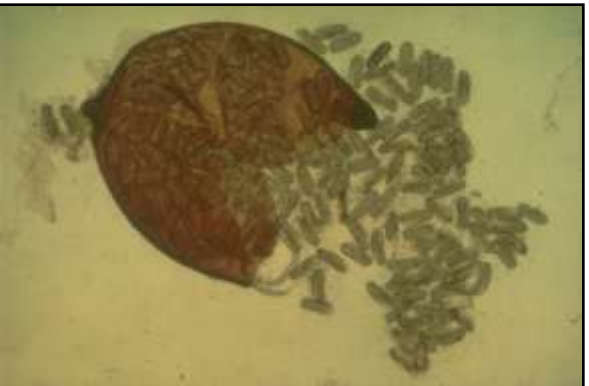
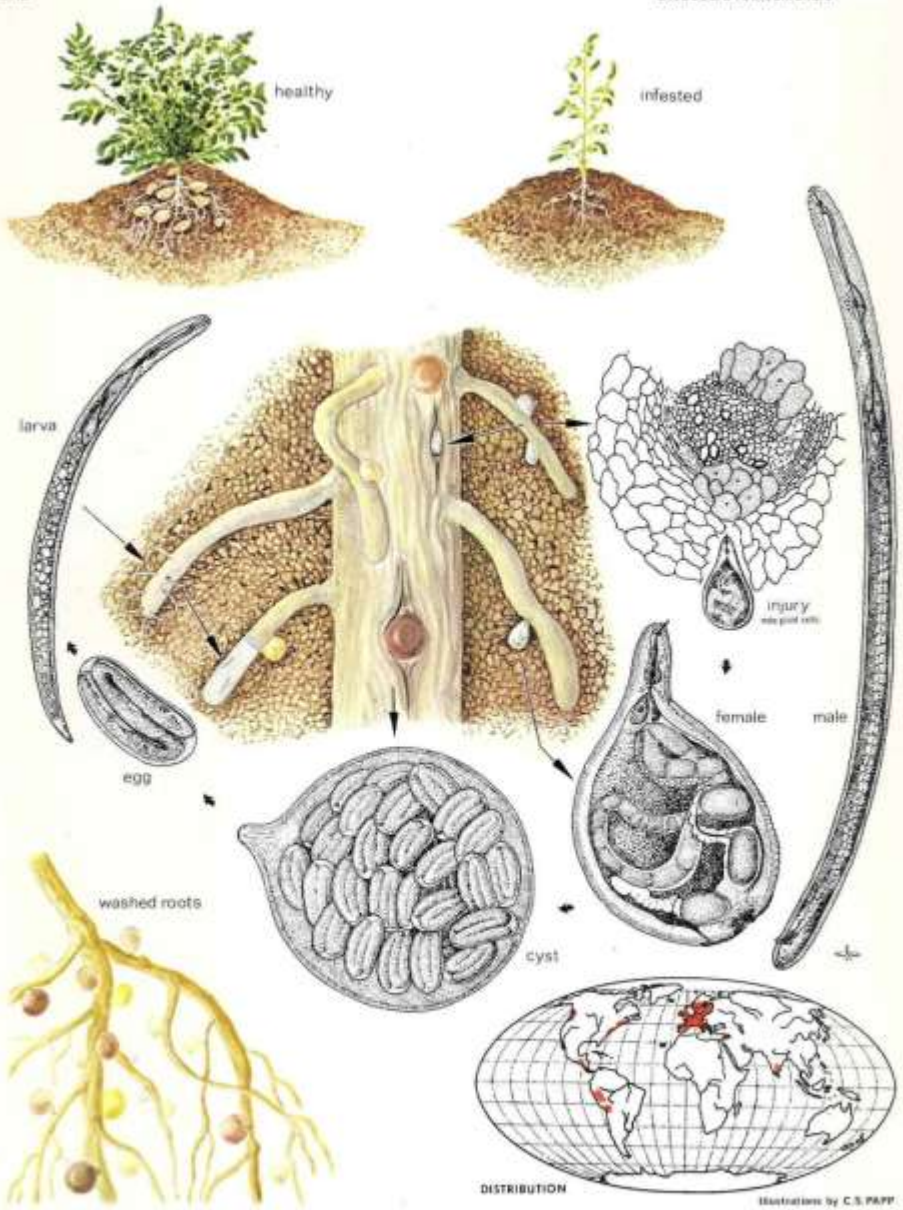




DETECTION MANUAL
D.T. 5:1

THE GOLDEN NEMATODE

Globodera rostochiensis



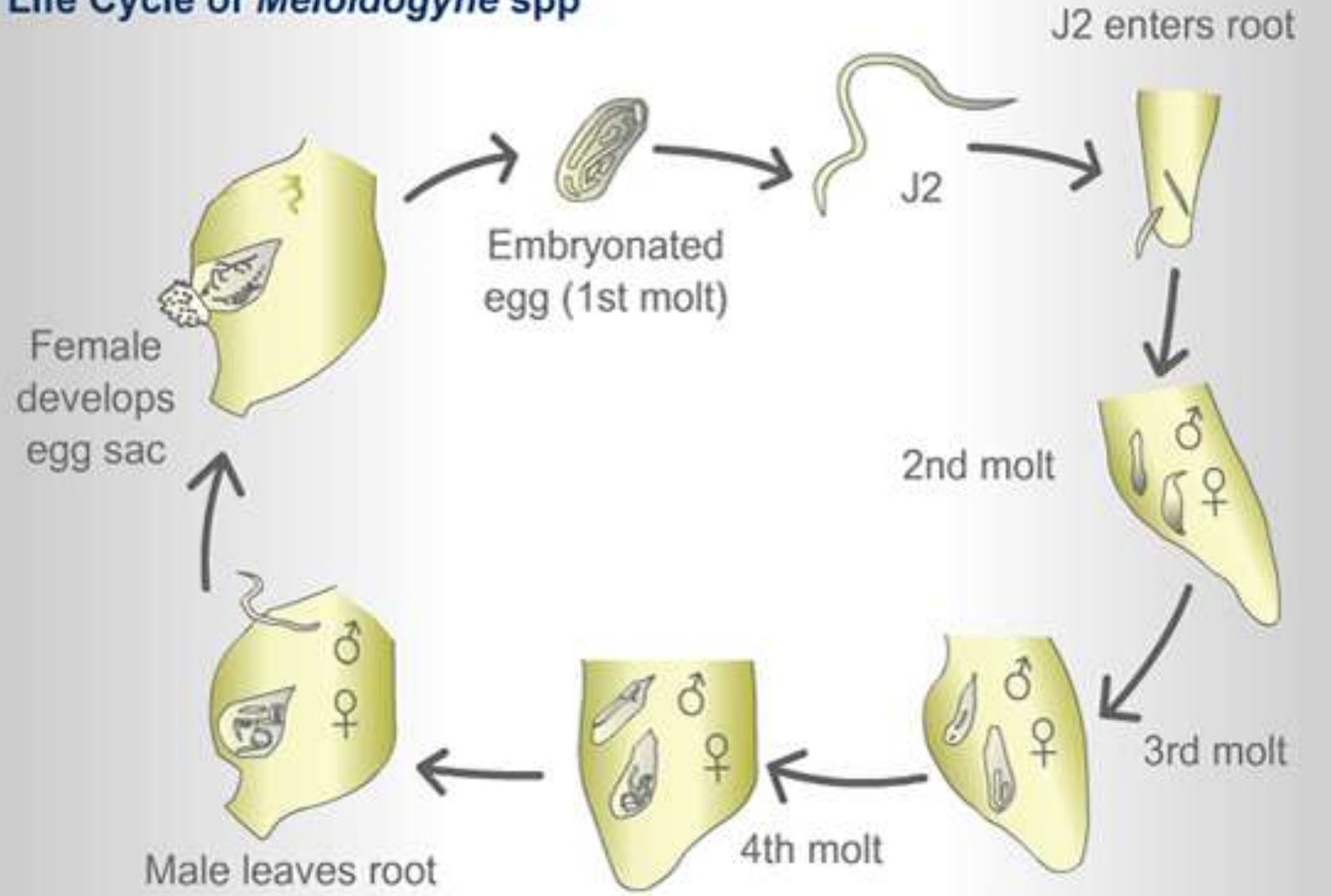
Root-knot nematodes

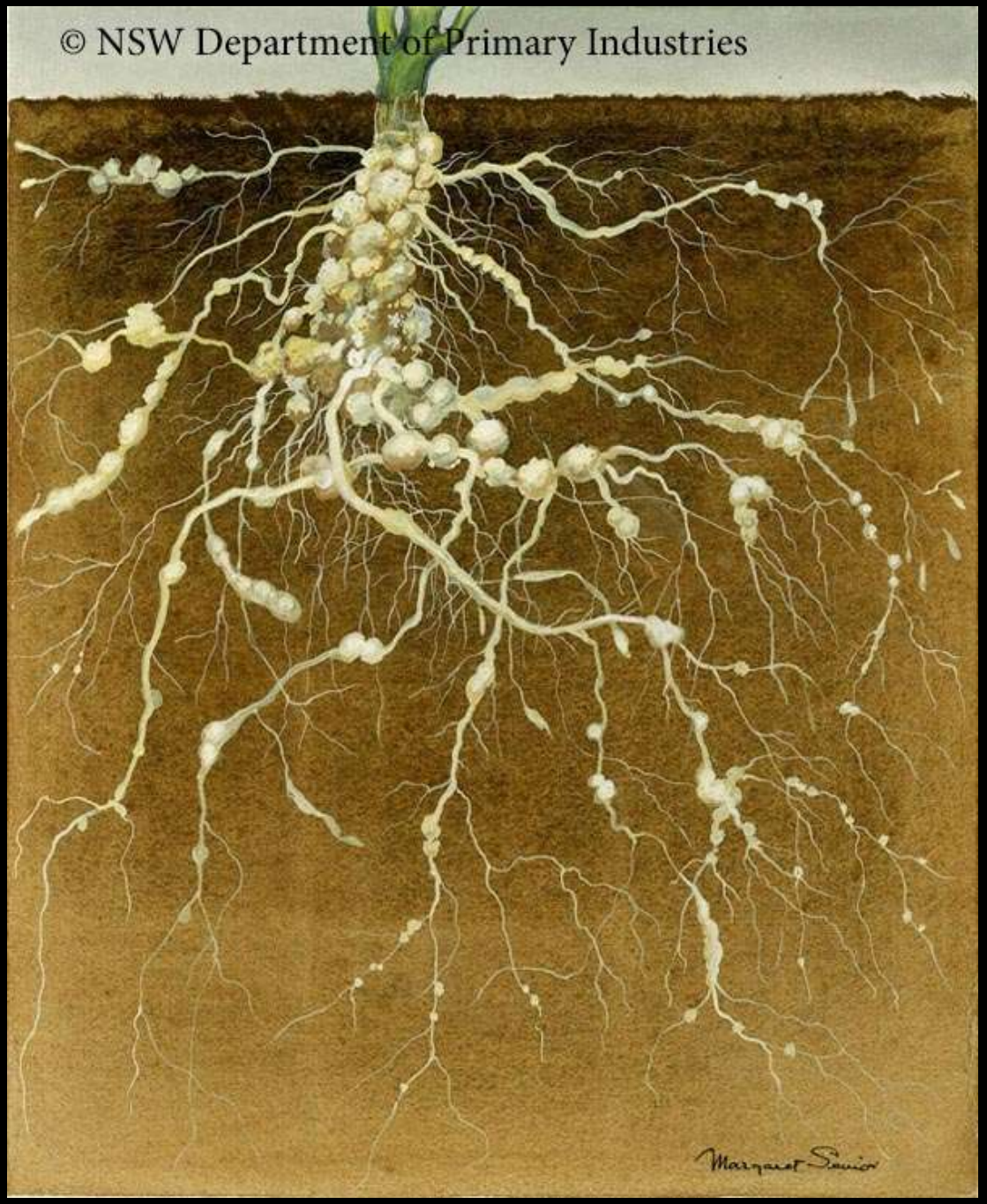
- They cause the formation of knots or galls roots of host plants
- The second-stage juvenile (J_2) becomes sedentary and as it feeds on special nurse (giant) cell, it undergoes morphological changes

- Marked sexual dimorphism
  - Adult female are pyriform or saccate
  - Adult males does not feed and are vermiform

