Phylum Platyhelminthes

You will need:

- five colours of pencil crayon or pen (preferably blue, green, red, orange and purple)

Phylum Platyhelminthes

- bilaterally symmetrical
- have all 3 embryonic germ layers: mesoderm allows for more complex organ systems
- acoelomate
- aquatic, both free-living and parasitic species

A marine flatworm of the coral reefs

Digestive system

- gut is a simple gastrovascular cavity, but is highly branched to increase the surface area
- the mouth/anus is at the end of a muscular tube called the pharynx
- no circulatory or respiratory systems, both occur by diffusion

Flatworm head showing branched gastrovascular cavity

Nervous system

Flatworms are the first to show cephalisation:

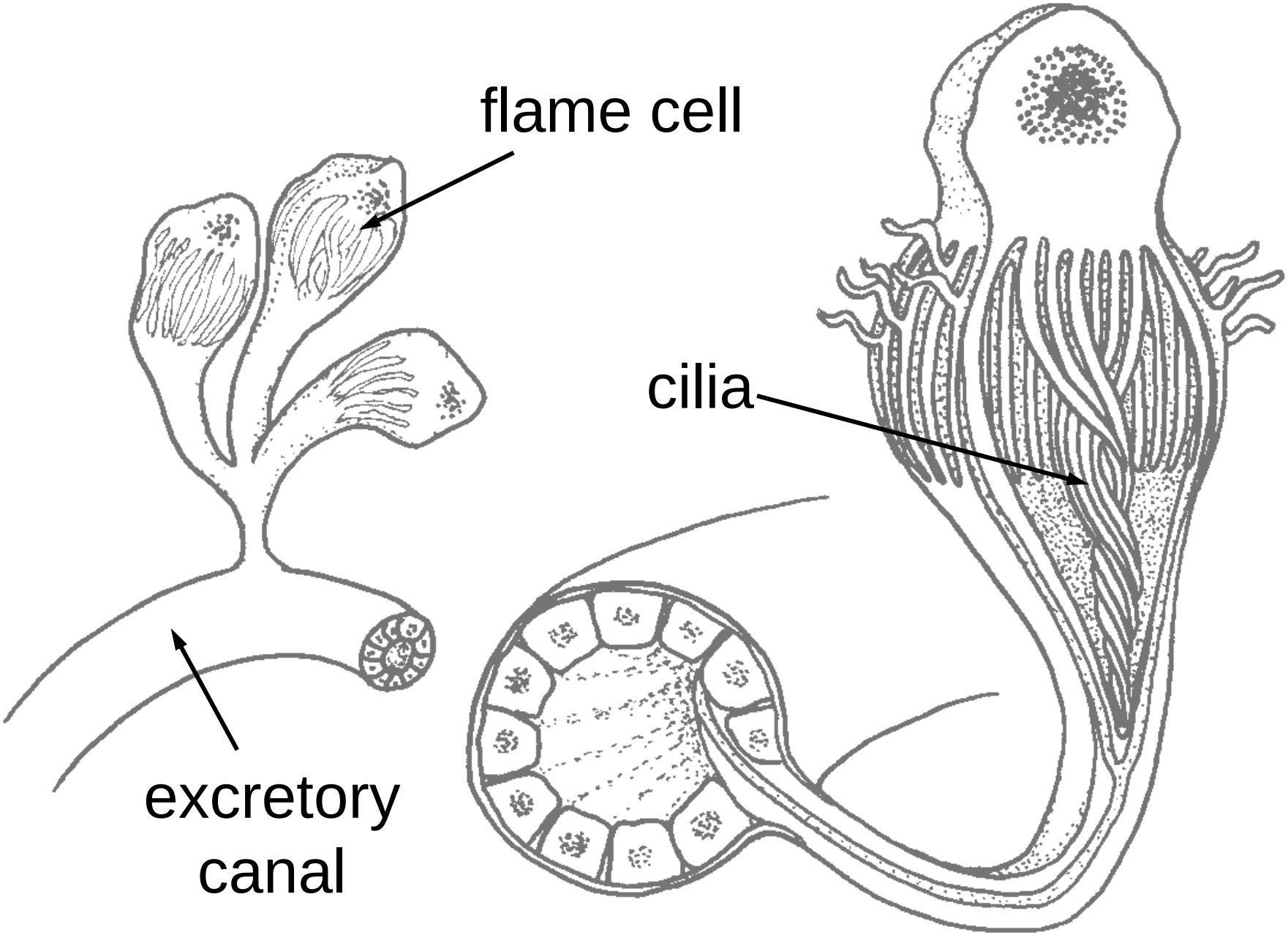
- a pair of small brains in the head connect to long, ladder-like nerve cords
- eyespots = small light-sensitive organs located next to the brains
- auricles = a pair of chemically-sensitive organs on the head, look like ears

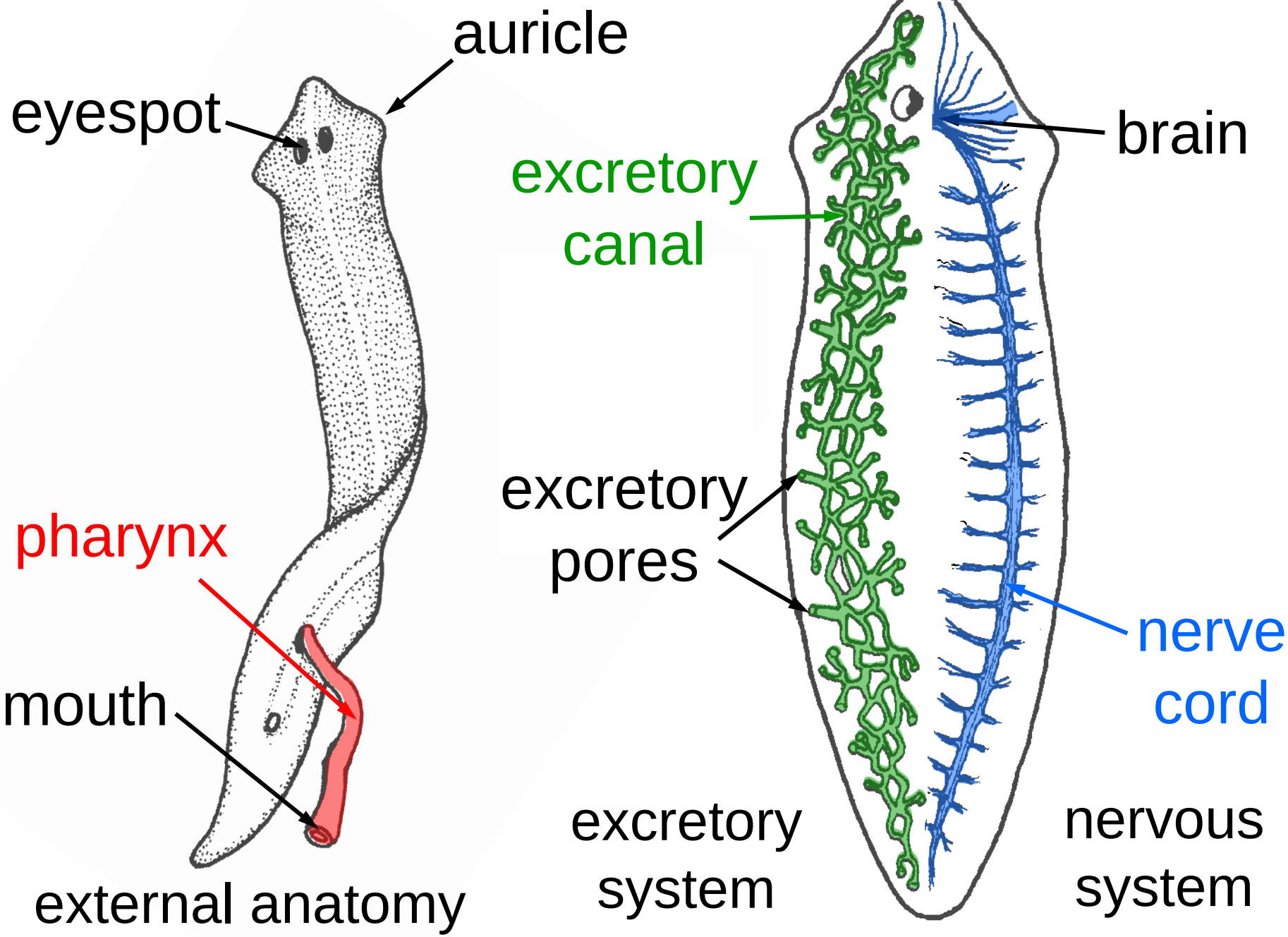
Excretory system

- excretory canals run along both sides of the body
- feeding into these canals are flame cells, which concentrate wastes out of the body

flame cells = excretory cells with a tuft of cilia which beat to move waste fluids

- wastes move along canals and out excretory pores by the current created in the flame cells


flame cell
cilia
excretory
canal


auricle
eyespot
pharynx
mouth
external anatomy
excretory canal
excretory pores
excretory system
brain
nerve cord
nervous system

Flatworm reproduction

- most flatworms are hermaphrodites (have both male and female organs)