- *Meloidogyne* species are pests of major food crops, vegetables and fruit

Life Cycle of *Meloidogyne* spp



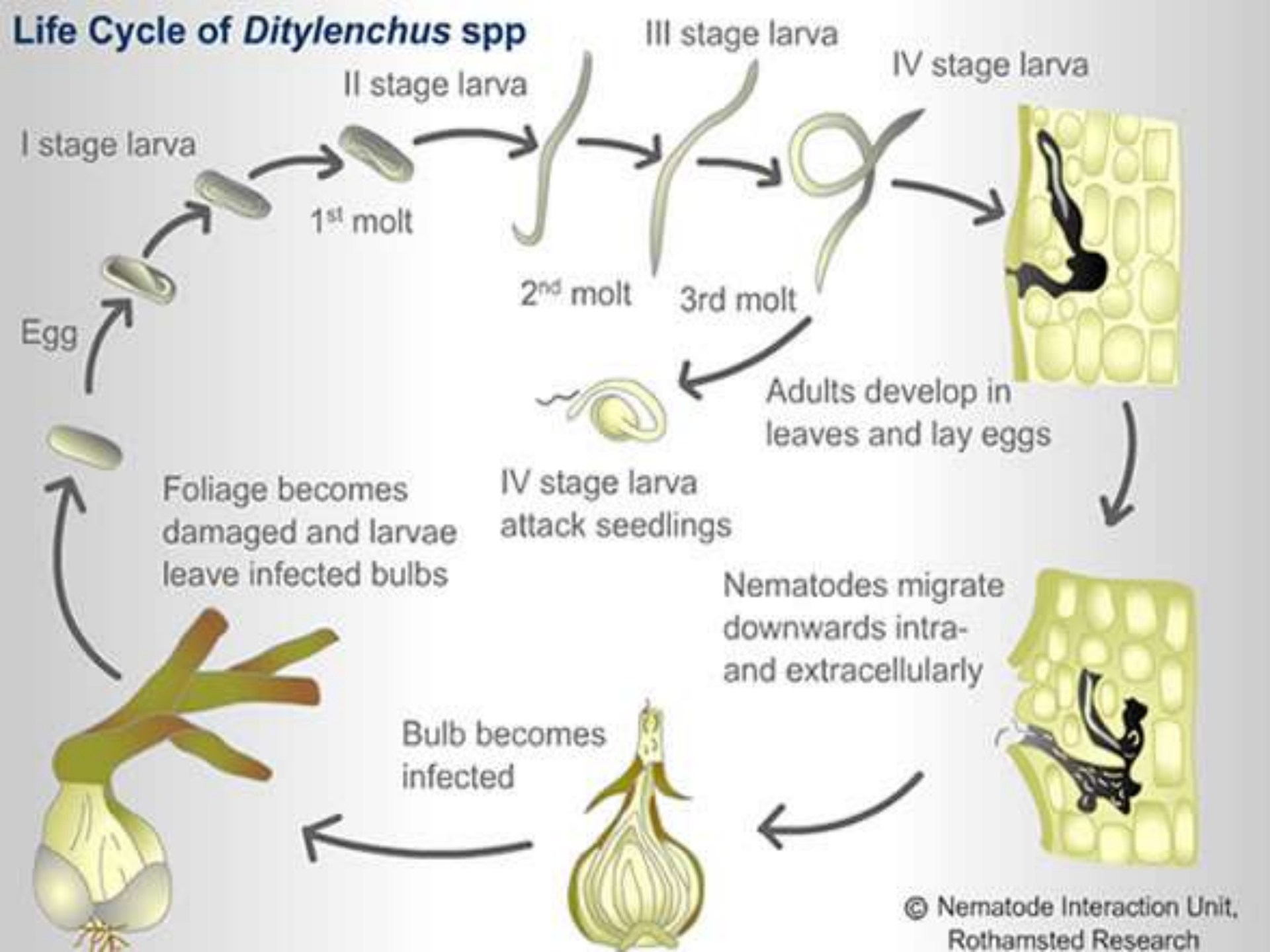

© NSW Department of Primary Industries
Margaret Stevens

Stem and bulb nematodes

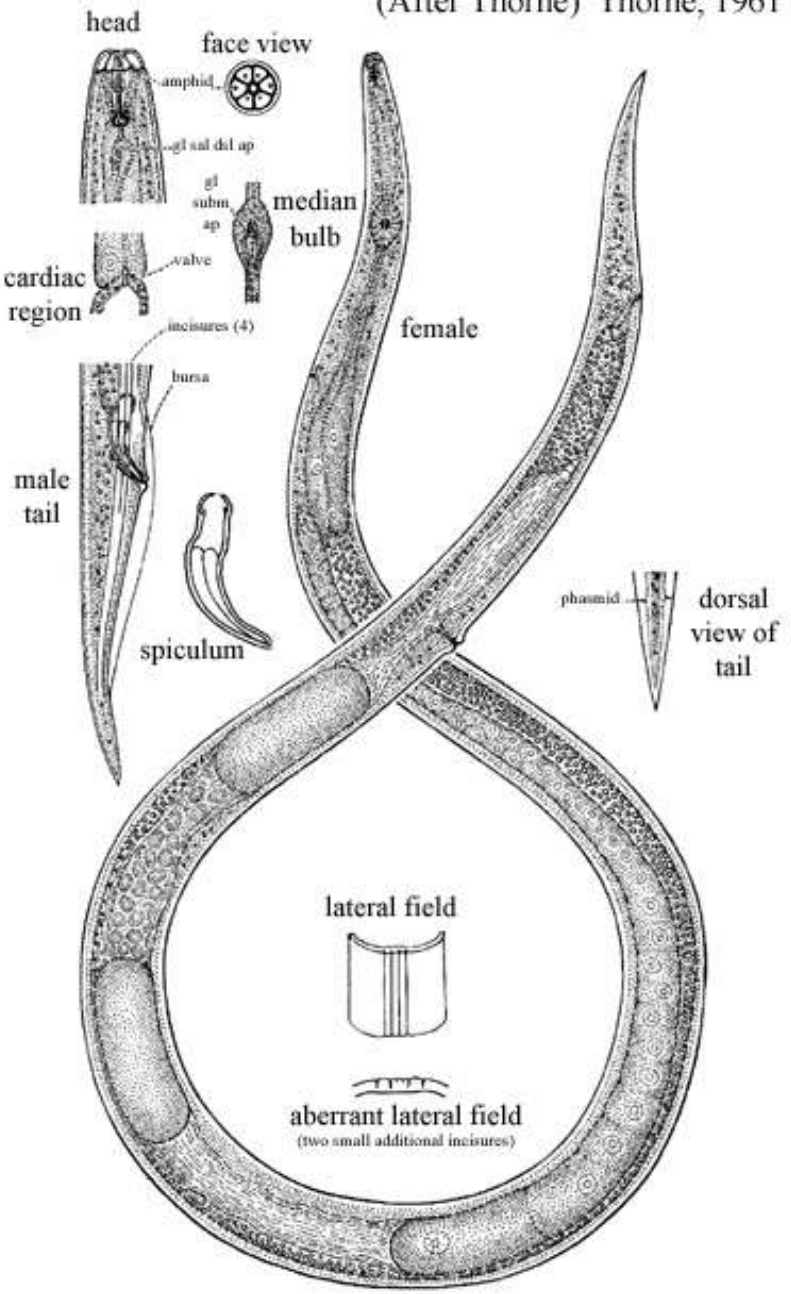
- Important pest of vegetables and other crops
- Live as endoparasites in above-ground parts of plants or in roots, stolones, tubers and rhizomes
- Some species feeds ectoparasitically on plant tissues

- The most problematical species in tylenchs in genera *Ditylenchus*
  - *Ditylenchus dipsaci* is among nematodes of greatests economic impact worldwide
  - Migratory endoparasite that feeds upon parenchymatous tissue in stems and bulbs

Life Cycle of *Ditylenchus* spp

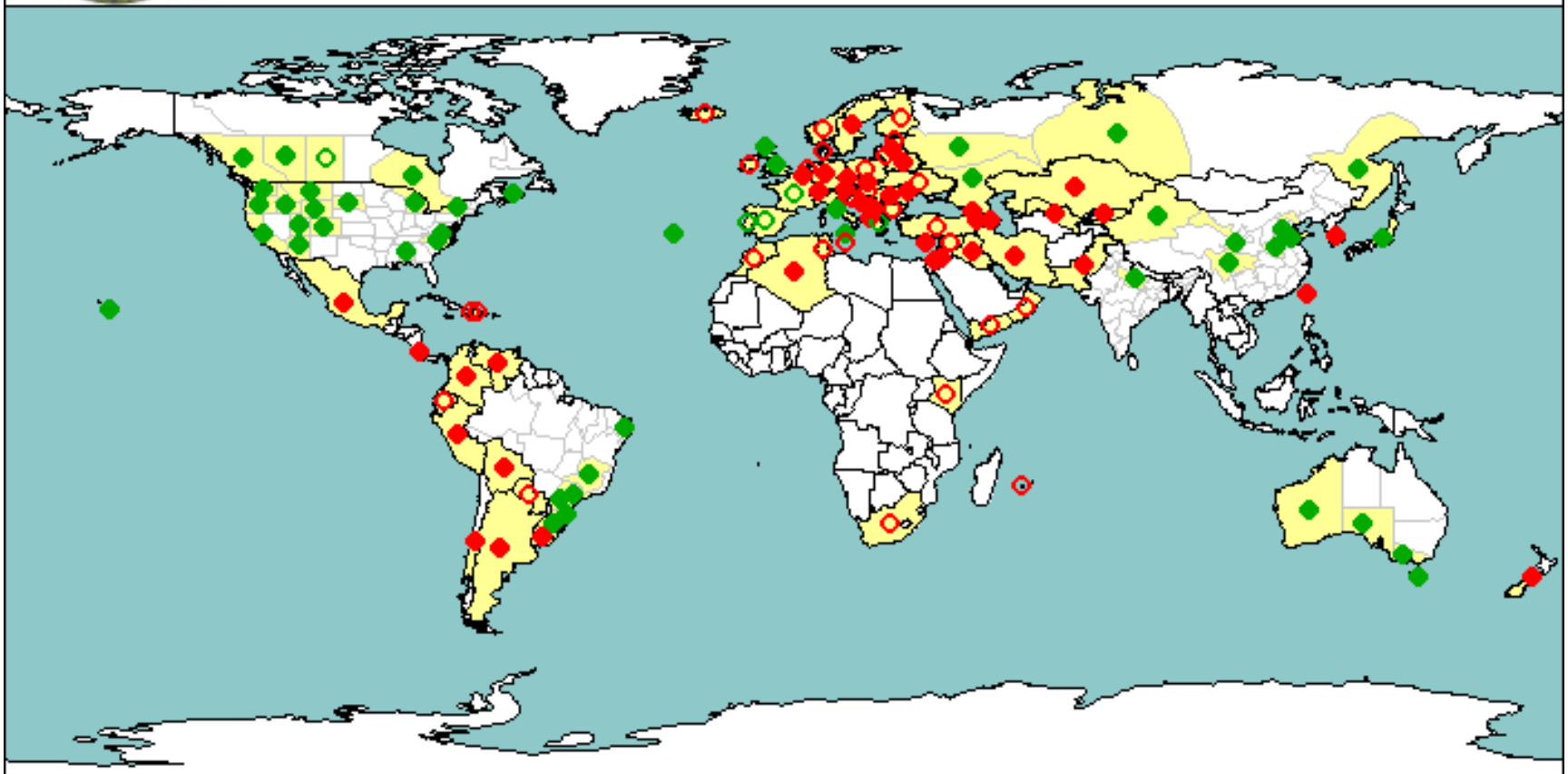


Ditylenchus dipsaci
(After Thorne) Thorne, 1961



Distribution Maps of Quarantine Pests for Europe

Ditylenchus dipsaci



National record

Present

Present only in some areas

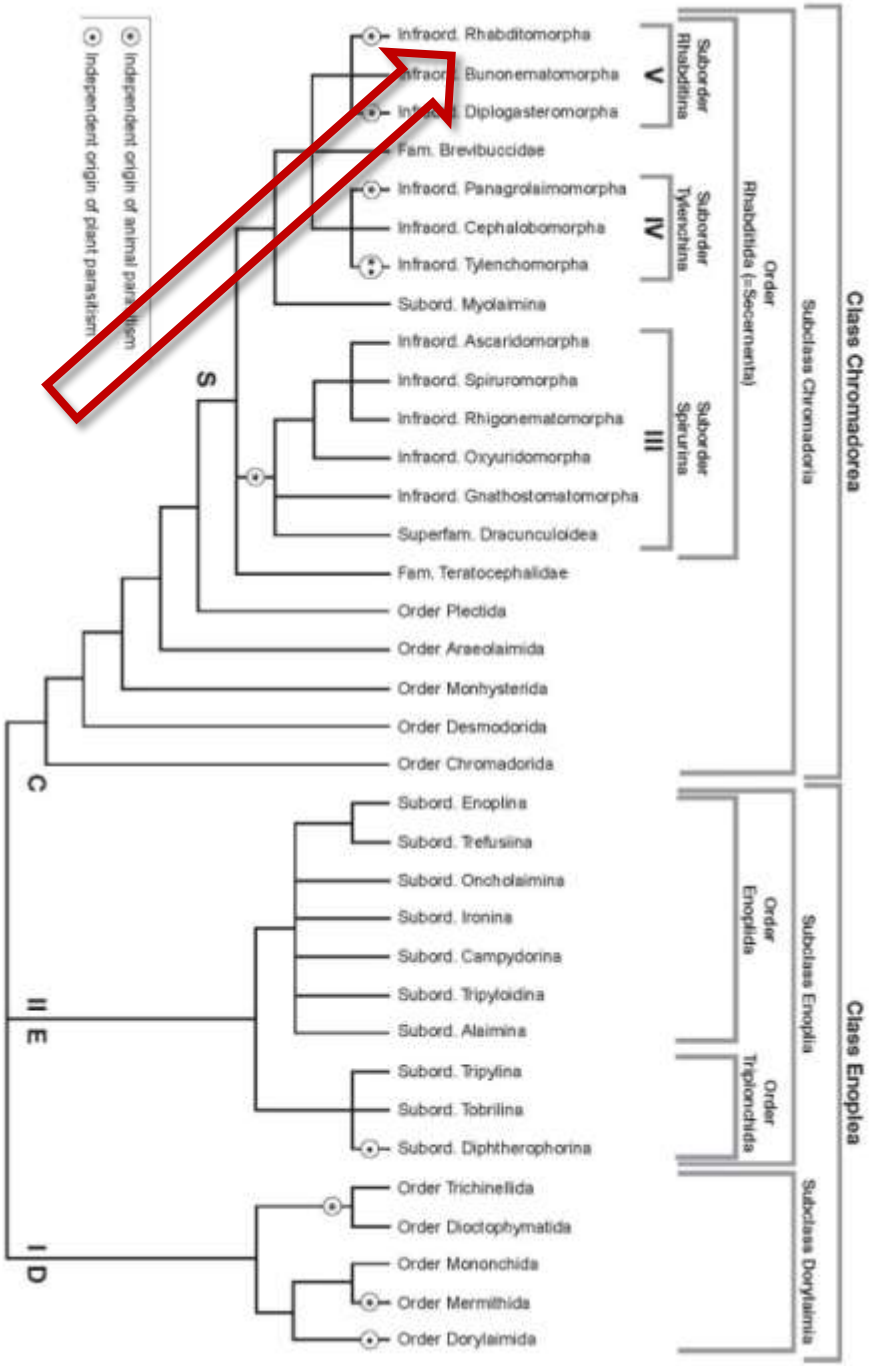
Subnational record

Present

Present only in some areas

2006-09-19

Kingdom: animals (Animalia)
Phylum: nematodes (Nematoda)
Class: Chromadorea
Family: Rhabditidae

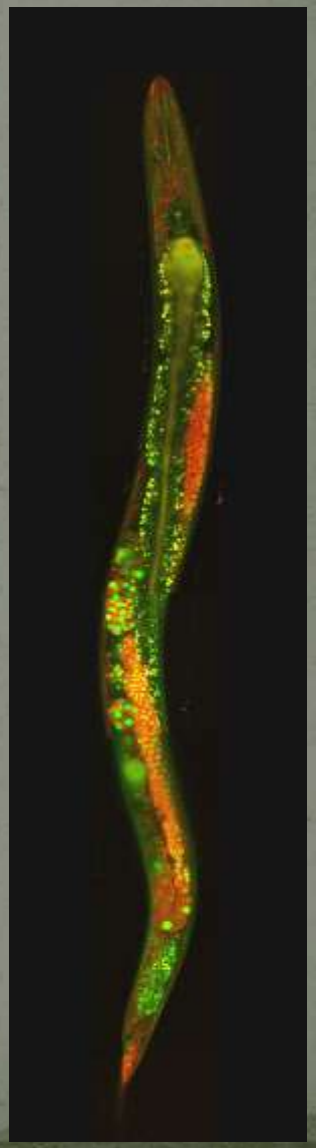


Caenorhabditis elegans

- Free-living soil nematode
  - Adverse conditions survives in Dauer stage

- Celebrity in the world of science

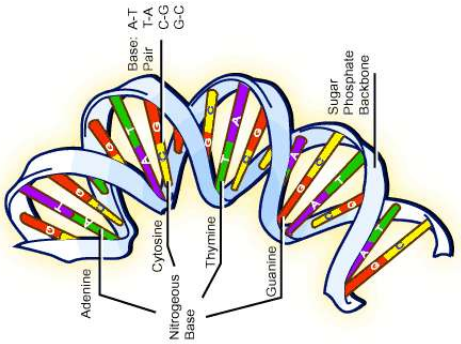
Born for science:	1974
Lenght of adults:	approx. 1 mm
Weight of adults:	5 μg
Movement speed:	6 – 8 mm/min
No. of cells:	959
Life span:	15 – 20 days
No. of Nobel prizes:	3 for last 10 years
VIP…	approx. 15,500 articles



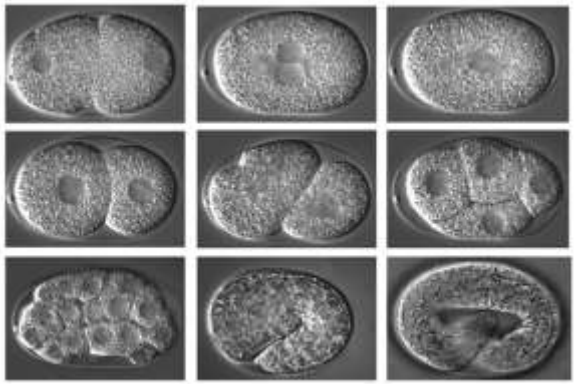
Sydney Brenner

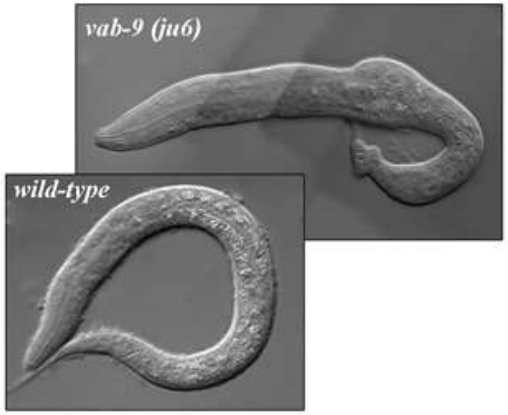
Robert Horvitz

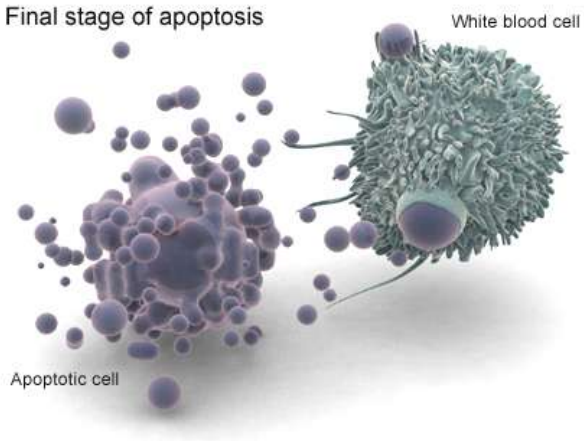
John Sulston



The Nobel Prize in Physiology and Medicine 2002







Kingdom: animals (Animalia)
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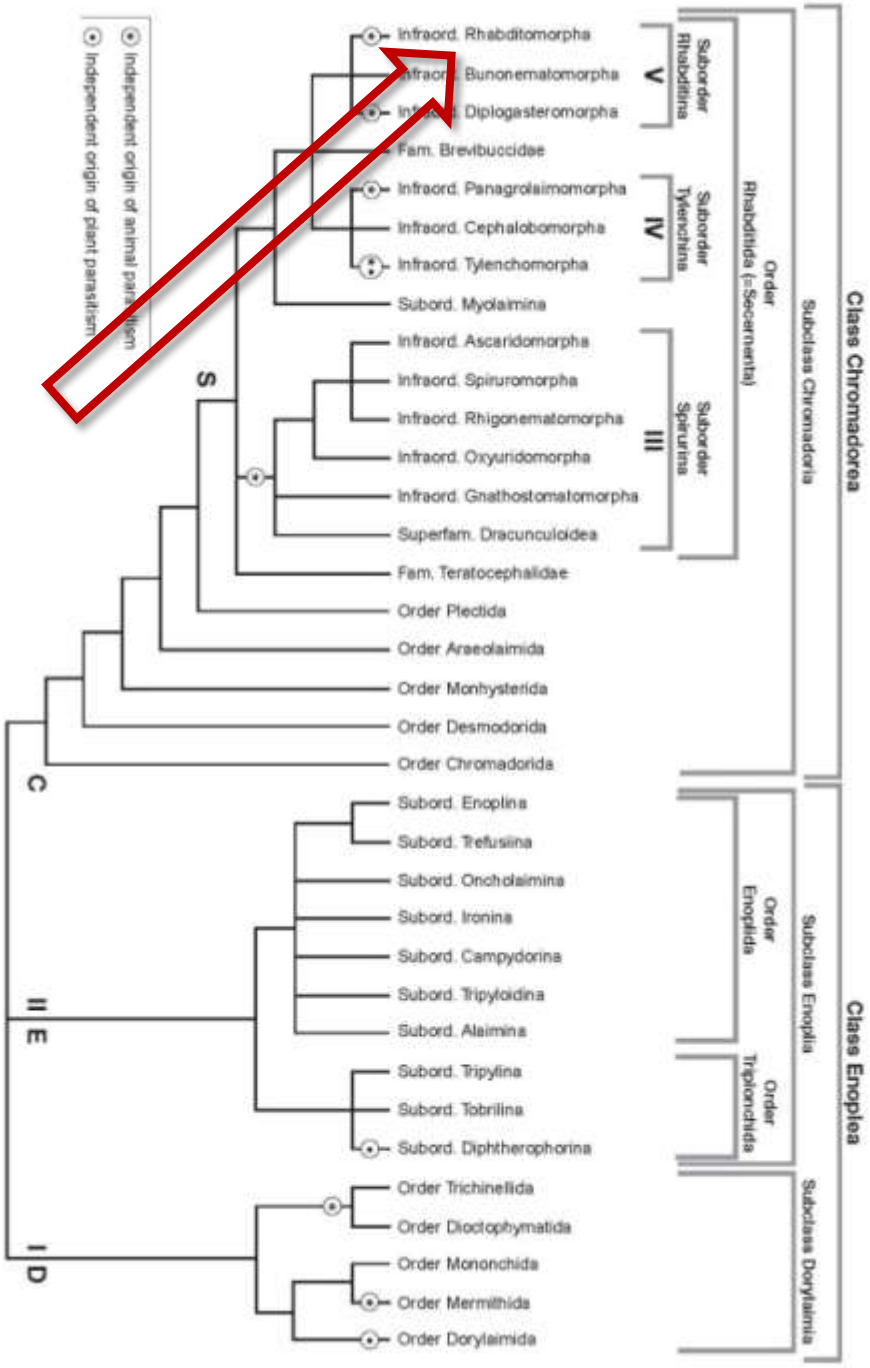


- All strongylid nematodes are parasitic
- Both genders has well developed buccal capsule
- Marked sexual dimorphism
  - Male have highly elaborated triangular bursa (dorsal, lateral and ventral part)
- Preinfective stages which usually feed on bacteria have rhabditiform pharynx
- Infective larvae and adults are filariform

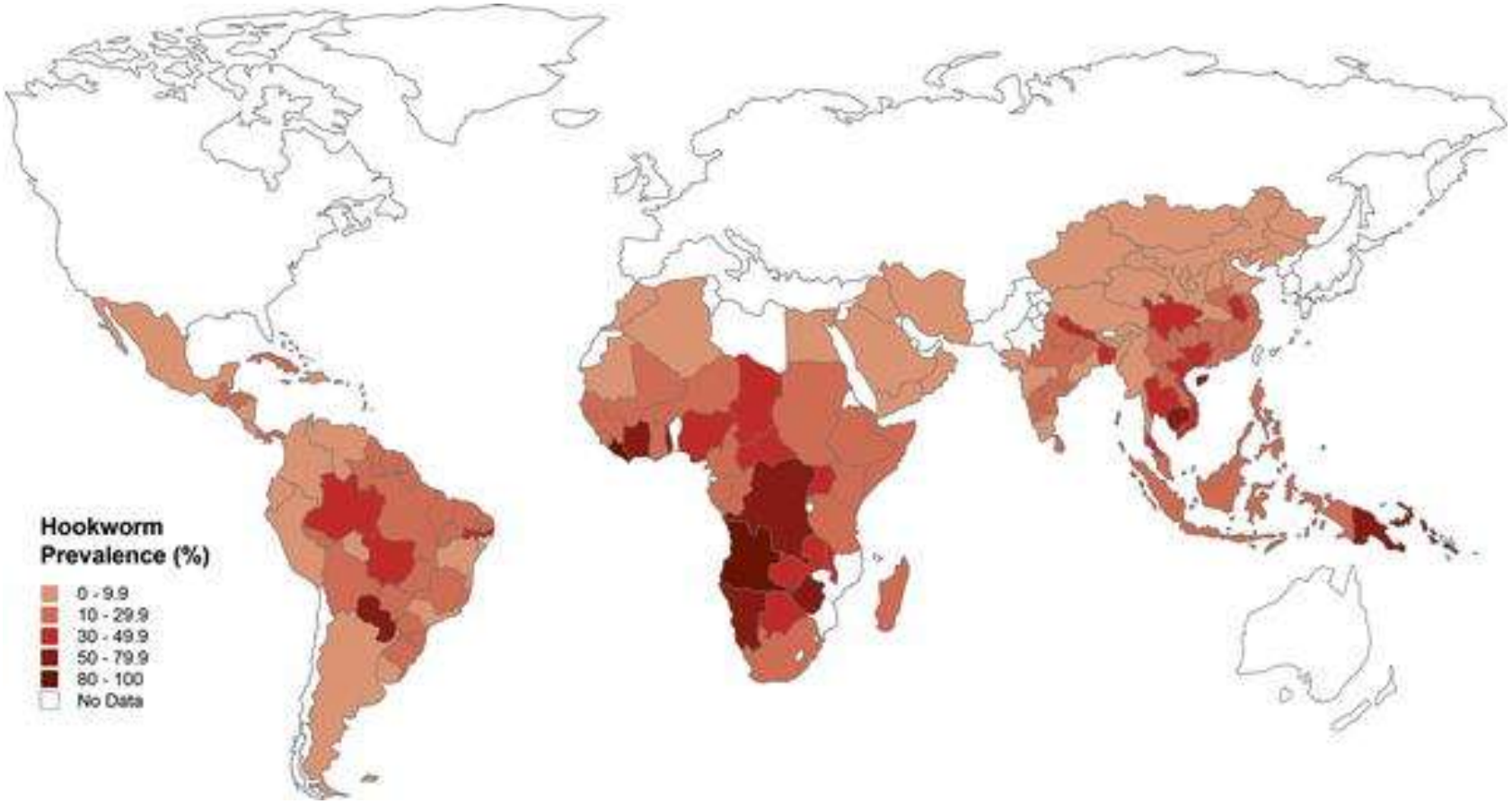
Hookworms

- *Ancylostoma duodenale* and *Necator americanus* commonly infect humans
- *Ancylostoma caninum* and *Uncinaria stenocephala* occurs in canids and felids

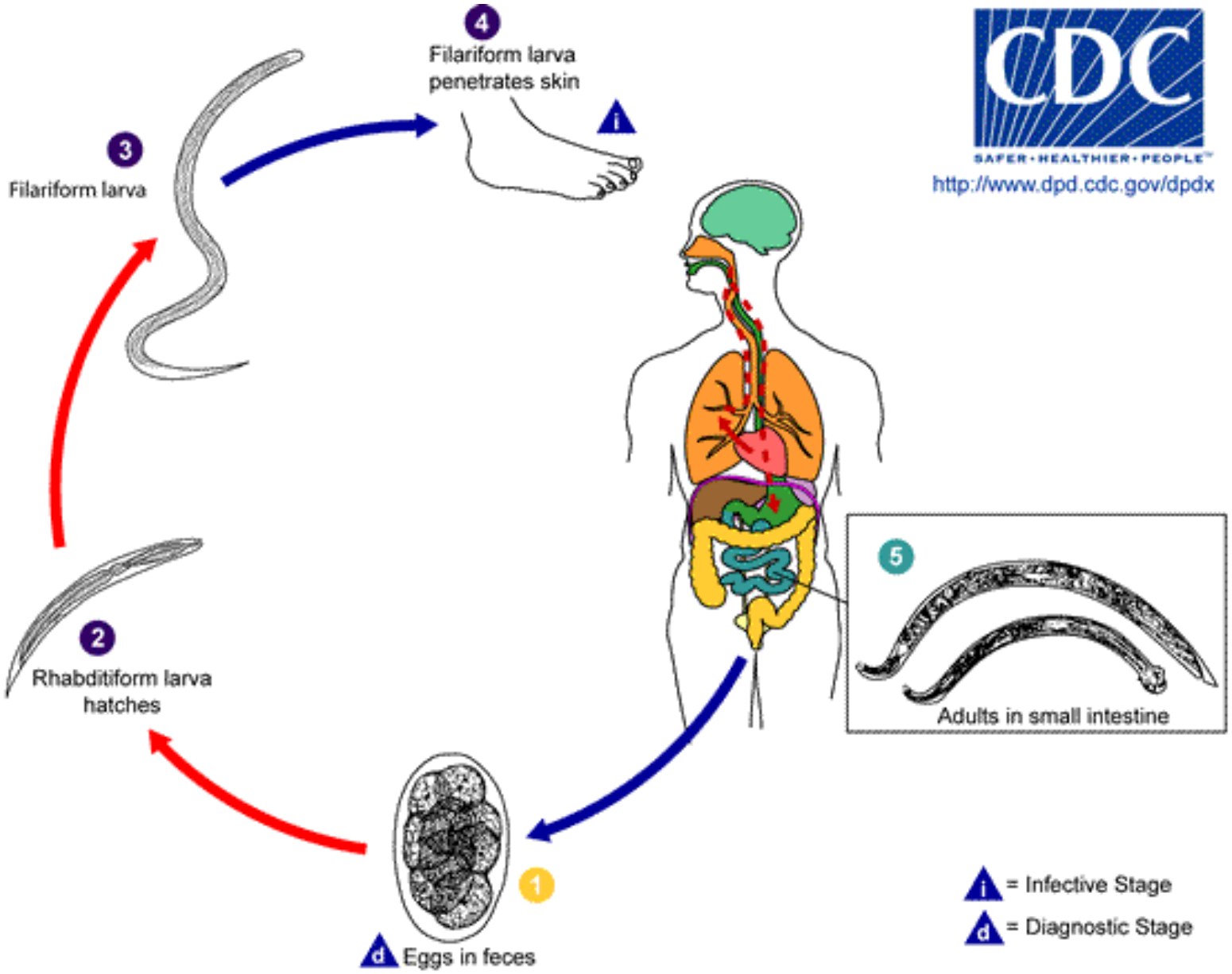
- The worms possess well developed mouths with two pairs of teeth, they suck blood and damage the mucosa

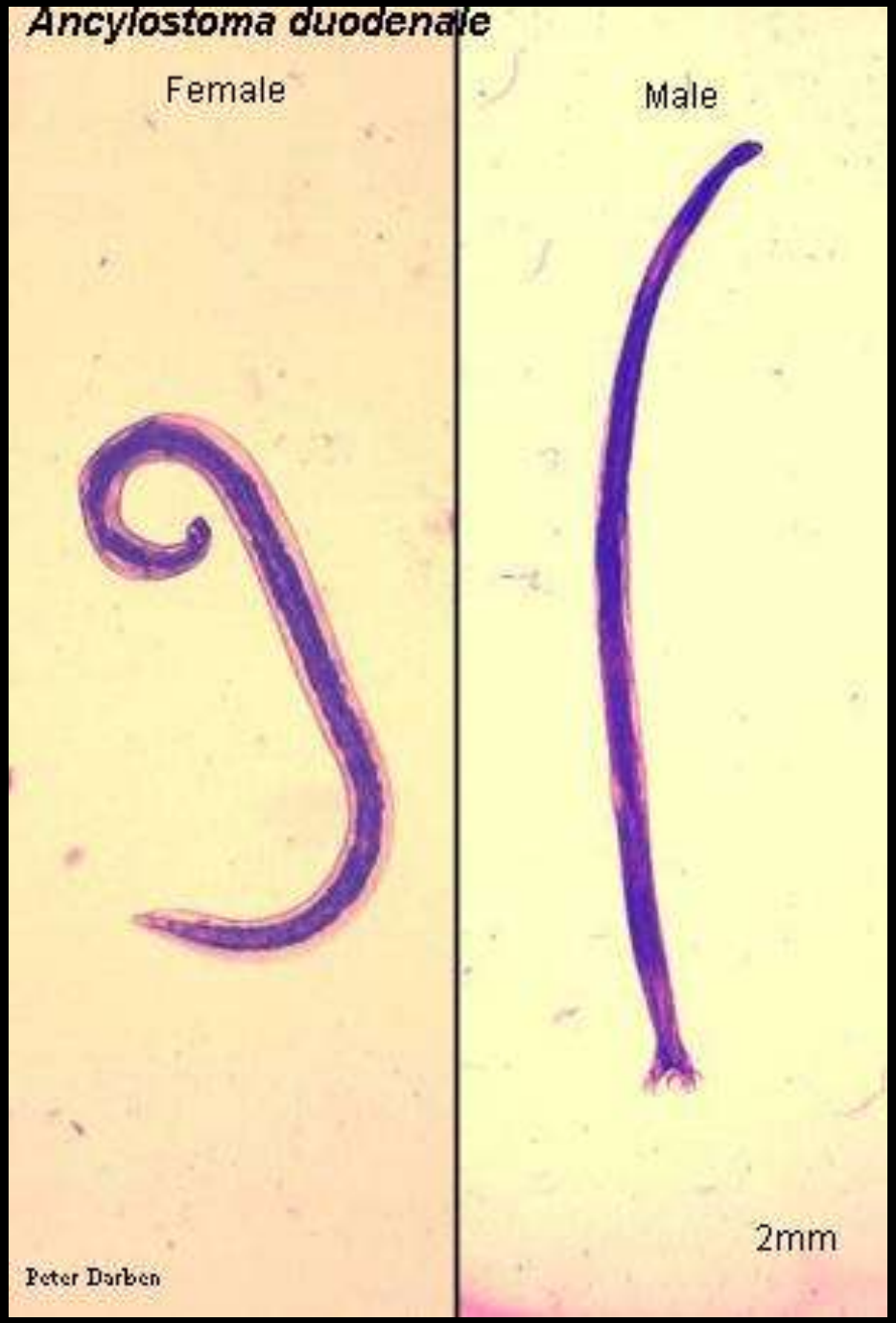
- Leading cause of maternal and child morbidity in the developing countries of the tropics and subtropics
- The most significant risk of hookworm infection is anemia, secondary to loss of iron and protein in the gut

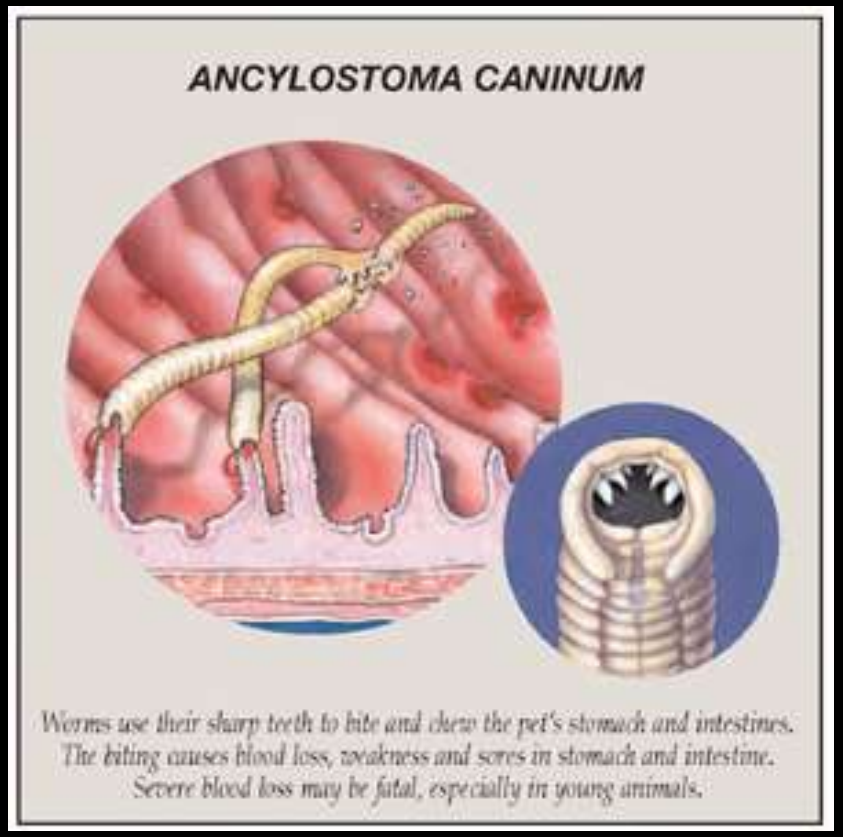
Hookworms geographical distribution



Ancyslotoma duodenale Life Cycle




Ancylostoma duodenale
Female
Male
2mm
Peter Darben


ANCYLOSTOMA CANINUM
Worms use their sharp teeth to bite and chew the pet's stomach and intestines.
The biting causes blood loss, weakness and sores in stomach and intestine.
Severe blood loss may be fatal, especially in young animals.