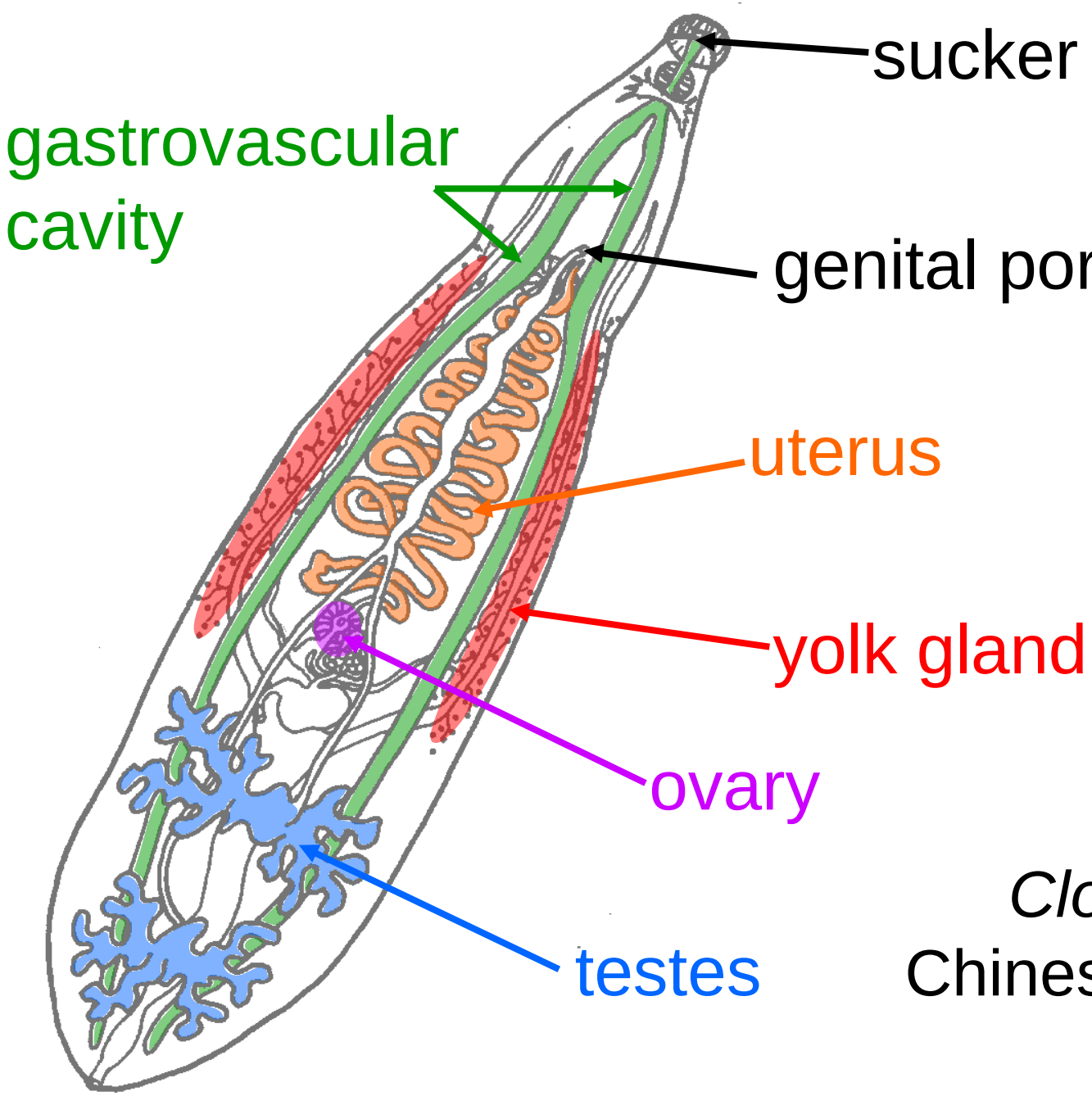
testes = male gonad, produces sperm

ovary = female gonad, produces eggs

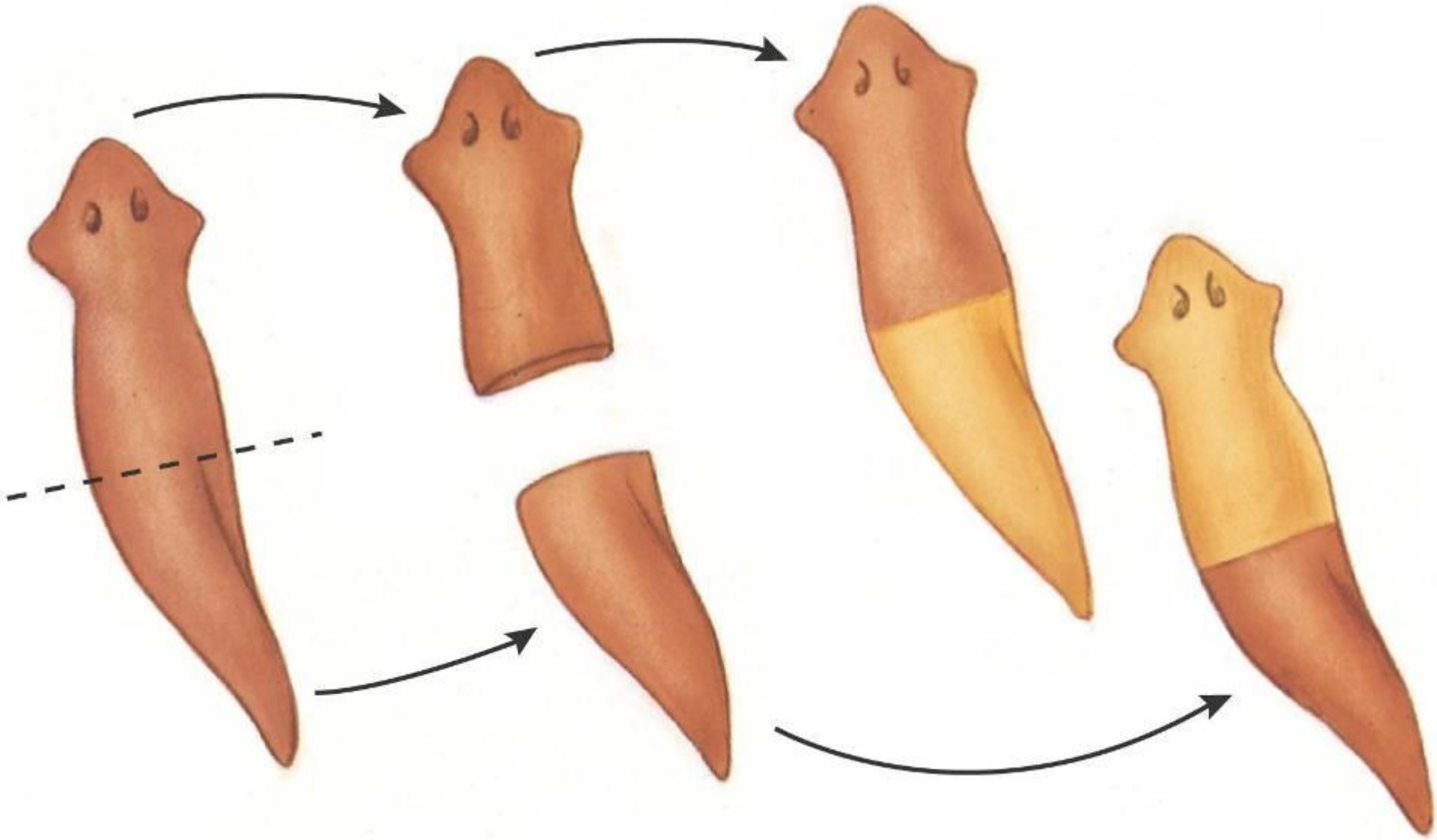
uterus = organ where fertilised eggs mature

yolk gland = makes yolk and shell for eggs

genital pore = common opening for male and female organs



Clonorchis:
Chinese liver fluke



Asexual reproduction in flatworms

Flatworm diversity

You will need:

- four colours of pencil crayon or pen (preferably red, blue, green, and orange)

Flatworm diversity

Class Turbellaria

- mostly non-parasitic species, e.g. *Dugesia* the common laboratory specimen
- predators and scavengers in aquatic and moist land habitats
- typical anatomy we have studied already