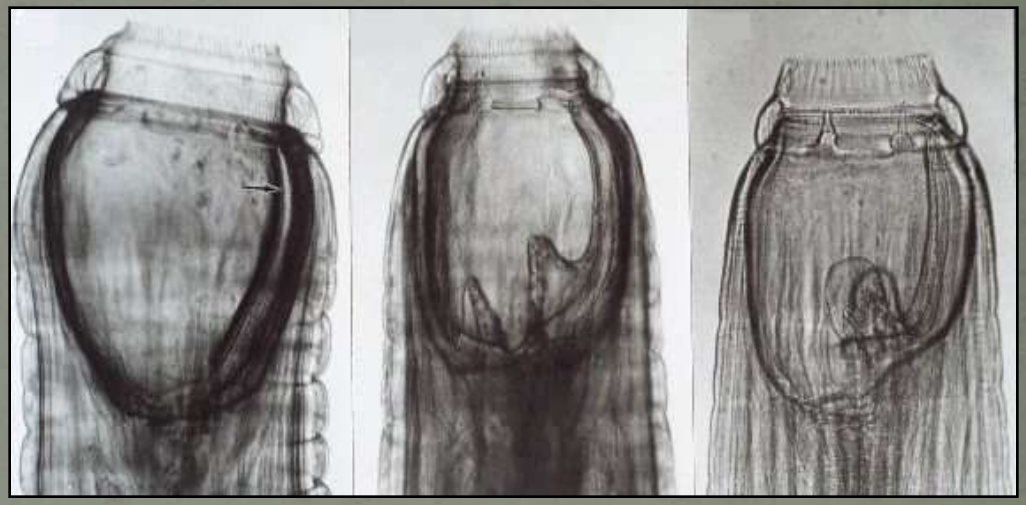
Cutaneous larva migrans

- Skin disease in humans, caused by the larvae of various nematode parasites
  - Animal parasites are able to infect the deeper tissues, in humans they are only able to penetrate the outer layers of the skin and thus create the typical wormlike burrows visible underneath the skin
- The infection causes a red, intense itching eruption, which is painful

Strongyles

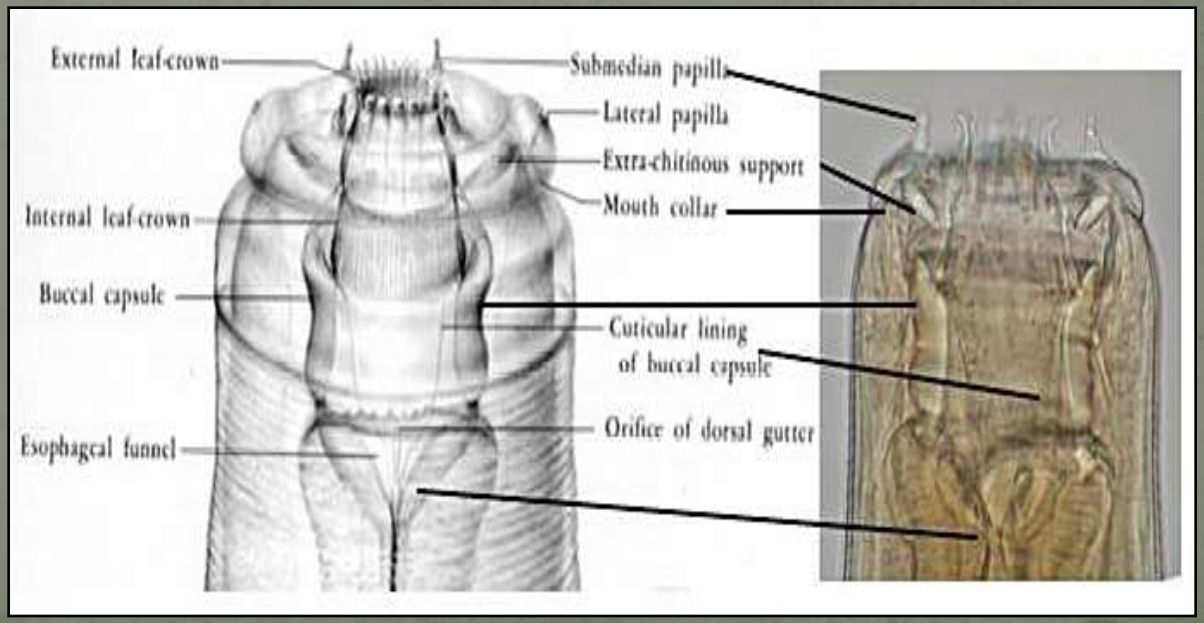
- Large and small strongyles of horses

- Large strongyles
  - *Strongylus vulgaris*
  - *Strongylus edentatus*
  - *Strongylus equinus*

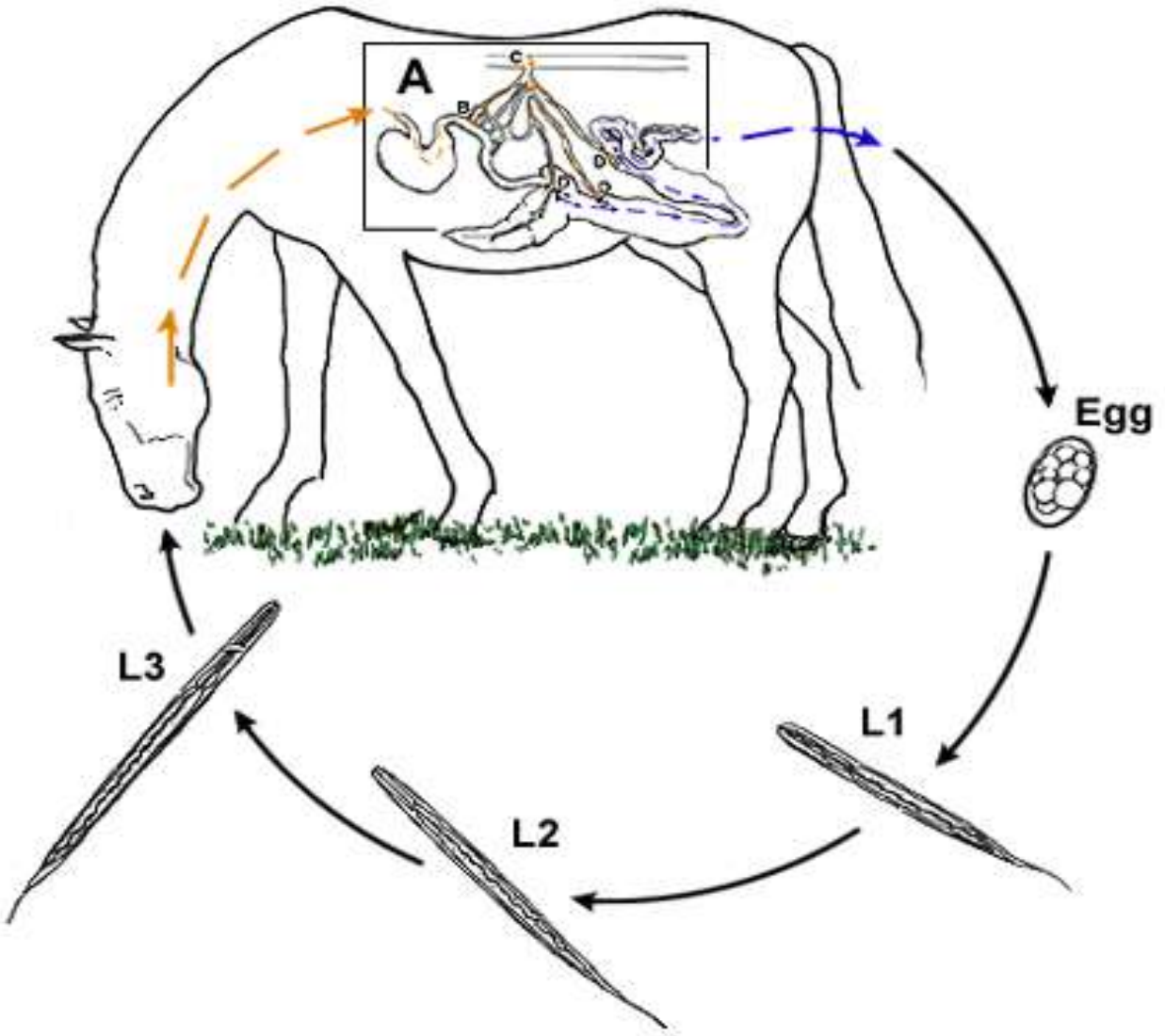


- Up to 50 mm in lenght
- Big buccal capsule present with various number of teeth
- Complicated endogenous migration of larvae and adult nematodes – the most destructive nematodes in horses

- Small strongyles of horses – Cyathostomini
  - Cyathostomini larvae do not migrate beyond the mucose membrane of intestine
  - Pathogenic effect usualy less dramatic than by large strongyles
  - Small strongyles infect virtually all grazing horses



Strongylus Life Cycle



Trichostrongyle nematodes

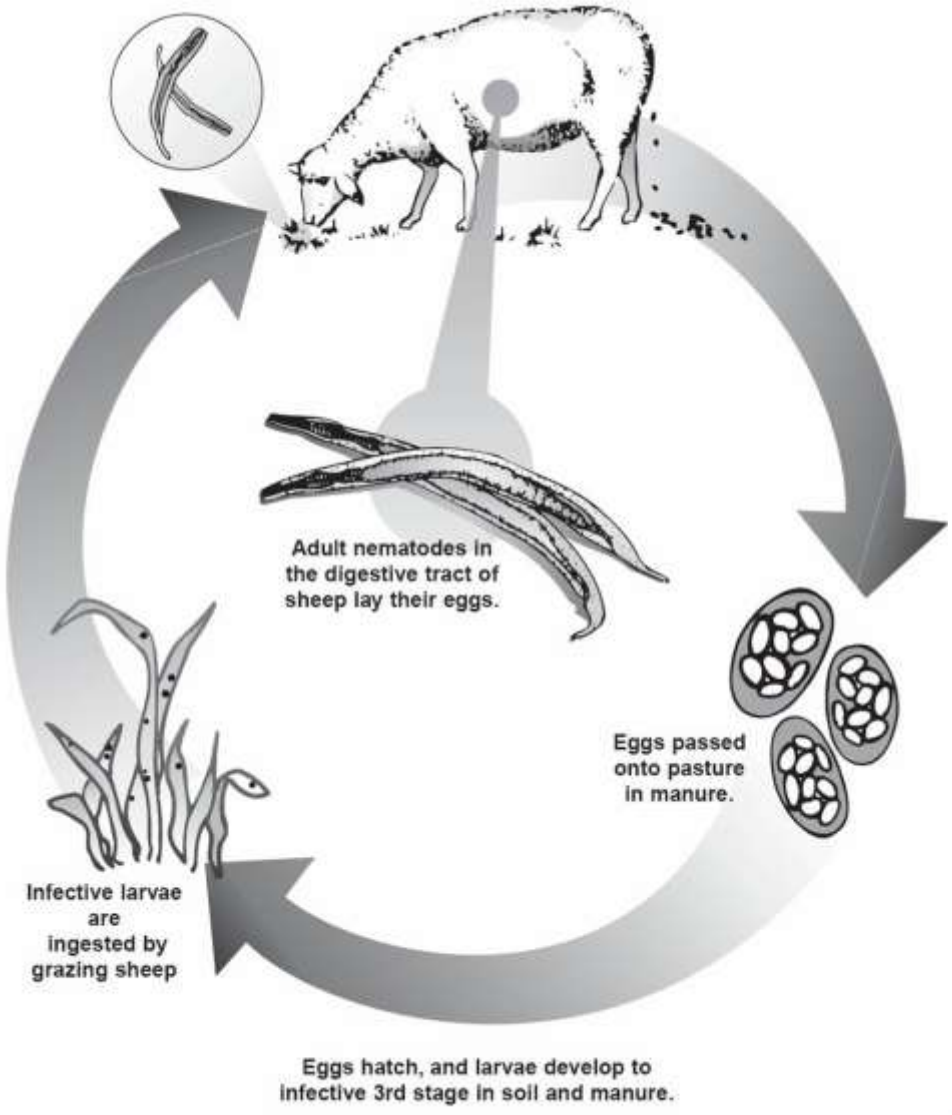
- Hair-like worms, small and thin nematodes
- Small buccal capsule without teeth
- Males with marked accesory copulatory organs (bursa, spicules)

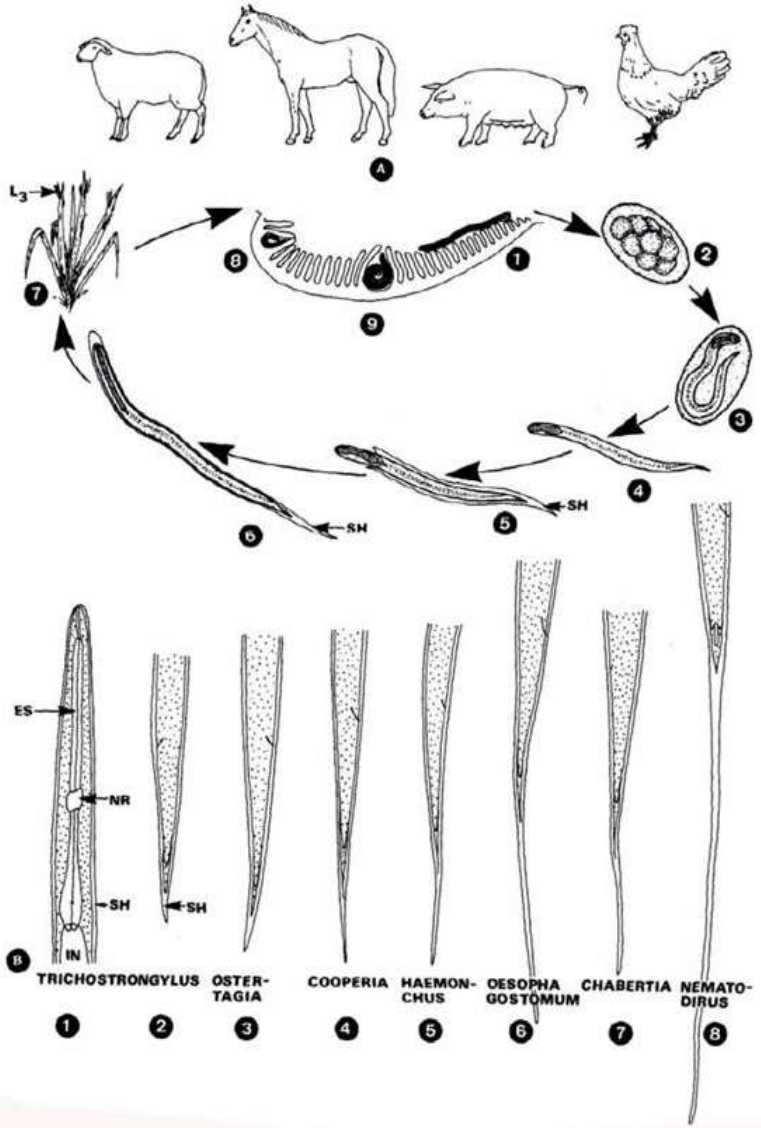
- Direct life cycle without intermediate host (geohelminths)
  - Infection by ingestion of infective larvae L_3

- Various localization in the gastrointestinal tract

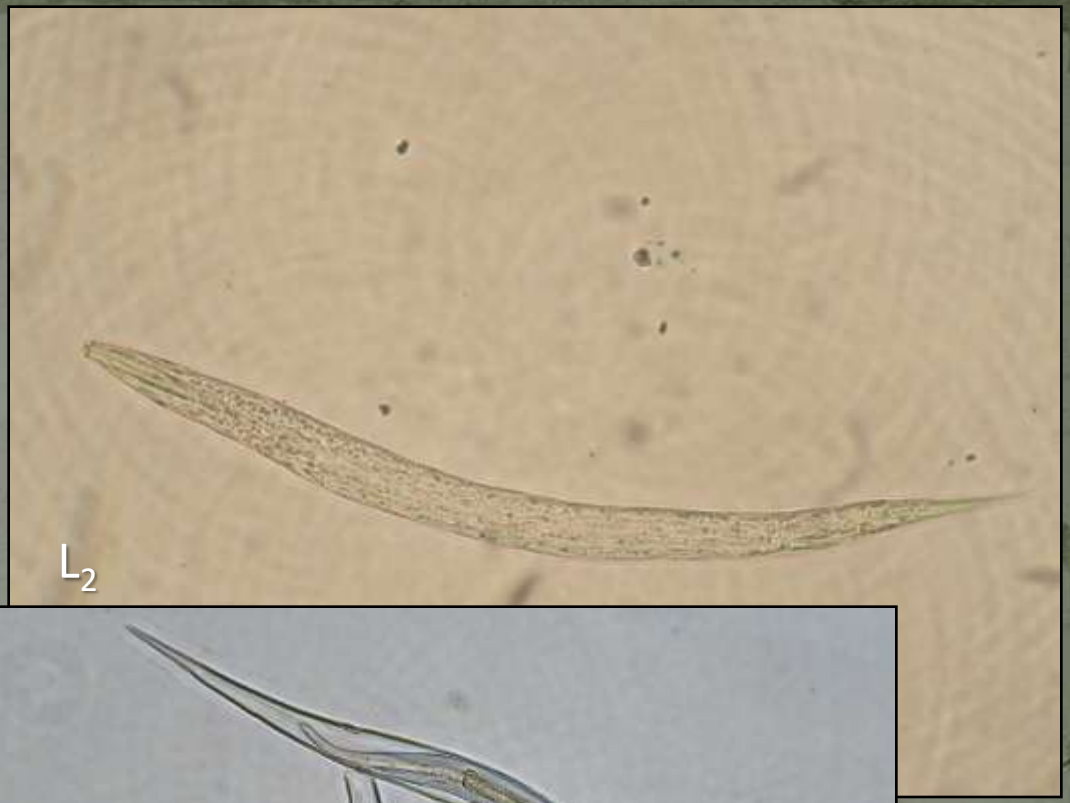
- Mixed trichostrongyle infections causing important worldwide loss in ruminants production

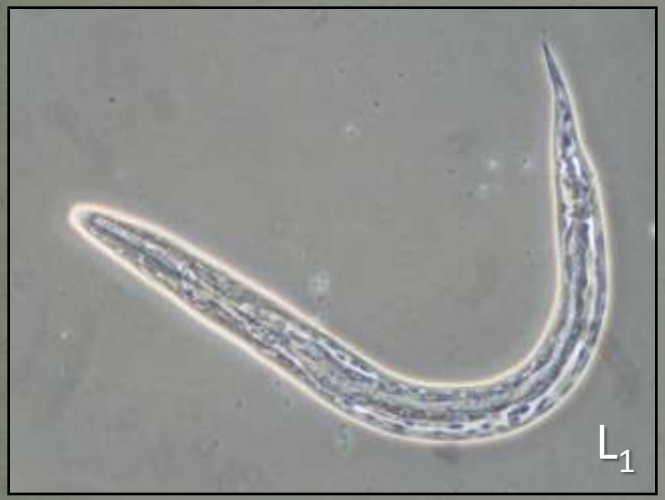
Trichostrongyles Life Cycle



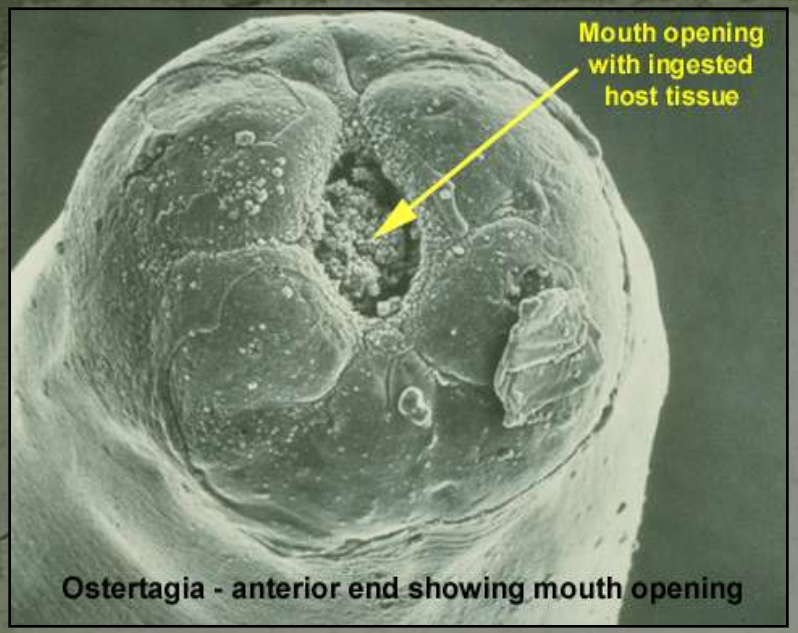



egg

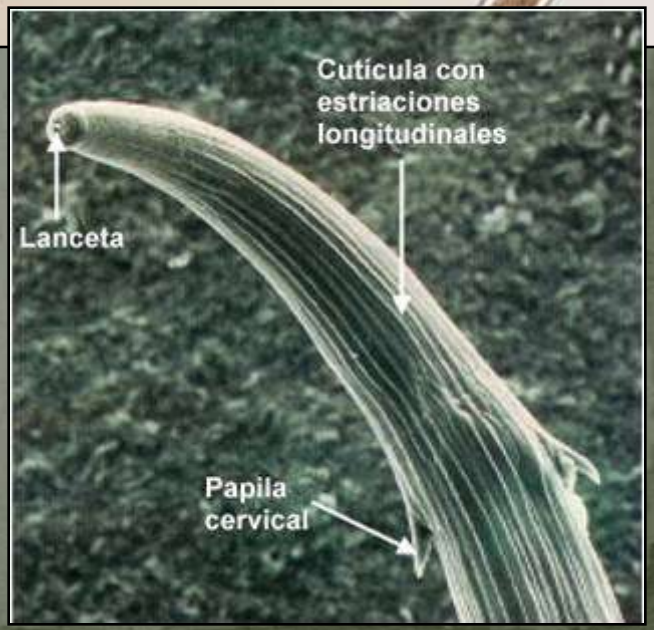

L_2


L_1


infective L_3



Ostertagia - anterior end showing mouth opening



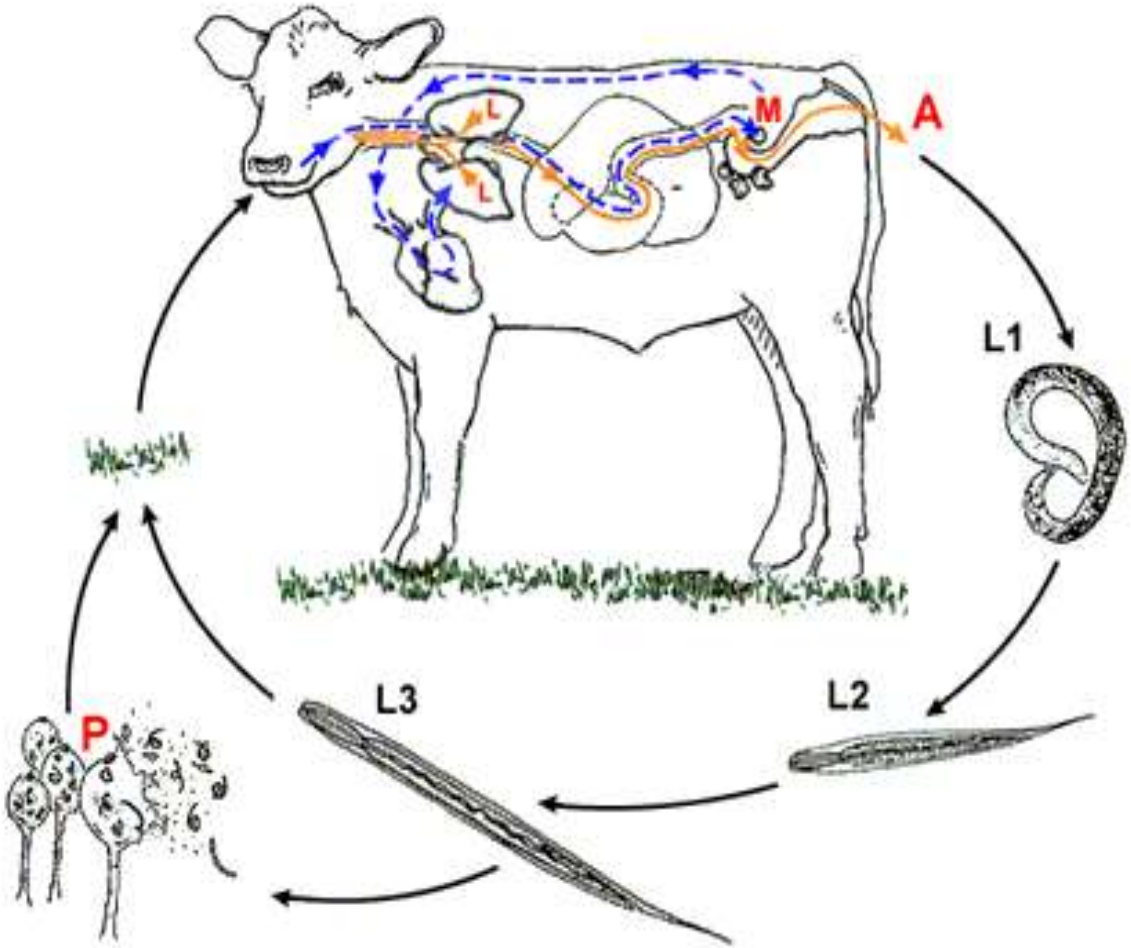
Lungworms

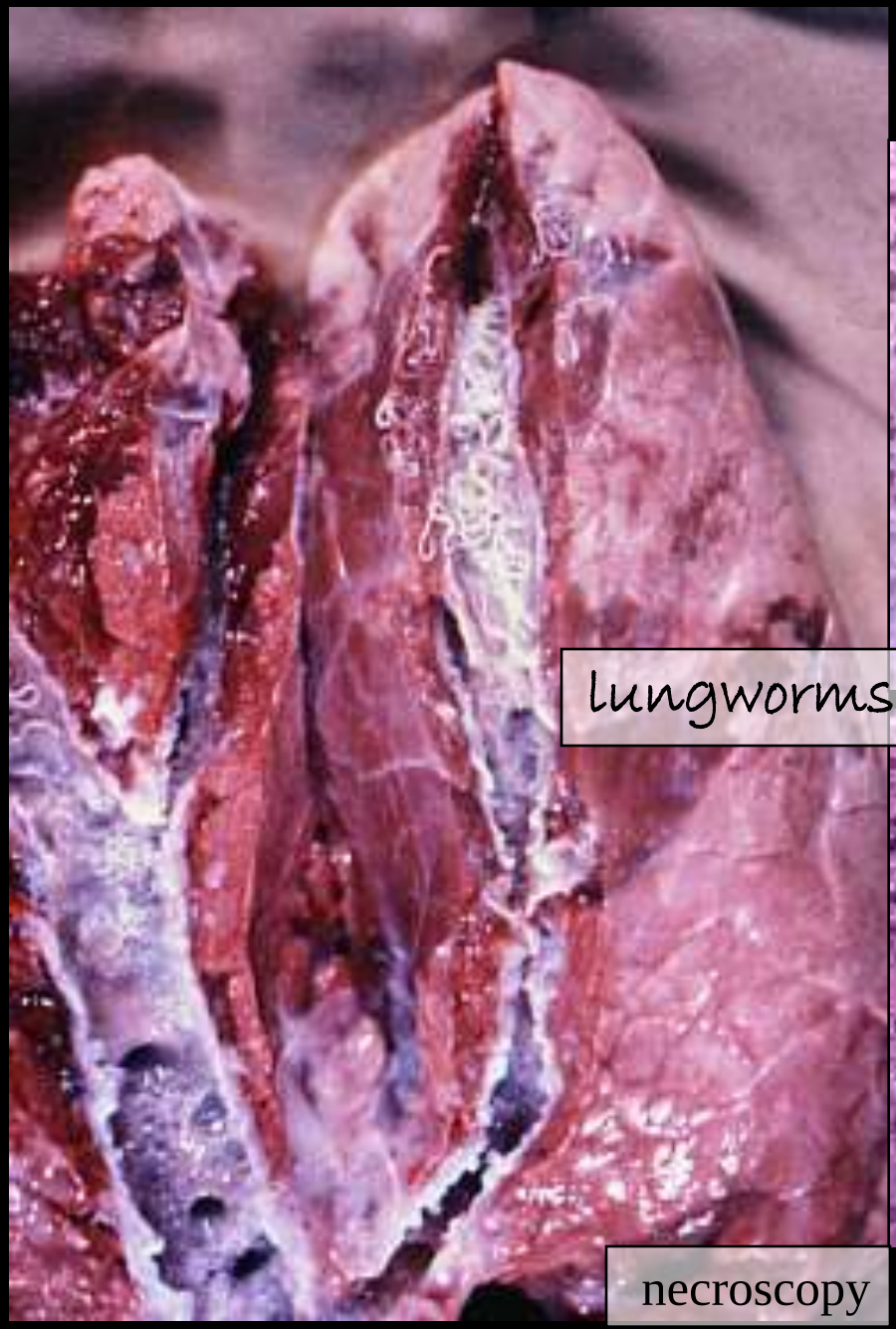
- Nematodes in airways and pulmonary parenchyma
- Causal agent of parasitous bronchopneumonia
- Big and small lungworms