marine
turbellarian

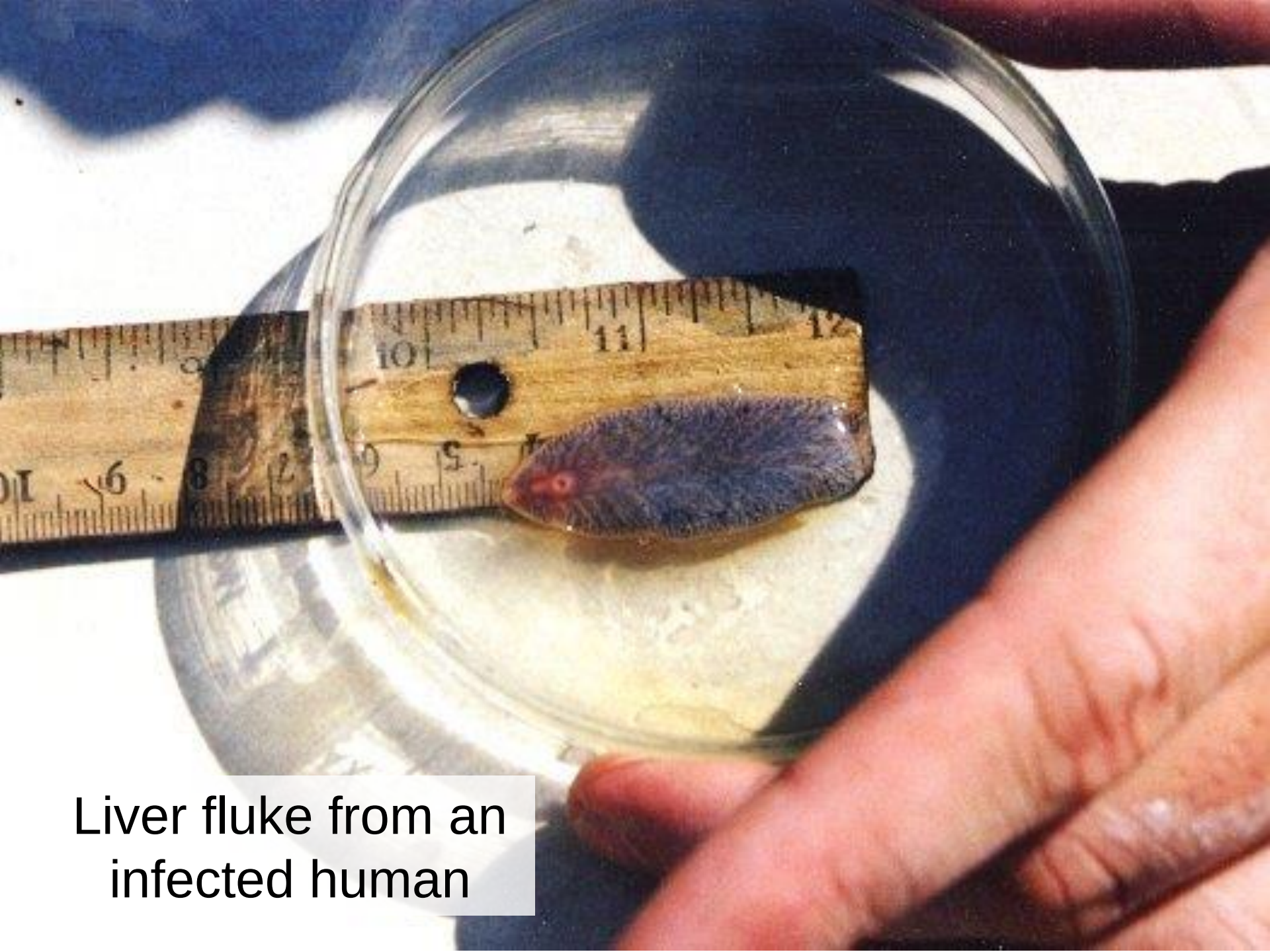
A terrestrial turbellarian

Flatworm diversity

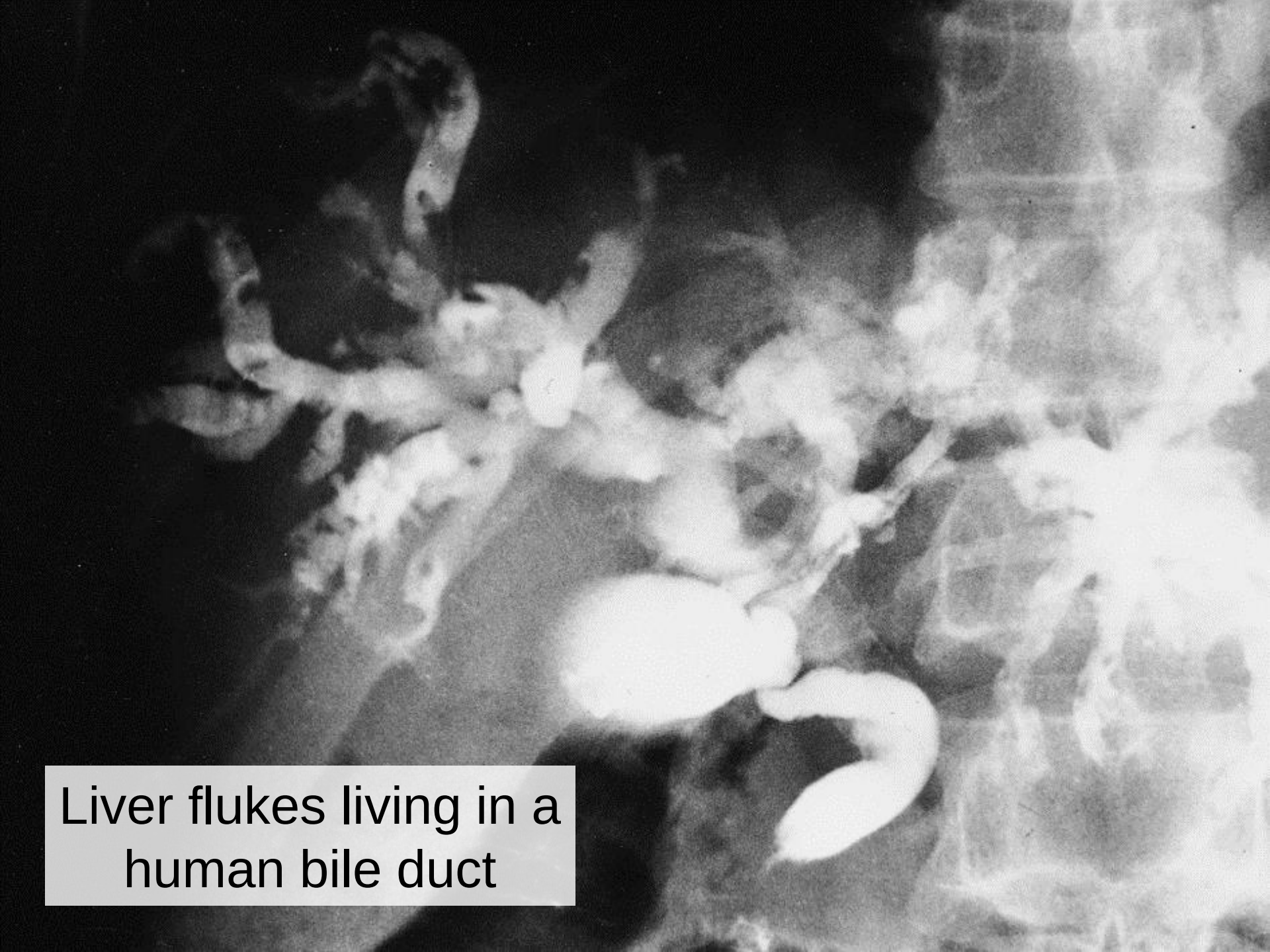
Class Trematoda – the flukes

- parasites of vertebrates and molluscs
- complex life cycles involving multiple hosts
- divided into two groups:

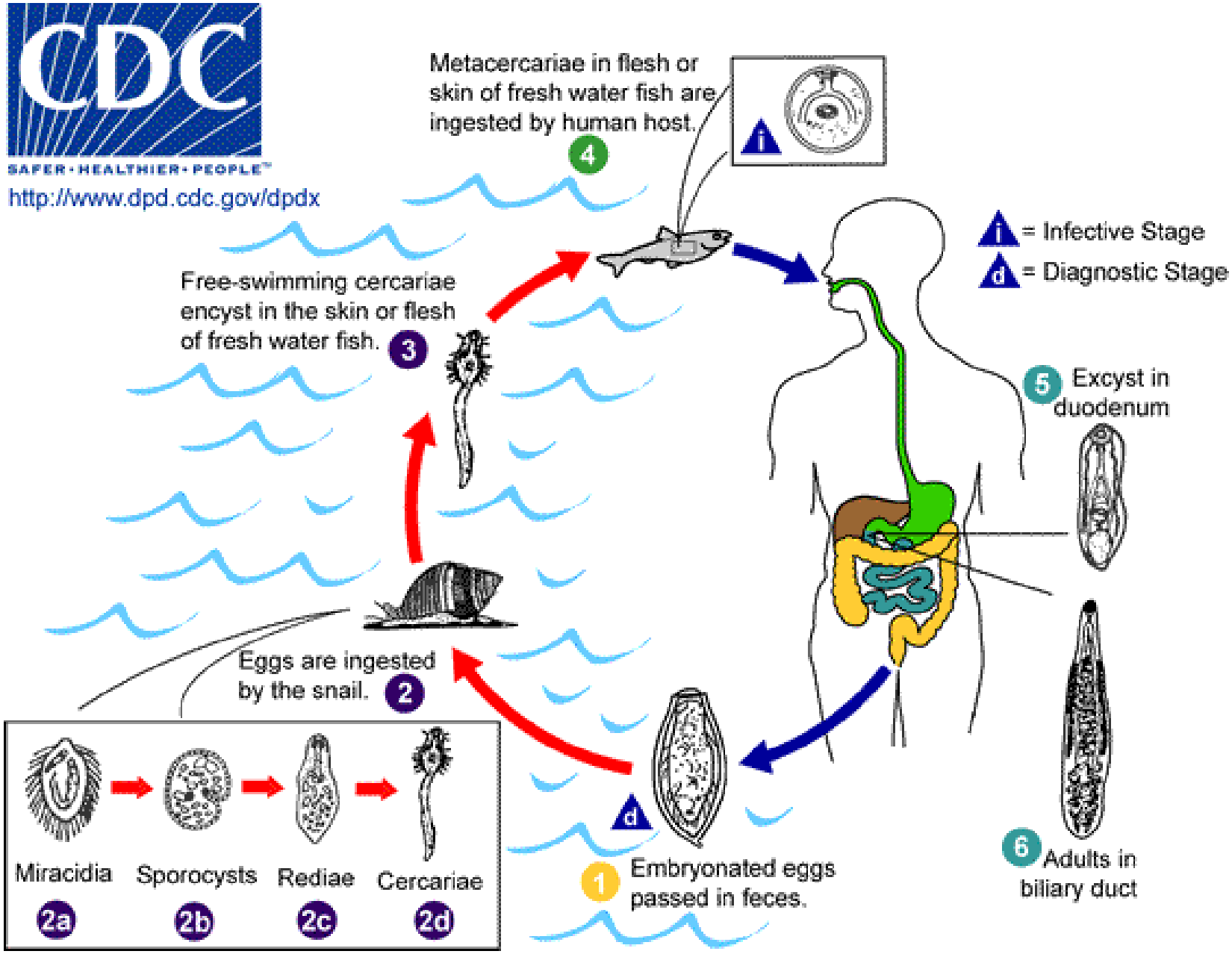
1. lungs, bile ducts, other tissues – e.g. liver fluke *Clonorchis*
2. blood – e.g. *Schistosoma*