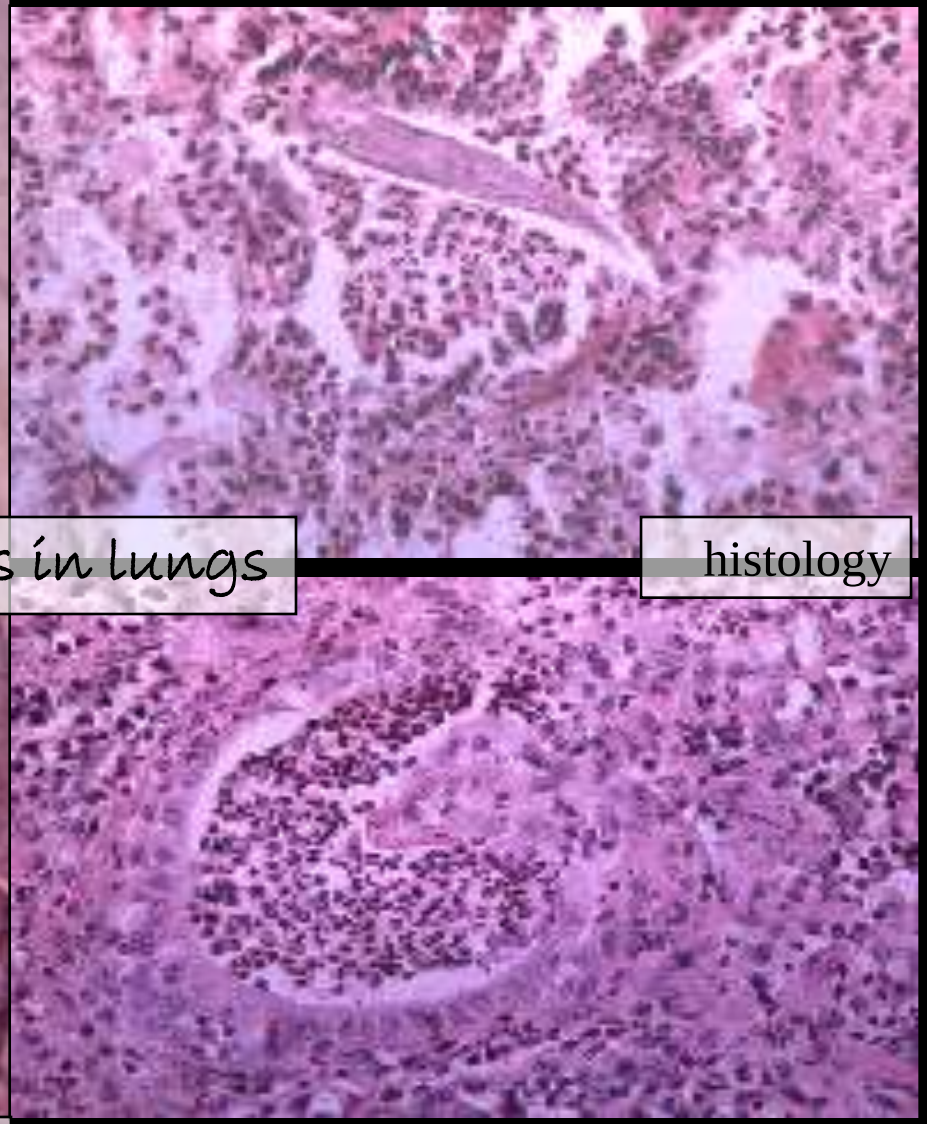
- Dramatic increase *Dictyocaulus* species in cattle in some countries
- Direct life cycle, earthworms serve as paratenic hosts

- Small lungworms with worldwide distribution
- Mixed infection of several genera
- Indirect development, ovoviviparous females, IH land snails

Dictyocaulus spp. Life Cycle







lungworms in lungs

histology

necroscopy

- *Metastrongylus* species common in wild pigs and in pigs on pasture run
- Indirect development with earthworms as intermediate host
- Important mainly in developing sucking pigs

Metastrongylus spp. Life Cycle

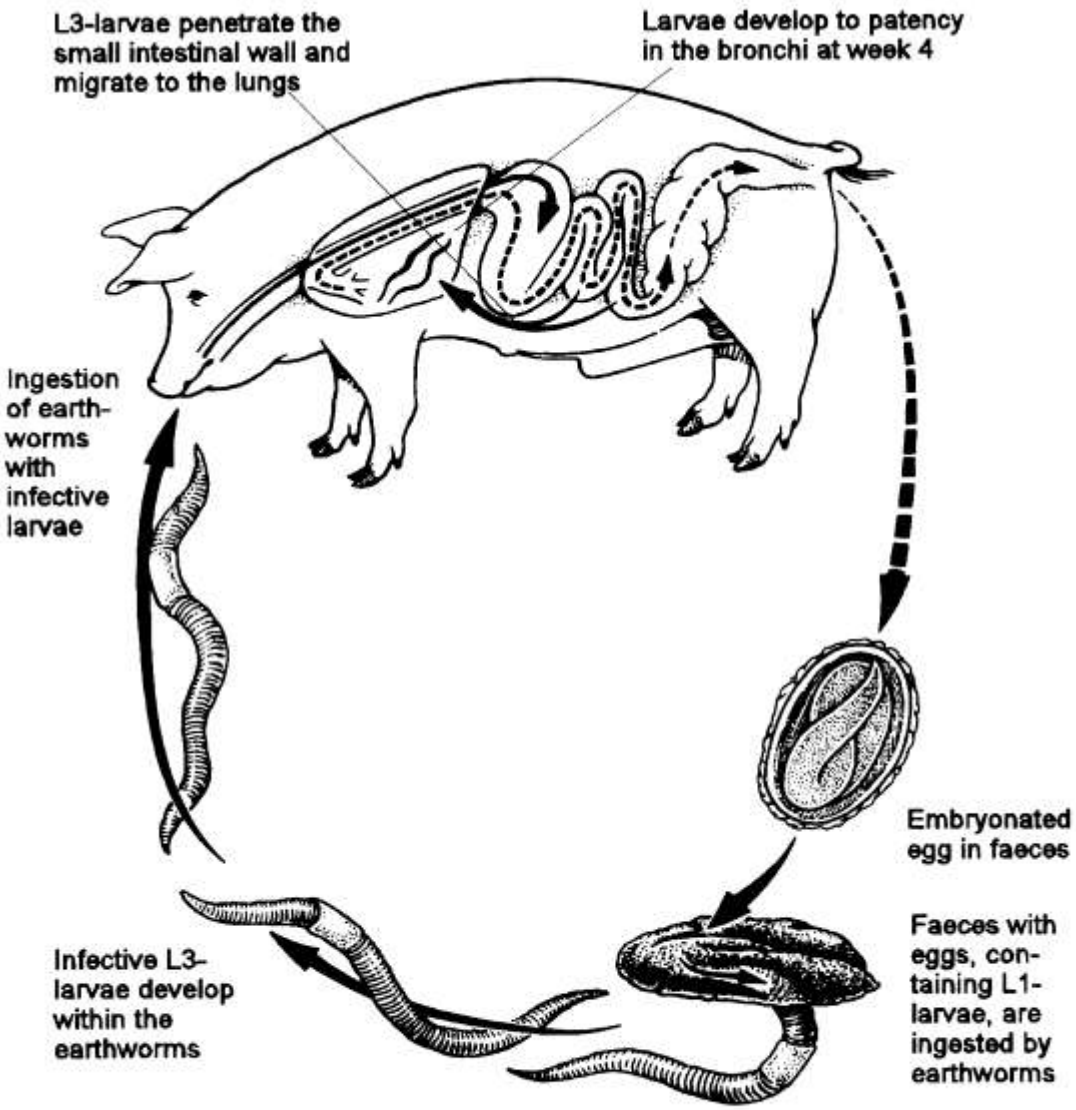
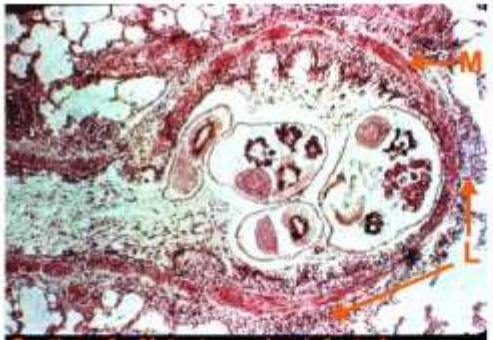


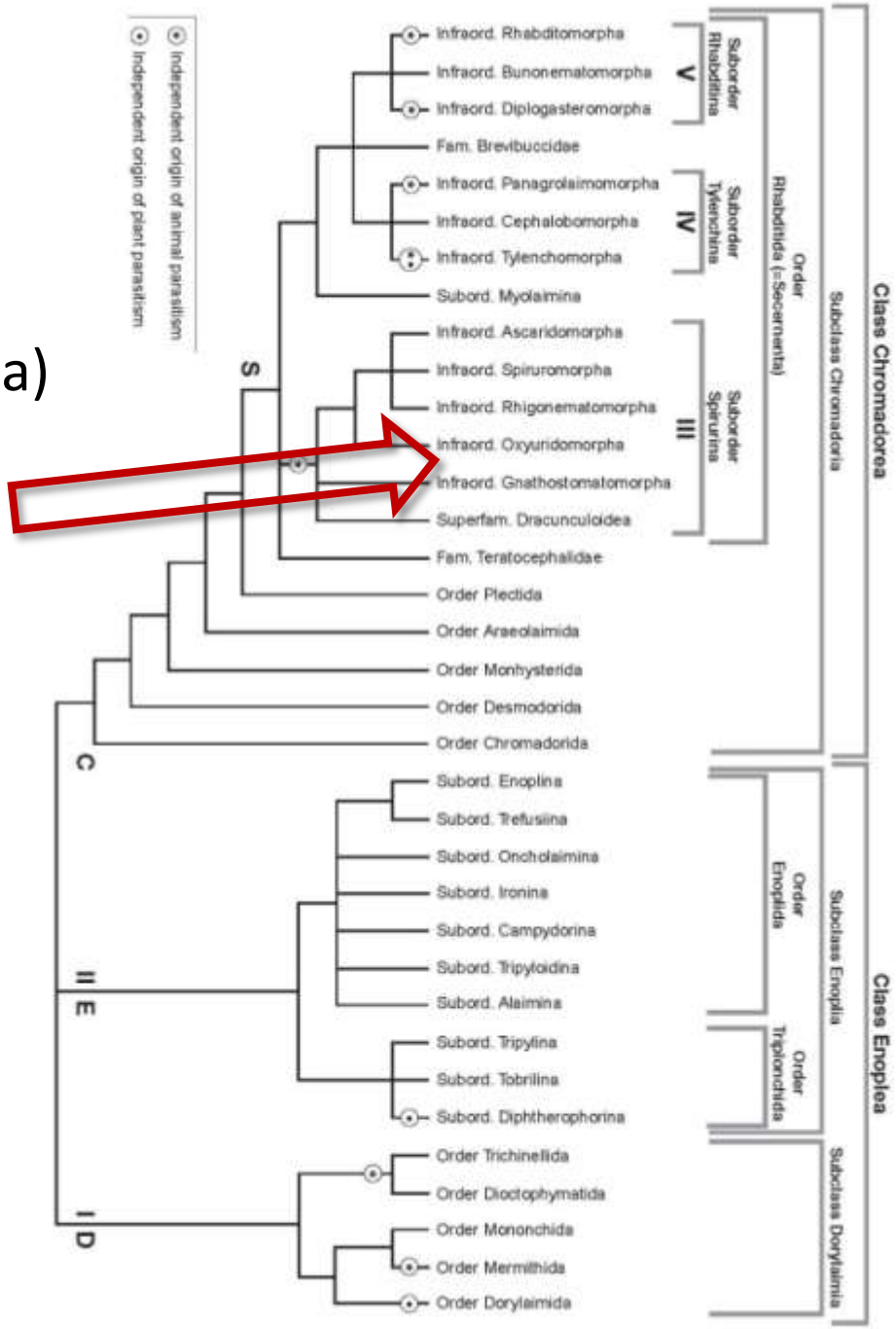
Illustration by Wm P Hamilton CMI



Section of a Metastrongylus-infected bronchiole showing muscular hypertrophy (M) and lymphoid infiltration (L)


lungworms in bronchioles – histology

Kingdom: animals (Animalia)
Phylum: nematodes (Nematoda)
Class: Chromadorea
Infraorder: Oxyuridomorpha



- *Enterobius vermicularis* (threadworm) parasite of humans, especially in children
- Common parasites in rodents worldwide are *Syphacia* species
- *Passalurus ambiguus* lives in the cecum and colon of rabbits and hares

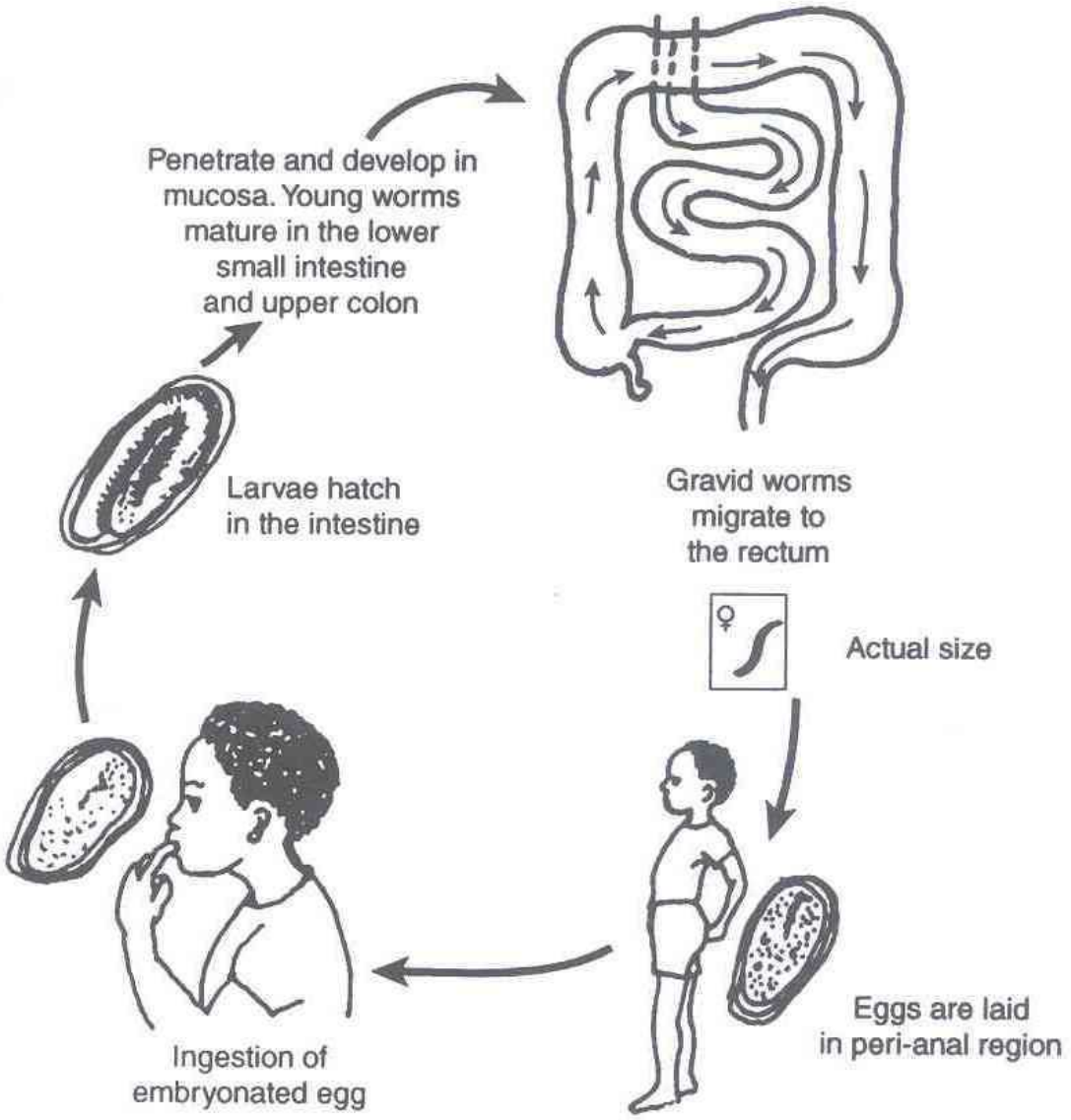
- They have short and stout body and typical pharynx with bulbus

- Pinworms are localized in posterior parts of the gastrointestinal tract of hosts
- Nematodes with low pathogenicity, close to commensalism

- Sexual dimorphism
  - Bursa in males is absent, generally only one spucile and caudal papilae present
  - Traumatic insemination in some species present
  - After mating, the male dies
- Eggs are deposited by the female on the perianal area of the host or in the colon