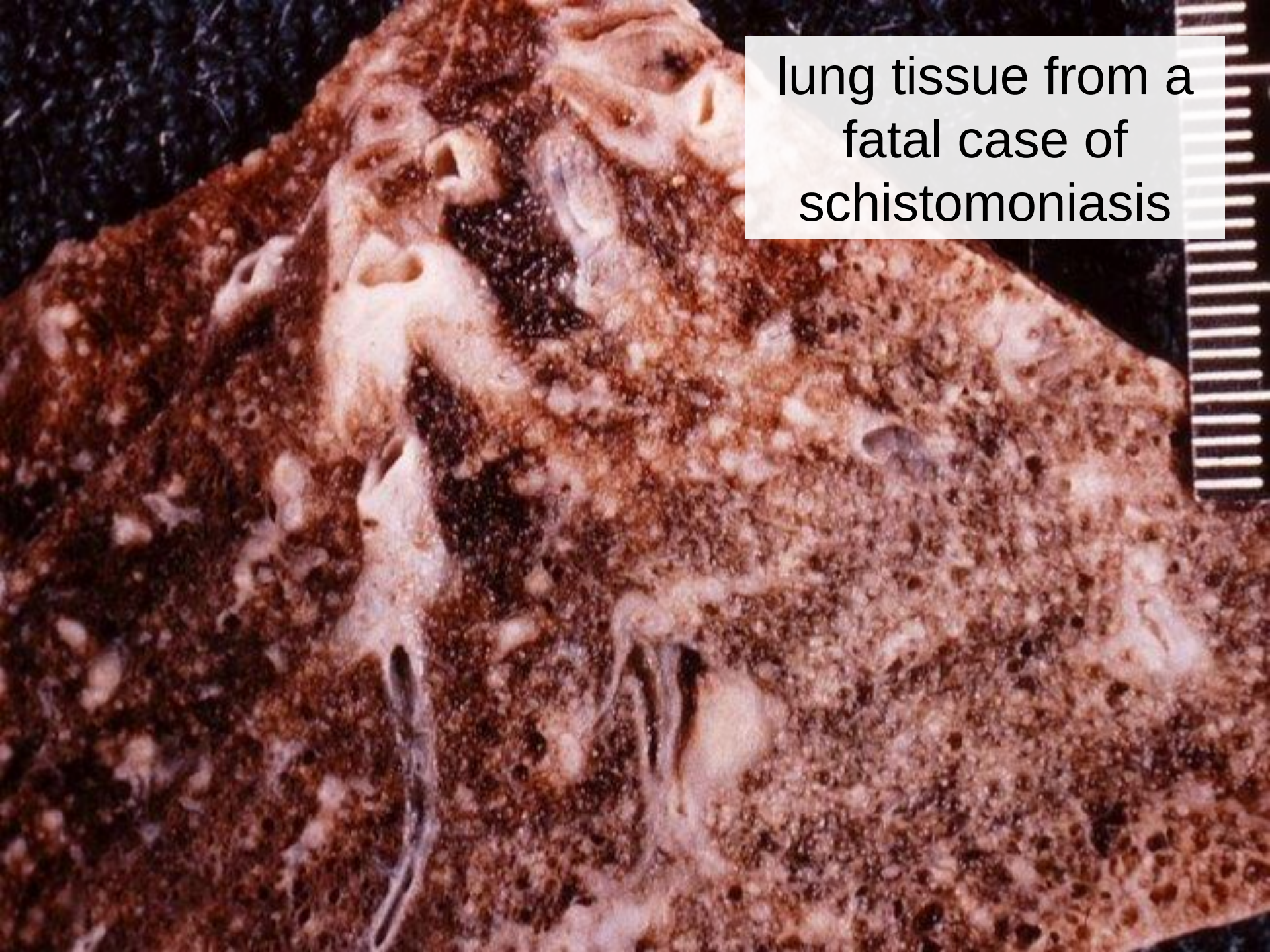
Liver fluke from an infected human



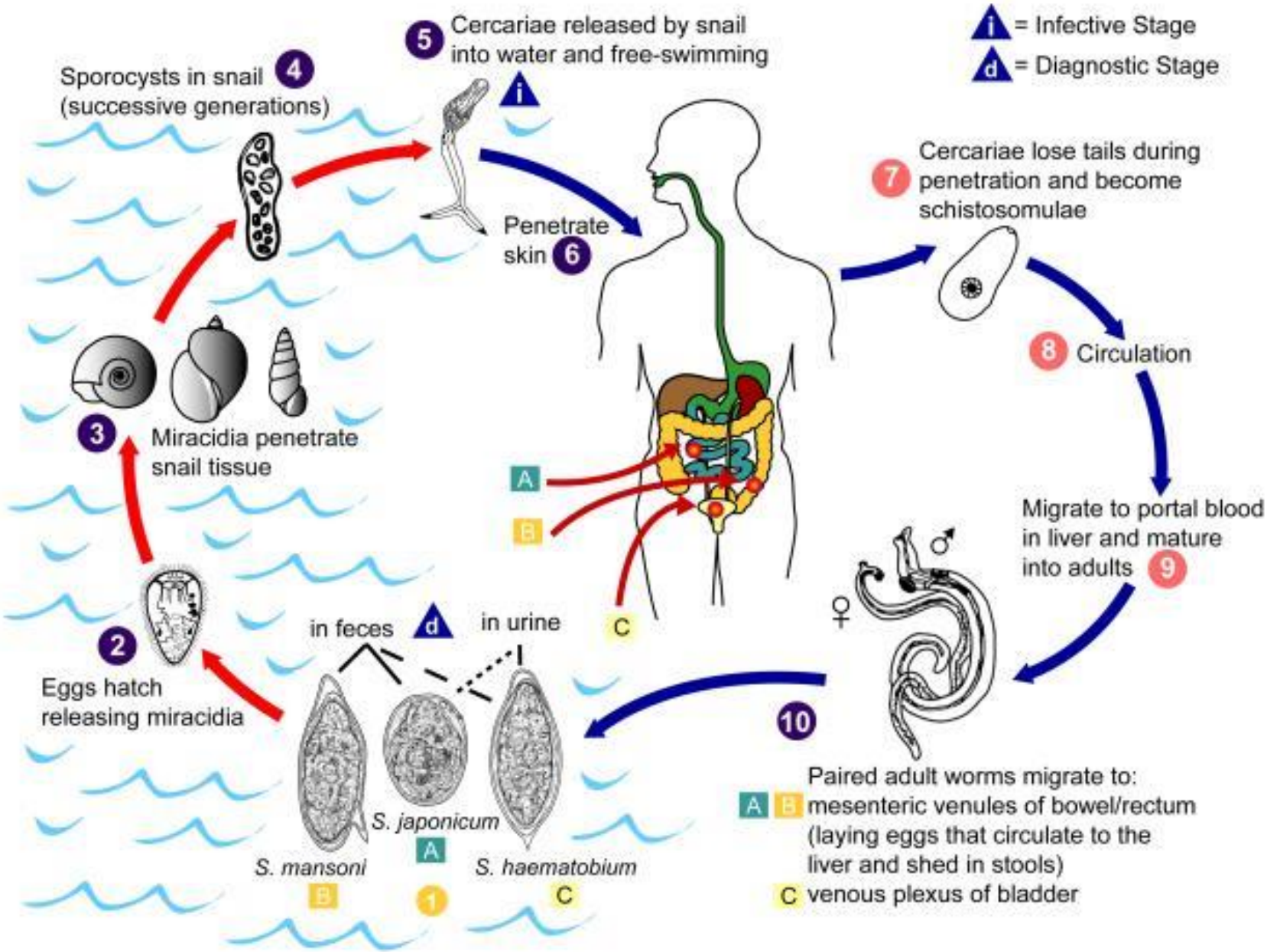
Liver flukes living in a human bile duct


CDC
SAFER • HEALTHIER • PEOPLE™
http://www.dpd.cdc.gov/dpdx
Metacercariae in flesh or skin of fresh water fish are ingested by human host. 4
i
i = Infective Stage
d = Diagnostic Stage
Free-swimming cercariae encyst in the skin or flesh of fresh water fish. 3
5 Excyst in duodenum
Eggs are ingested by the snail. 2
d
1 Embryonated eggs passed in feces.
6 Adults in biliary duct
Miracidia 2a
Sporocysts 2b
Rediae 2c
Cercariae 2d

Schistosoma male and female


lung tissue from a fatal case of schistomoniasis

Schistosomiasis



Flatworm diversity

Class Cestoda – the tapeworms

- parasites of vertebrates
- complex life cycles involving multiple hosts
- no gut or mouth, they absorb digested food directly from the host's intestine

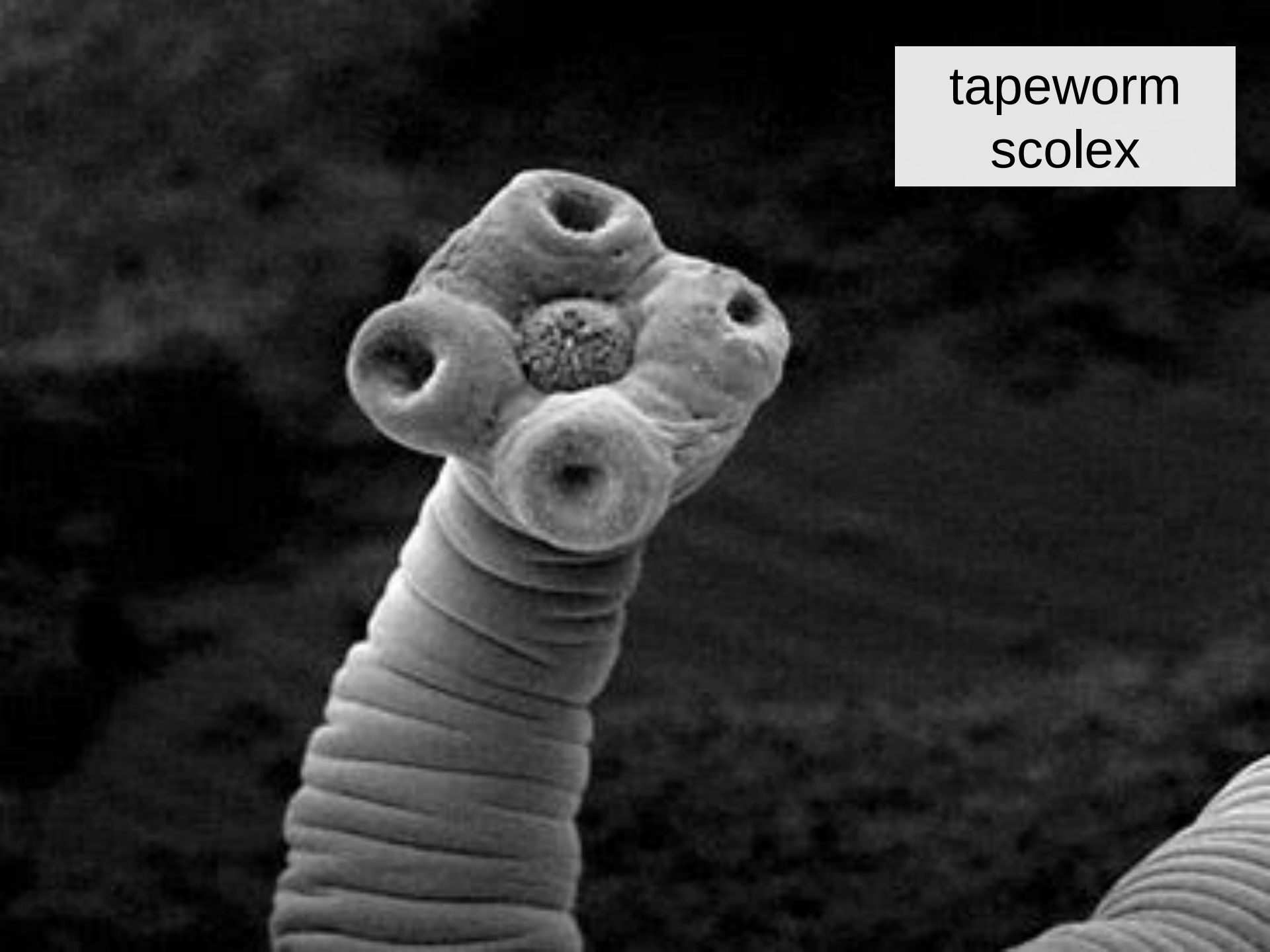

Taenia – tapeworm collected from a human

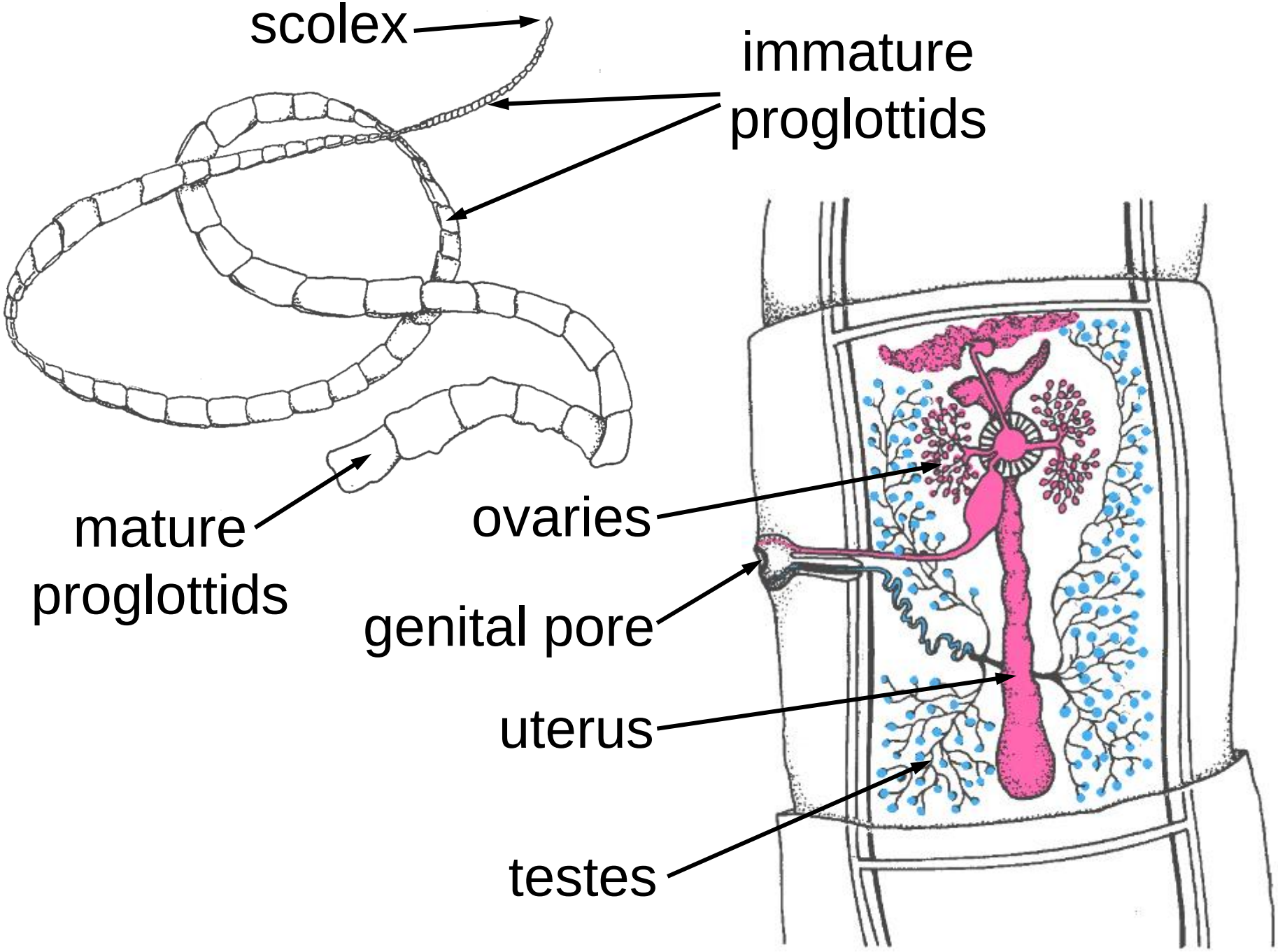

NO DIET - NO BATHS
NO EXERCISE!
NO DANGER
FAT
the ENEMY that is shortening Your Life
BANISHED!
HOW?
with
SANITIZED
TAPE
WORMS
Jar Packed
"FRIENDS FOR A FAIR FORM"
Easy To Swallow!
No Ill Effects!
Prepared By
W. T.
BRIDGE, Chemist
New York
SEND NO MONEY
PARTICULARS MAILED
FREE
CASWELL'S
NATIONAL CREST
COFFEE
MILK CO.
OLIVE OIL
CLUFF
PURITAN
MUSTARD
LESLIE
ALPA
PEOPLES BA
M&L
GLOBE MILLS
GLOBE "A1" FLOUR
GLOBE MILLS
GLOBE "A1"
PRUNES
BORAX CHIPS
ROYAL MACARONI
CLUFF
TOMATOES
PURITY
SAHARA CRACKERS

Tapeworm anatomy

The body of tapeworms is divided into:

1. scolex = ‘head’ with hooks and suckers for holding onto the host
2. proglottids = repeated segments making the tape-like body, these form at the ‘head’ end and move along as they mature

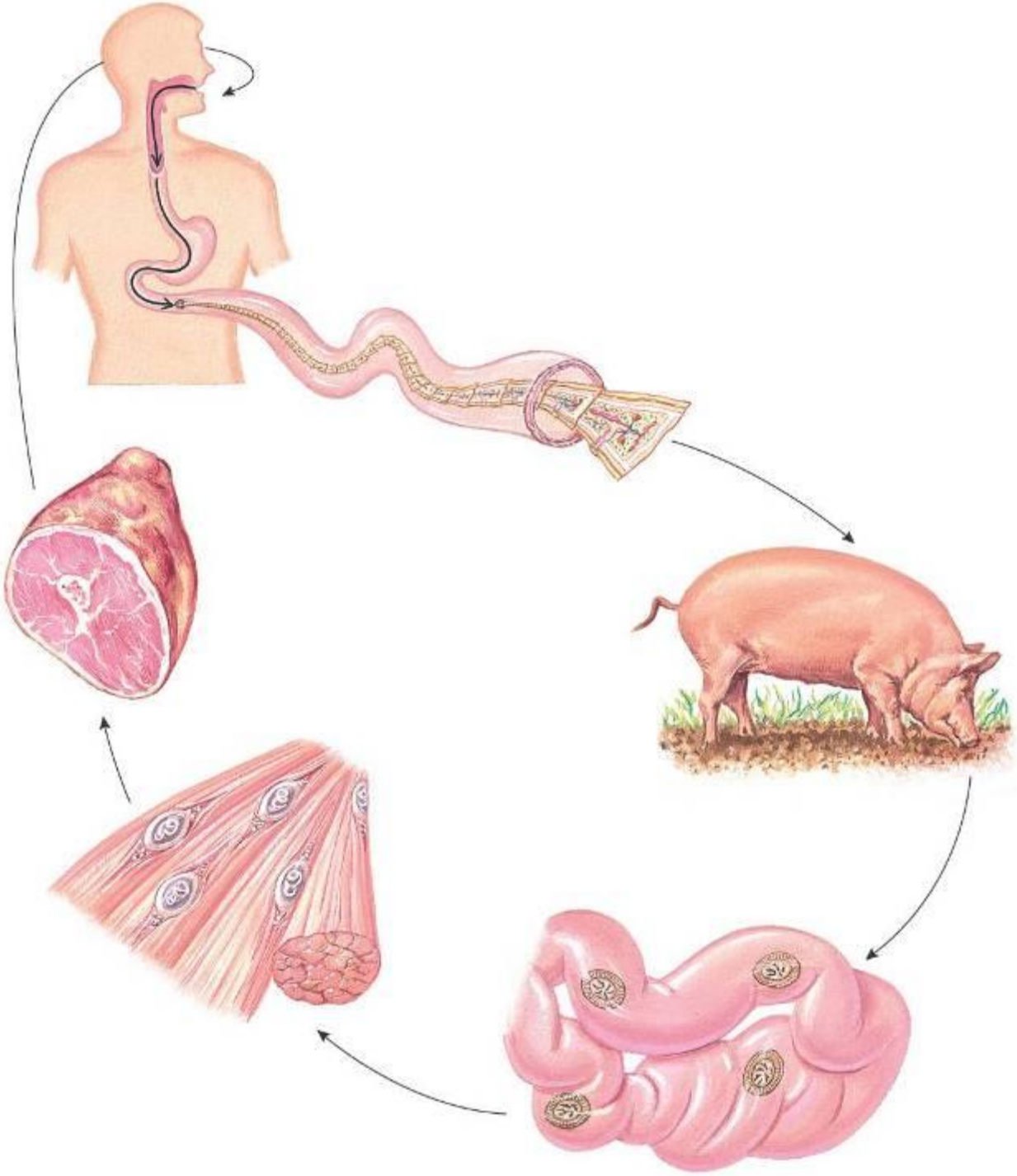

tapeworm
scolex


scolex
immature proglottids
mature proglottids
ovaries
genital pore
uterus
testes

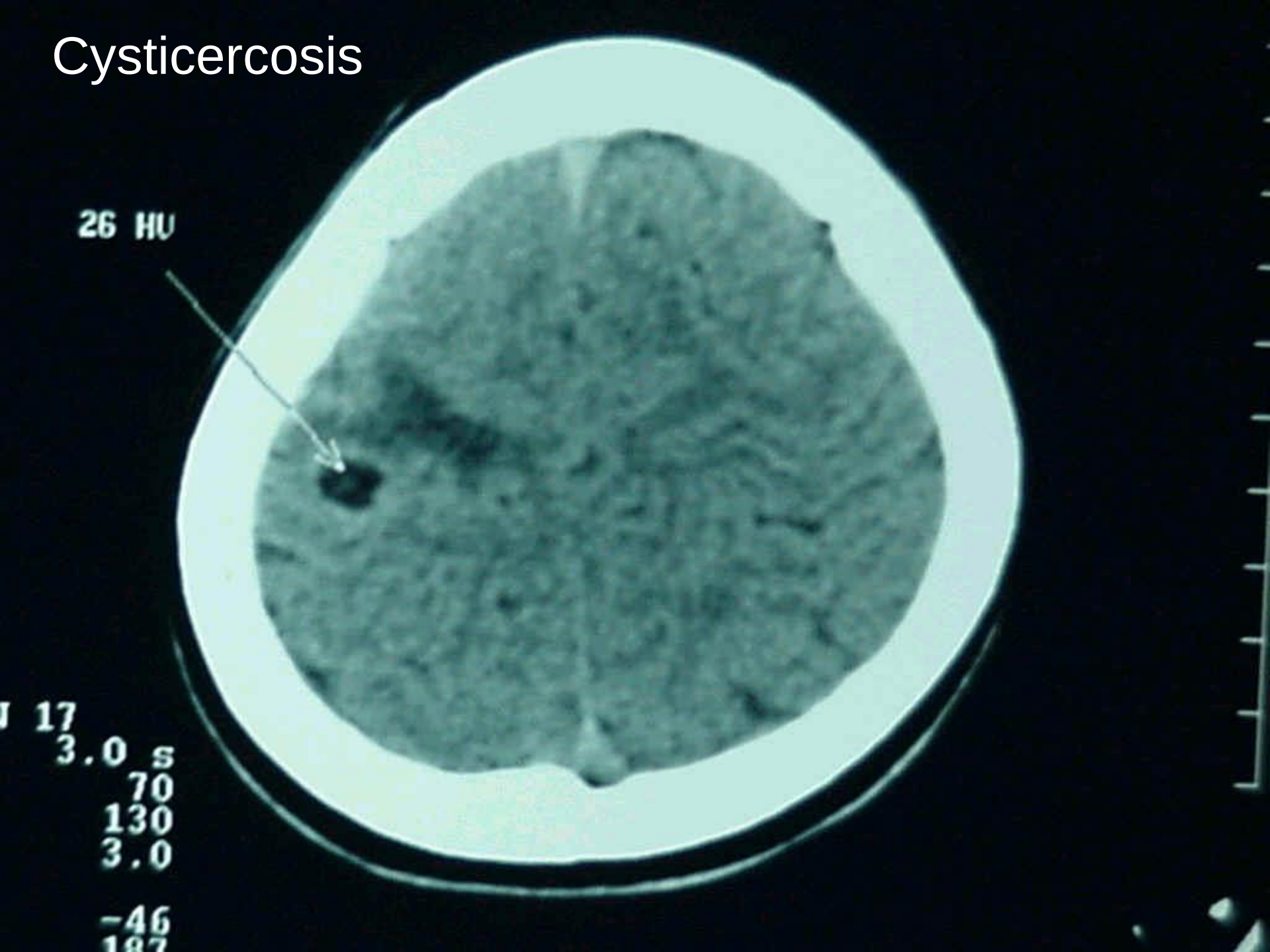
Life cycle of a tapeworm

- the pork tapeworm, *Taenia solium*, is an important human parasite
- infection begins by pigs eating the eggs
- eggs hatch in the intestine and young worms burrow into the host's muscles, forming cysts
- humans eat pig muscle containing cysts, the worms break out and attach to the intestine
- worm matures and begins releasing eggs