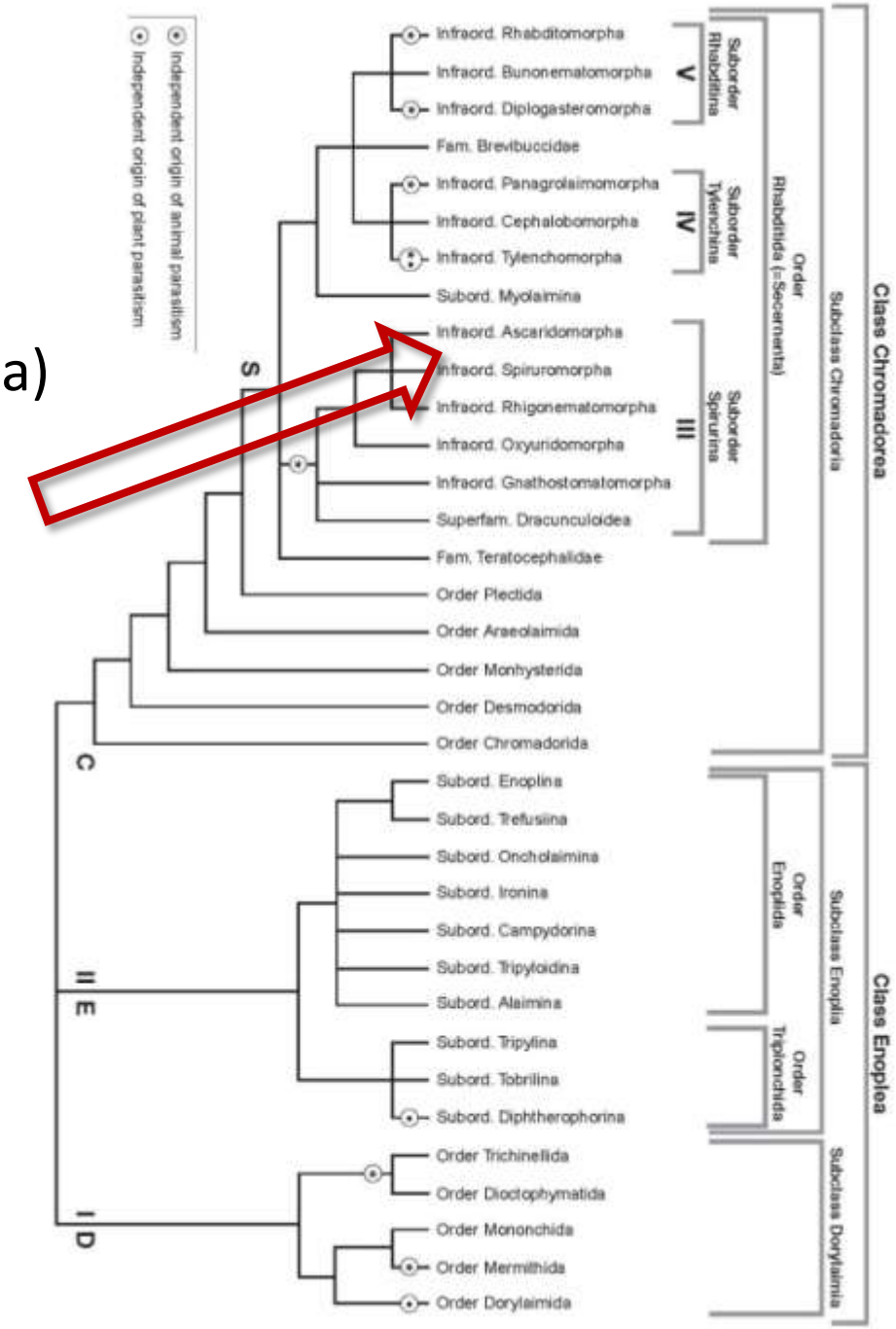
- Soil-transmitted helminth infection
  - Problematic nematode in young girls
  - Diagnosis by schotch-tape test (CTT)

Enterobius vermicularis Life Cycle




12
13
14

Kingdom: animals (Animalia)
Phylum: nematodes (Nematoda)
Class: Chromadorea
Infraorder: Ascaridomorpha

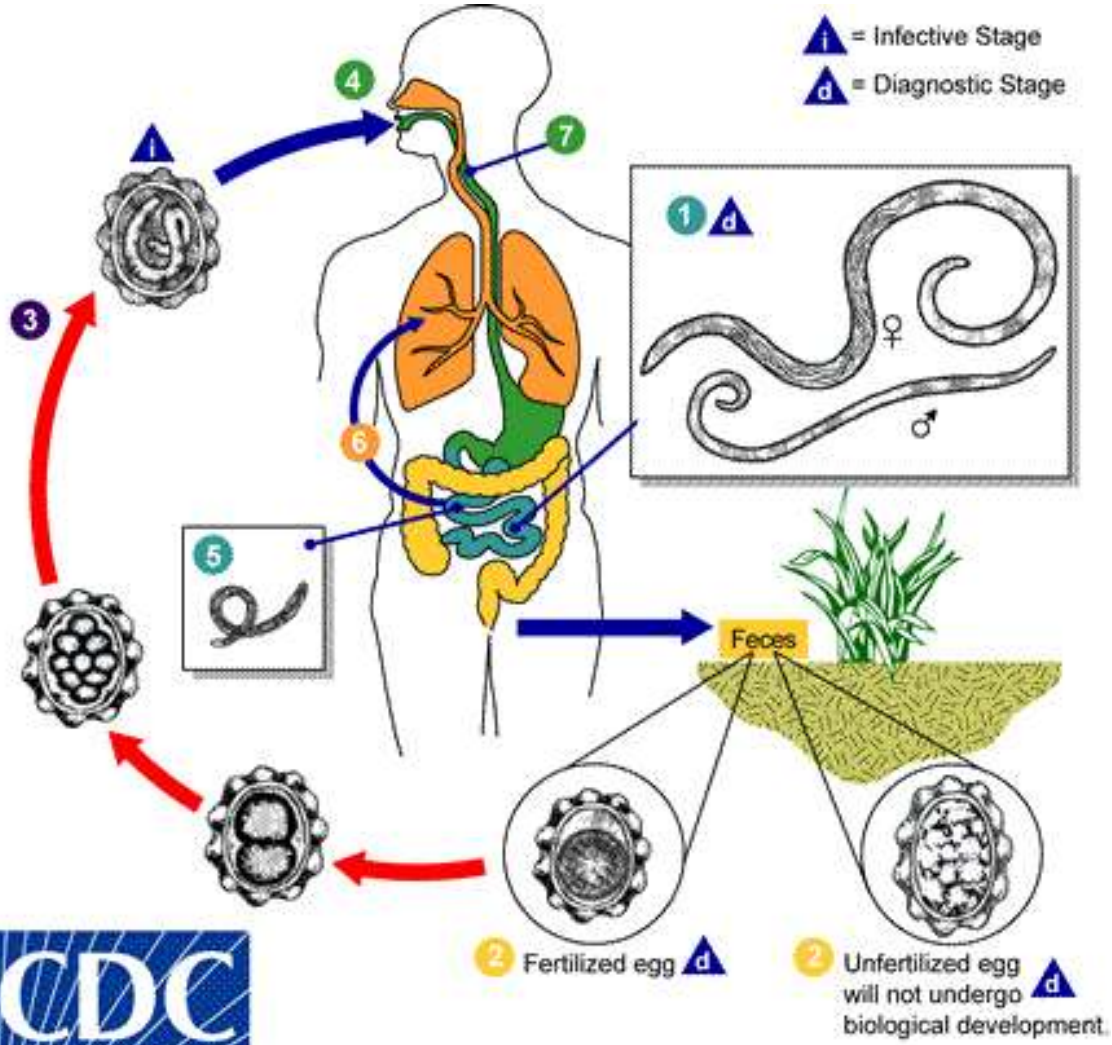


- *Ascaris lumbricoides* is the largest intestinal nematode and is the most common helminth infection of humans worldwide
- 50 – 75% of pigs infected by *Ascaris suum* worldwide
- *Toxocara* species in candis and felids

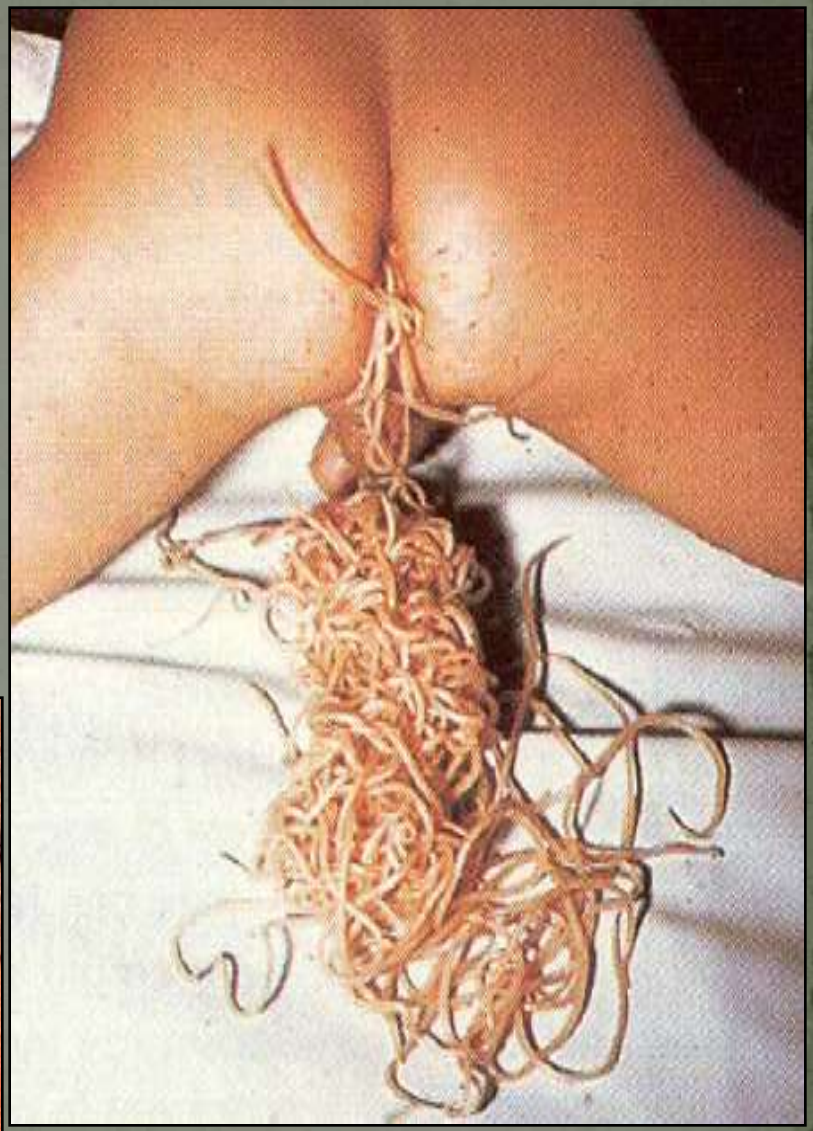
- Intestinal parasites of vertebrates, adults feed on the contents of the small intestine
- Three labia (lips) on the anterior end

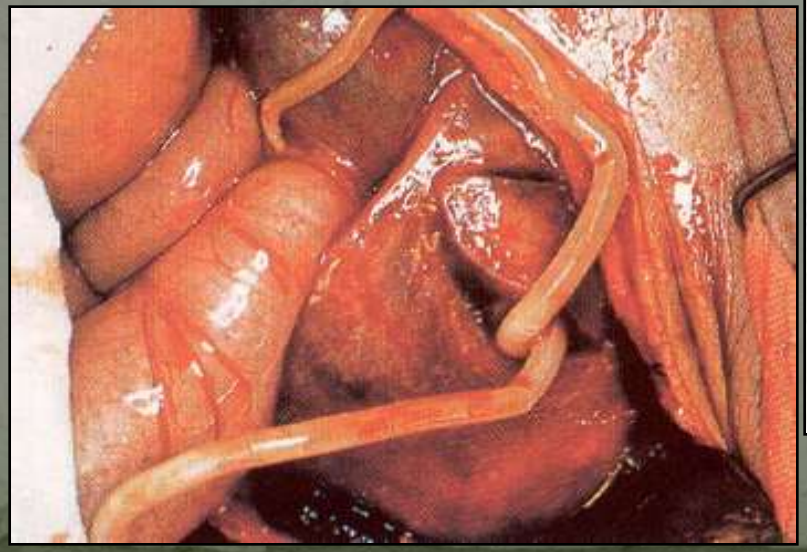
- Direct life cycle with complicated somatic migration
- Thick shelled eggs can survive many years in environmental conditions

Ascaris lumbricoides Life Cycle




H 12

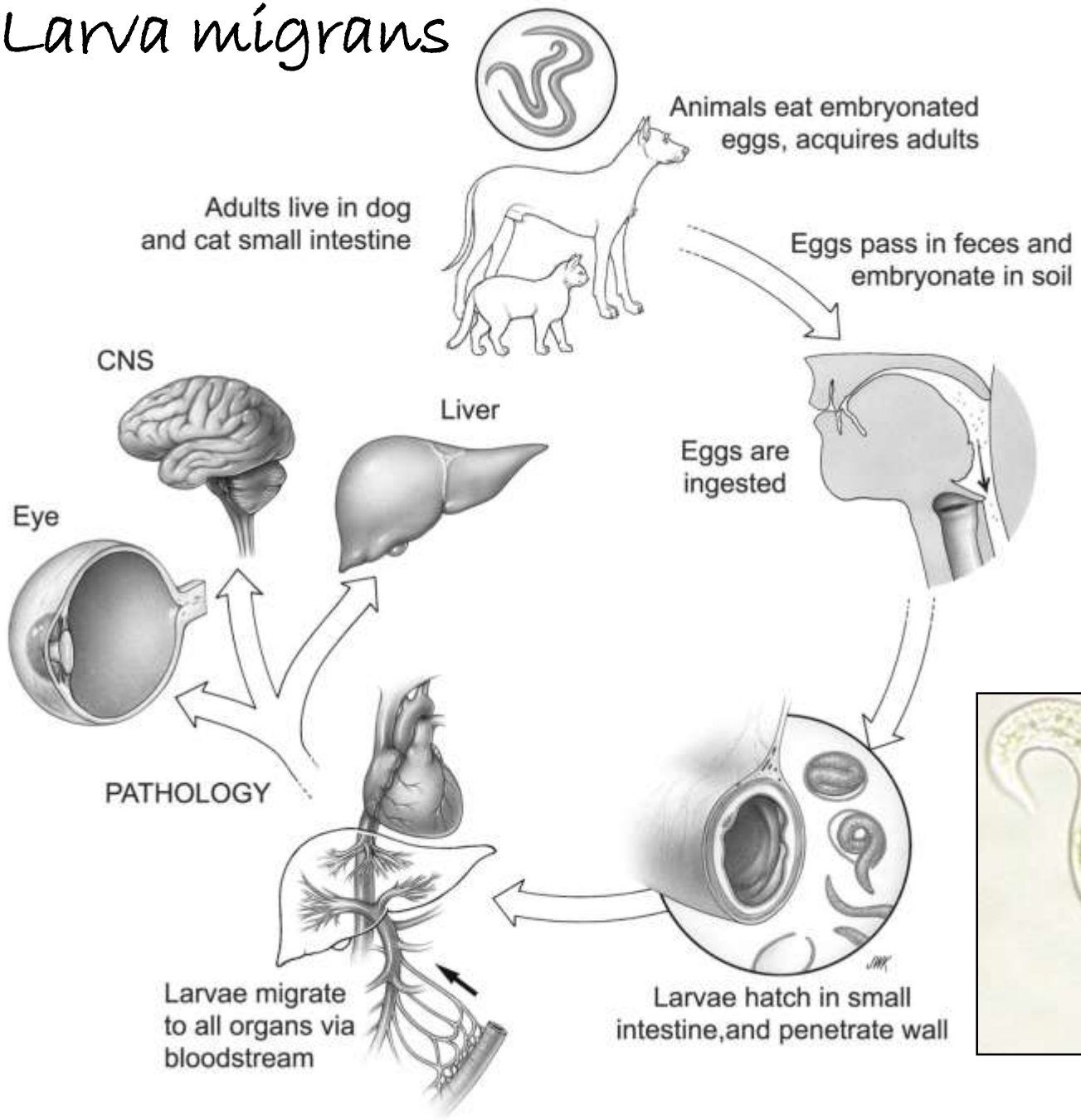


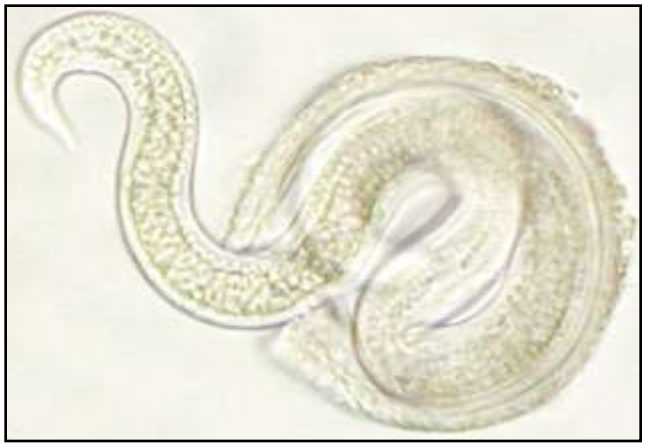


Syndrom larva migrans

- Ocular and visceral form
- Occurs when parasitic larvae migrate through the internal organs of the paratenic host
- Humans can acquire these infections by ingesting eggs of ascarid which is not a specific human parasite
- In paratenic hosts, the larvae do not complete normal migration and encyst in the tissues