Life cycle of *Taenia solium*

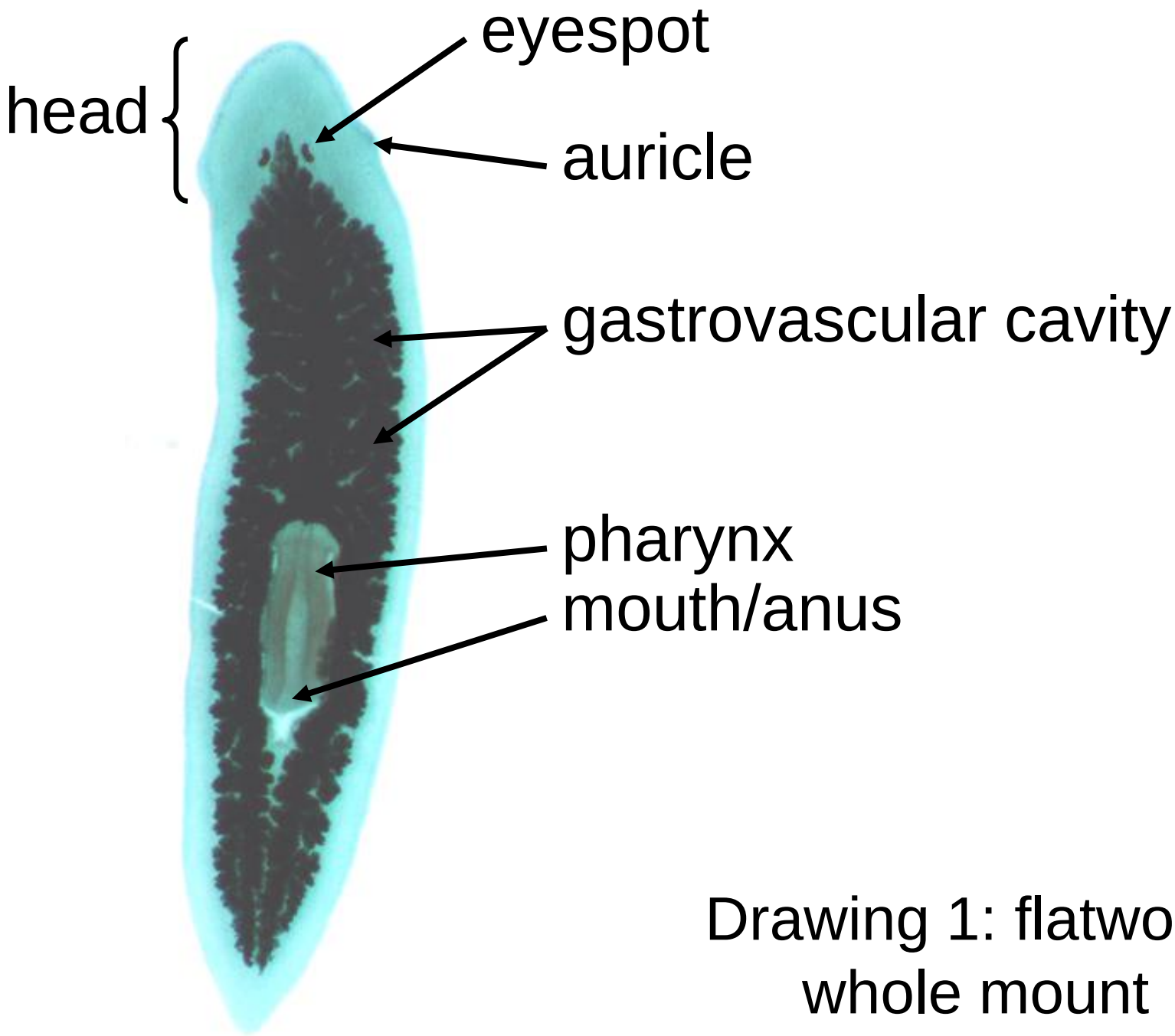


Cysticercosis

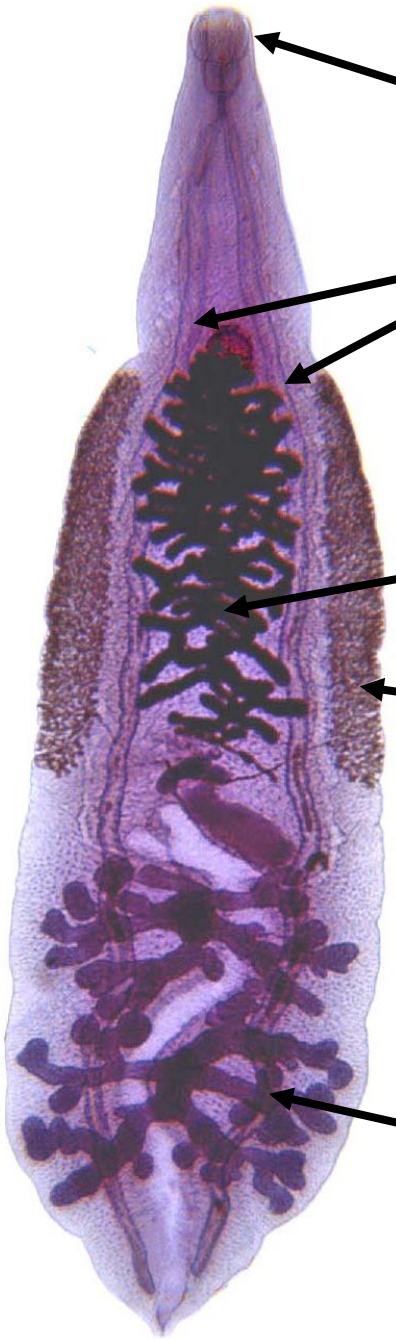


Phylum Platyhelminthes observation

1. Flatworm whole mount
   - pharynx, mouth/anus, gastrovascular cavity, head, eyespot, auricle
2. *Clonorchis* whole mount
   - sucker, gastrovascular cavity, testes, uterus, yolk gland
3. *Taenia* whole mount (4 parts)
   A. scolex: hooks, suckers
   B. immature proglottid
   C. sexually mature proglottid: testis, ovary, uterus, genital pore
   D. gravid proglottid: uterus filled with eggs



Drawing 1: flatworm whole mount



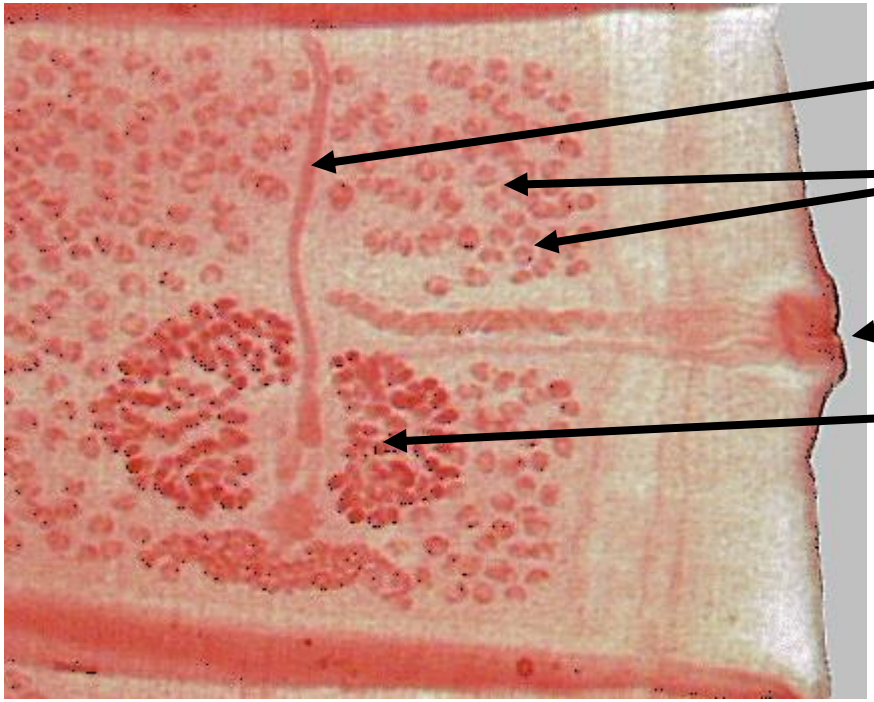
Drawing 2:
Clonorchis whole mount

Drawing 3: *Taenia* whole mount

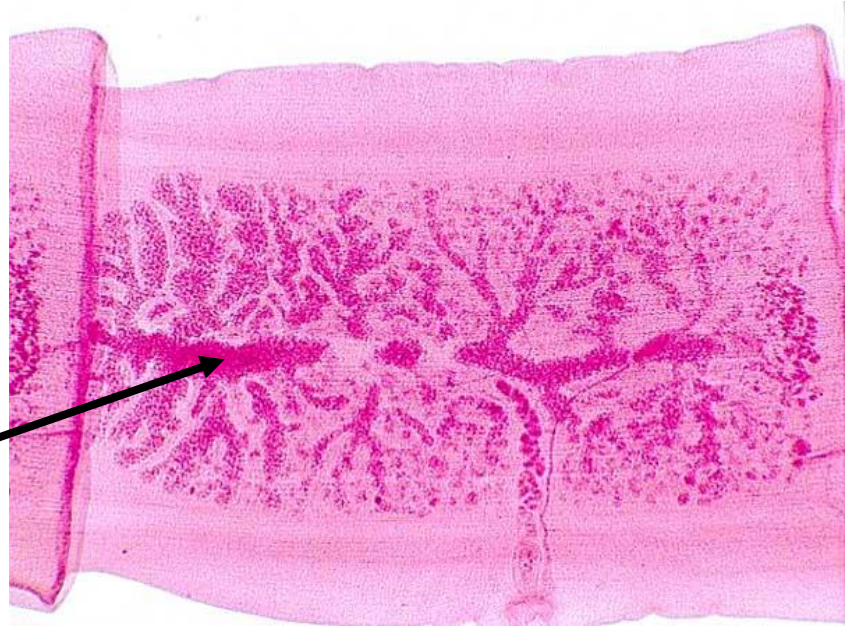
A. scolex

B. immature proglottid

Drawing 3: *Taenia* whole mount



C. mature proglottid



D. gravid proglottid

Phylum Nematoda

The roundworms

Phylum Nematoda

- bilaterally symmetrical
- 3 embryonic germ layers
- pseudocoelomate
- both free-living and parasitic species

Organ systems

- first animals to have a complete digestive system, with separate mouth and anus
- nervous system is a ring around the mouth and a pair of nerve cords along the top (dorsal) and bottom (ventral)
- excretion, circulation, and respiration occur by diffusion, but a fluid circulates within the pseudocoelom

Gut evolution

nature Vol 456|20 November 2008|doi:10.1038/nature07309

LETTERS

Acoel development indicates the independent evolution of the bilaterian mouth and anus

Andreas Hejnol[1] & Mark Q. Martindale[1]

Most bilaterian animals possess a through gut with a separate mouth and anus[1]. It is commonly believed that during the transition from radial to bilateral symmetry, both openings evolved simultaneously by the lateral closure of a slit-like blastopore[1–4]. Molecular phylogenies however, place the acoel flatworms, which have only one opening to their digestive system, as the sister group to all remaining Bilateria[5–7]. To address how this single body opening is related to the mouth and anus of the protostomes and deuterostomes, we studied the expression of genes involved in bilaterian foregut and hindgut patterning during the development of the acoel *Convolutriloba longifissura*. Here we show that the genes *brachyury* and *goosecoid* are expressed in association with the acoel mouth, suggesting that this single opening is homologous to the mouth of other bilaterians[8]. In addition, we find that the genes *caudal*, *orthopedia* and *brachyury*—which are expressed in various bilaterian hindguts[9–16]—are expressed in a small region at the posterior end of the animal, separated from the anterior oral *brachyury*-expressing region by a dorsal domain of ectodermal *bmp2/4* expression. These results contradict the hypothesis that the bilaterian mouth and anus evolved simultaneously from a common blastoporal opening, and suggest that a through gut might have evolved independently in different animal lineages.

Bilaterian animals are subdivided into two main clades, which were named according to the position of the mouth in relation to a transient embryonic structure called the blastopore[11]. In deuterostomes ('secondary mouth') the site of gastrulation becomes the anus and the mouth is formed at a different site. However, in protostomes ('first mouth') the relationship between the site of gastrulation (the site at which the endomesoderm forms) and the site of mouth formation is much more variable than the clade name suggests[1]. The evolutionary origin of the bilaterian mouth and anus, and their relationship to the blastopore, however, have an integral role in hypotheses about the evolution of bilateral animals from a radially symmetric ancestor with a single opening to its digestive cavity[1–4,12–15]. Most models begin with either a radially symmetric larva or a cnidarian polyp-like organism that elongated its body along the future anterior–posterior axis, followed by a lateral closure of this slit-like blastoporal opening with the ends giving rise to a mouth and anus (Fig. 1a). Derivatives of this idea, which assumes the simultaneous evolution of mouth and anus, are the 'trochaea'[1], the 'enterocoely'[3], the 'bilaterogastraea'[14] and the 'amphistomy' hypotheses[2]. In contrast to these ideas is the suggestion that a posterior blastoporal opening of a radially symmetric planula-like organism shifted anteriorly, resulting in a bilateral organism with a single ventral 'mouth' (acoeloid–planuloid–hypothesis[1,3,4,16]; Fig. 1a). Morphology[17] and recent molecular phylogenies place the Acoela and the nemertodermatid flatworms as basal branches of the Bilateria[5–7] (Fig. 1b). These bilaterally symmetric triploblastic worms possess a mid-ventral mouth and lack an anus, which suggests that a single opening to the endodermal digestive system represents the ancestral state of the Bilateria (Fig. 1c–h). To investigate how the acoel mouth opening is related to the mouth and anus of protostomes and deuterostomes, we investigated the embryonic and juvenile expression of the genes that have been used to argue for the homology of the protostome and deuterostome foregut (oral ectoderm)[8]. The *brachyury* orthologue (*bra*) from the acoel *C. longifissura* contains the T-box DNA-binding site but, like cnidarians and ctenophores, it lacks the amino-terminal Smad-binding domain, which is found in most bilaterian orthologues[18]. *bra* is expressed in a domain (Fig. 2a) that gives rise to the ectoderm, anterior to and surrounding the juvenile mouth (Fig. 2b, c). However, in addition to the oral domain, we find a second domain of *bra* expression at later stages in the ectoderm at the posterior tip of the juvenile tail (Fig. 2b, c). This domain is located in the posterior ectodermal region that gives rise to the future gonopore (Fig. 2s–u) and follows the same temporal delay as the hindgut expression of *bra* in protostomes and deuterostomes[19,20]. The *goosecoid* orthologue (*gsc*) in *C. longifissura* is expressed transiently in endomesodermal cells of the early embryo (Fig. 2d), but is downregulated during development, mirroring the localization and timing of the early function in endomesoderm specification found in some bilaterians[21]. Later in development, *gsc* is only expressed in the same oral ectodermal area as *bra* (Fig. 2e, f) but never in any posterior domain. Because *C. longifissura* lacks an internalized ectodermal component of the gut (foregut), the surface ectodermal expression of *gsc* and *bra* associated with the mouth supports the homology of the single body opening of acoels with the mouth of protostomes and ambulacrarians (echinoderms and hemichordates)[8].

To understand the importance of the posterior expression domain of *bra*, we studied the expression of further genes expressed in the hindgut of some bilaterians, *caudal* (*cdx*), *orthopedia* (*otp*), *forkhead* (*FoxA*, also known as *HNF3*) and *NK2.1* (also known as *ceh-22*; see Supplementary Table 2). The gene *cdx* is primarily expressed in the deuterostome and protostome hindgut[10]. *cdx* is expressed in juvenile acoels in neural and mesodermal tissue along the entire anterior–posterior axis (Fig. 2g–i), reminiscent of the pattern seen in the polychaete annelid *Capitella*[22]. However, in addition to this broad expression domain, *cdx* is also expressed in the most posterior ectodermal tip of the animal, at the same position as *bra* expression (Fig. 2h, i). The gene *otp* is expressed in anterior neural tissue in many bilaterians, however, it is also expressed widely in the posterior hindgut of some protostomes and deuterostomes (except chordates)[9]. *otp* is expressed in the hindgut of *Drosophila*[9] and in an internal posterior domain close to the future anus in the hemichordate *Saxoglossus kovalevskii*[23]. In *C. longifissura*, *otp* expression appears in neural precursors of the brain commissure, in presumptive sensory cells of the ventral fold (Fig. 2j), and in a posterior ectodermal domain just internal to the location of *cdx* and *bra* expression (Fig. 2k, l). *FoxA* is transiently expressed in the endomesoderm after

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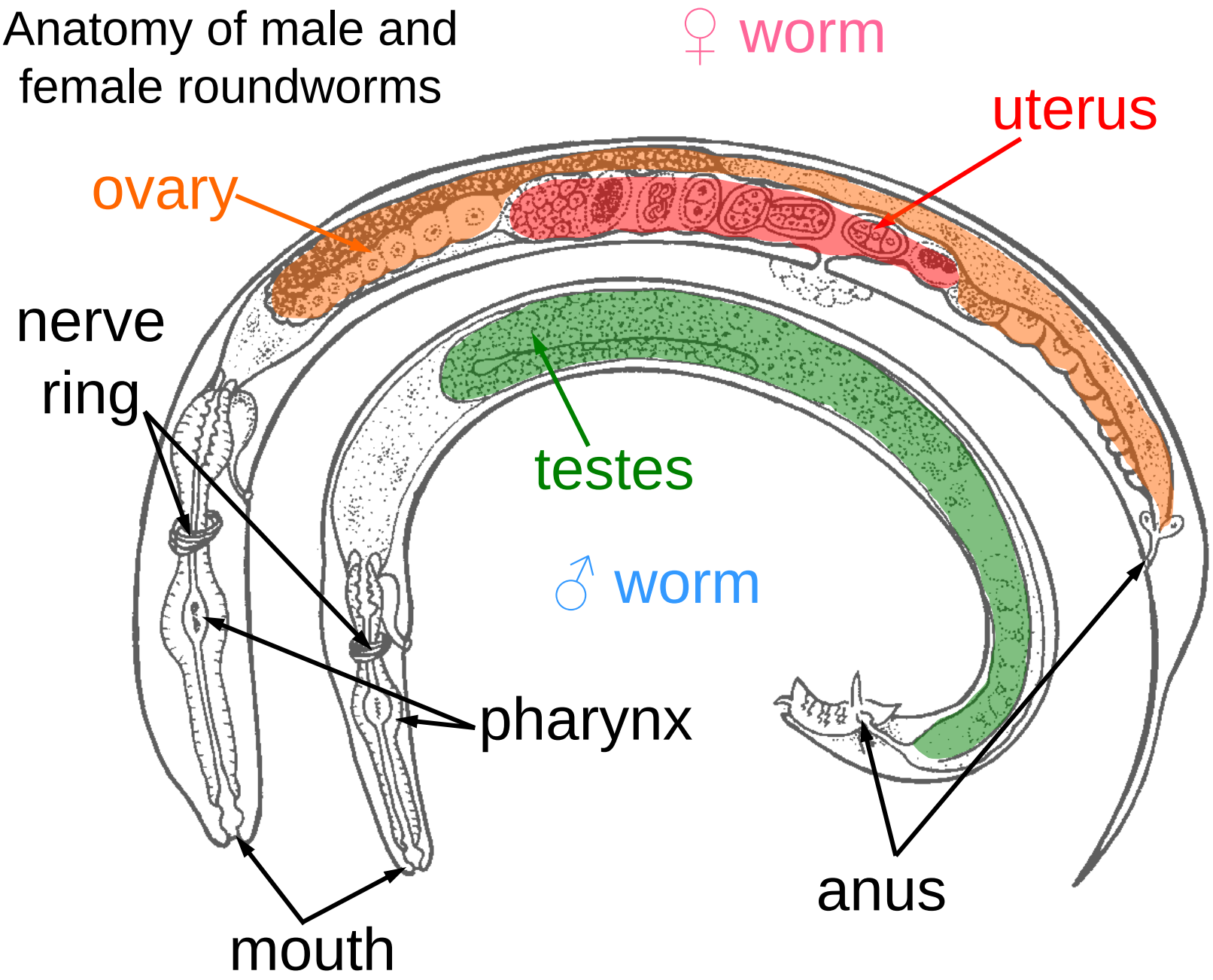
Roundworm reproduction

- most roundworms are not hermaphodites, the sexes are very different
- the male is smaller, and has a hook-shaped tail for grasping the female
- parasitic species have simple life cycles involving a single species of host