Larva migrans





Kingdom: animals (Animalia)
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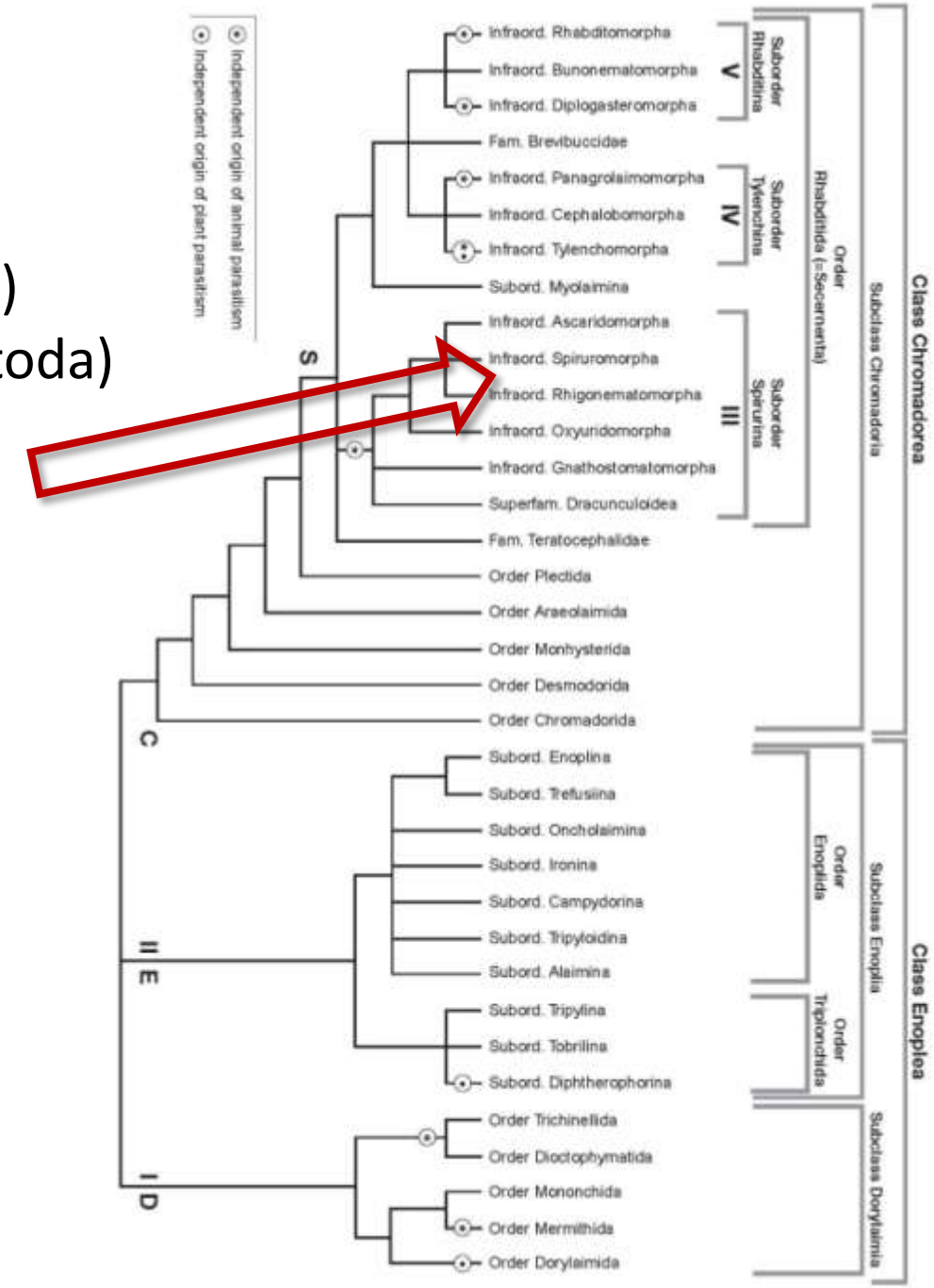
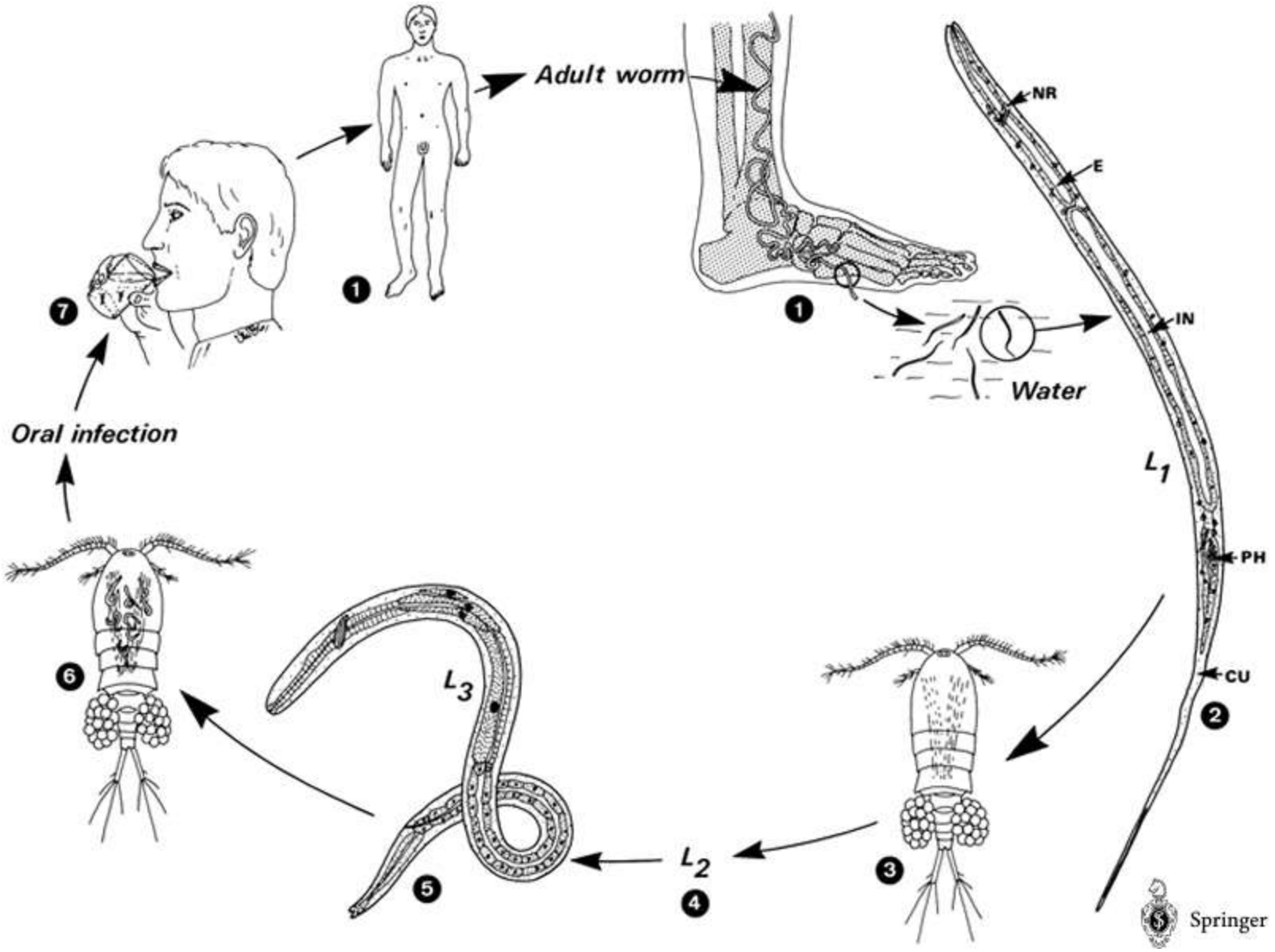


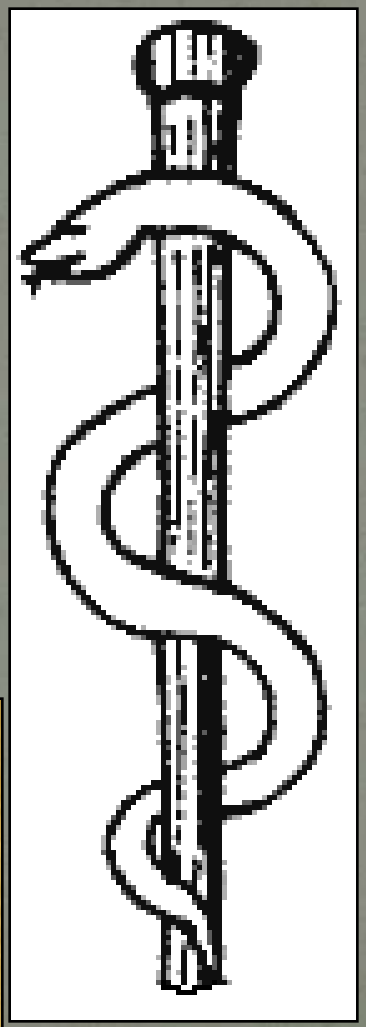
- Parasites of terrestrial and aquatic vertebrates
- Labial region is usually provided with two lateral labia or pseudolabia
- Stoma may be cylindrical and elongate or rudimentary
- Pharynx is generally divisible into an anterior muscular portion and an elongate swolen posterior glandular region

- Biohelminths, all spirurids use invertebrate for one host
- Ovoviviparous females, rarely viviparous

- Causative agents of severe diseases: Guinea worm disease (GWD), river blindness, lymphatic filariasis, hearthworm

Dracunculus medinensis Life Cycle





RIVER BLINDNESS

Onchocerciasis, also known as river blindness, is a parasitic disease caused by tiny worms or "microfilariae" and transmitted by flies. The disease affects an estimated 18 million people worldwide.

THE DISEASE CYCLE

1 Parasitized
The insect takes a blood meal from a human. A pool of blood is pumped up into the fly, saliva passes into the pool, and infective *Onchocerca* larvae pass from the fly into the host's skin.

2 Infection
The larvae enter the host's skin tissue, where they migrate and form nodules, and slowly mature into adult worms

3 Proliferation
New worms form new nodules or find existing nodules and cluster together. Smaller male worms migrate between nodules to mate.

4 Reproduction
After mating, eggs form inside the female worm and develop into microfilariae. A female may produce 1,000 microfilariae per day.

5 Transport
When the infected host is bitten by another fly, microfilariae are transferred from the host to the fly.

Carter Center-Assisted Onchocerciasis Control Programs

Highlighted areas in Africa represent areas where The Carter Center is actively working. The highlighted areas in Latin America represent the 13 remaining foci.

DISEASE SYMPTOMS

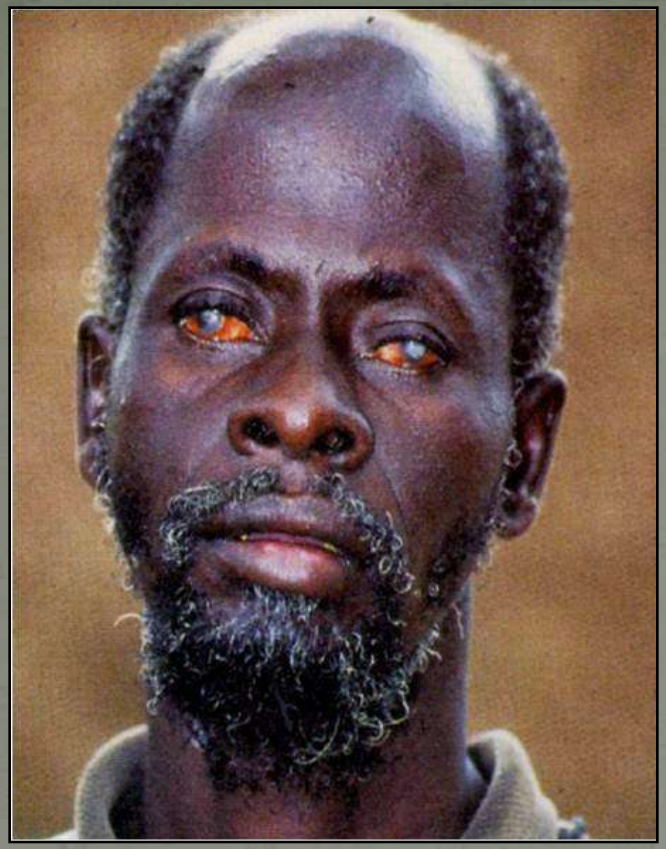
Eye lesions
If microfilariae migrate to the eye, they can cause severe lesions and in some cases blindness.

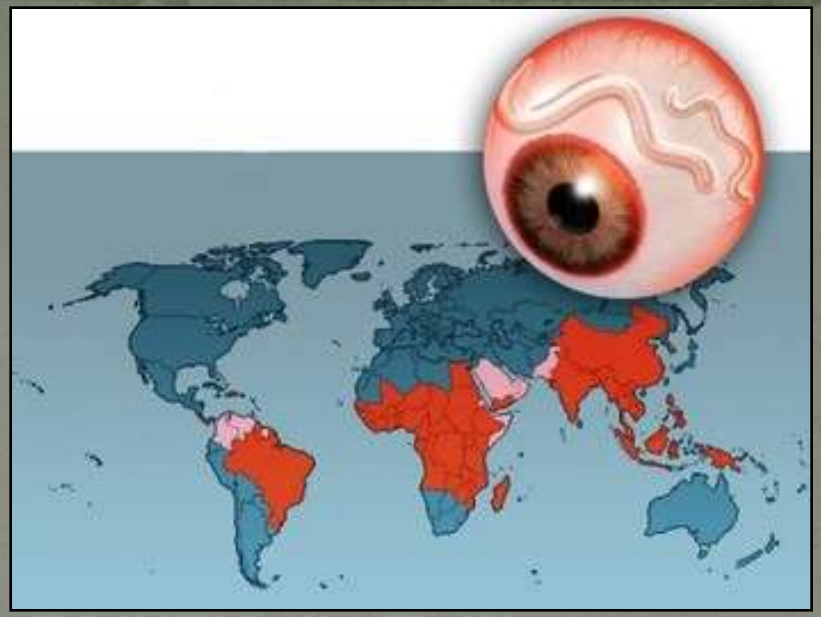
Microfilariae in the eye are actually about the size of the period at the end of this sentence.

Skin lesions
Many thousands of microfilariae migrate in the upper layers of the skin. When the microfilariae die, they cause skin rashes, lesions, intense itching and skin depigmentation.

Sources: World Health Organization, Centers for Disease Control; Map: The Carter Center

ALBERTO CUADRA : CHRONICLE





The Life Cycle of Lymphatic Filariasis

1 An infected mosquito deposits larvae on the skin while biting and the larvae enter the wound.

2 The larvae migrate to the lymphatic system, where they grow, mate and form nests. The nests cause blockages, resulting in swelling and fever.

ADULT WORMS

LYMPHATIC SYSTEM

3 Female worms produce microscopic worms called microfilariae, below, that swarm in the blood at night, when mosquitoes bite.

4 A mosquito bites the infected person, ingesting the microfilariae along with the blood.

5 Microfilariae develop into larvae over a period of a week.

BLOCKAGE

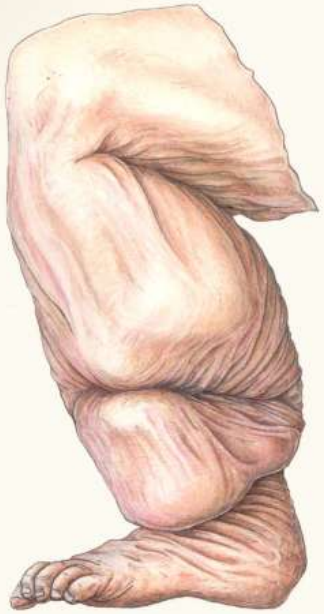
SWOLLEN LEG

Photo from C.D.C.

Source: The Carter Center

Al Granberg/The New York Times

Historical Medical Oddities



A lower leg and a scrotum showing the effect of Elephantitus.

A mosquito picks up some microfilaria when if feeds from an infected dog. Cats rarely have circulating microfilaria.

This is microfilaria magnified about 1000 times.

Microfilaria are tiny! They circulate in the infected animals blood stream.

Microfilaria live about 2 weeks in mosquito salivary gland and then become infective.

Adults give birth to live offspring called microfilaria. (Like a Guppy fish)

The Start

The mosquito bites a dog or cat releasing heartworm larvae into the wound.

Heartworm Preventatives Kill the Larvae Here!

Adult Heartworms (About the size of spaghetti strands)

Larvae molt and grow as they migrate through tissue heading to the heart and lung vessels.

Larvae finally reach the right heart where they impede blood flow and cause damage to the heart and lung vessels.

Heartworm Life Cycle