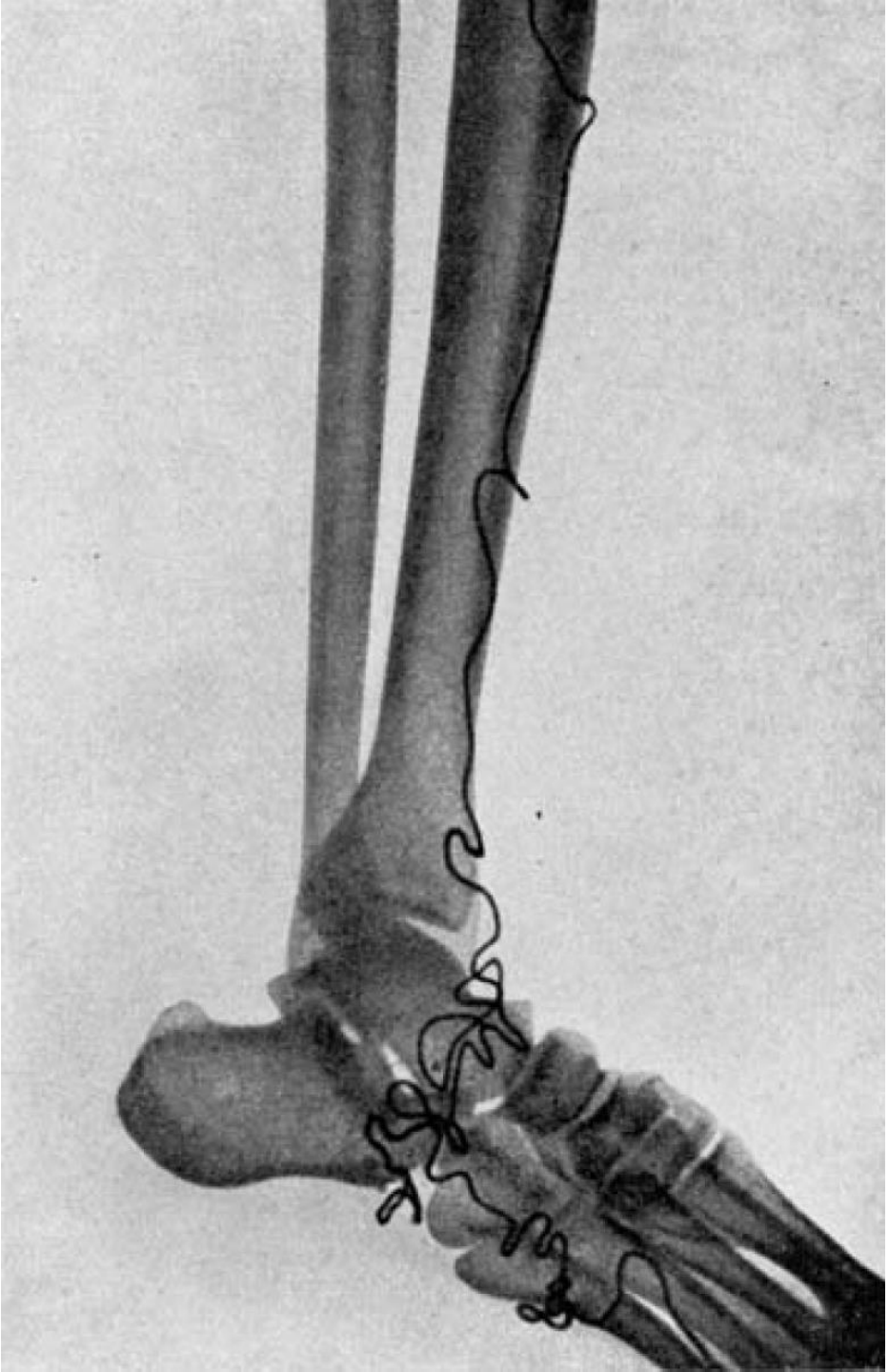
Anatomy of male and female roundworms



Parasitic roundworms

- the hookworm, *Ascaris*, may infect as much as ¼ of the world's population
- *Trichinella* causes trichinellosis, reproducing in the intestine and burrowing into their host's muscles
- elephantiasis is caused by roundworms which block the lymphatic system, causing huge swellings

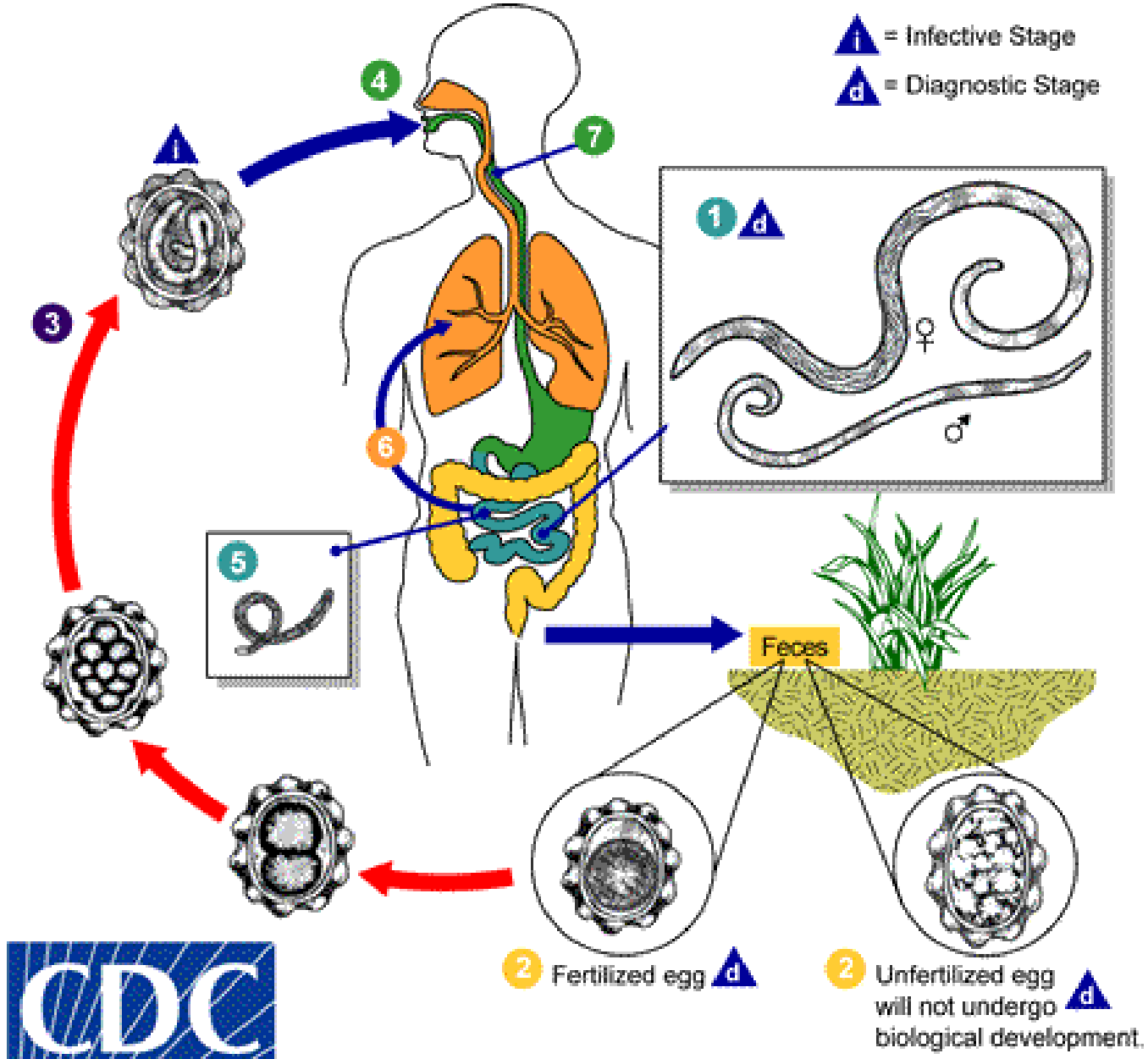
Dracunculus medinensis, the Guinea worm



Ascaris roundworms

Ascaris in a young child

Life cycle of *Ascaris lumbricoides*



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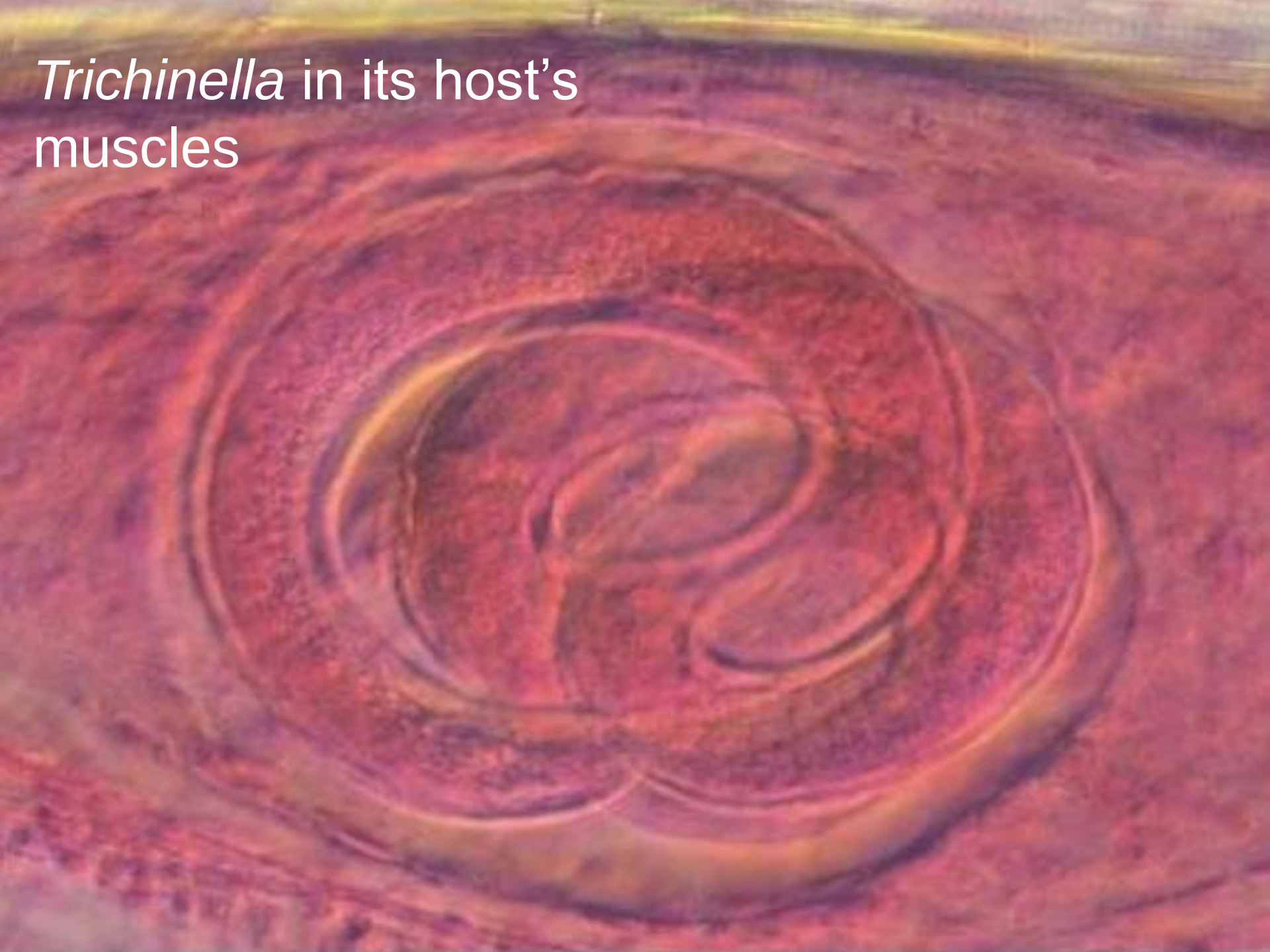
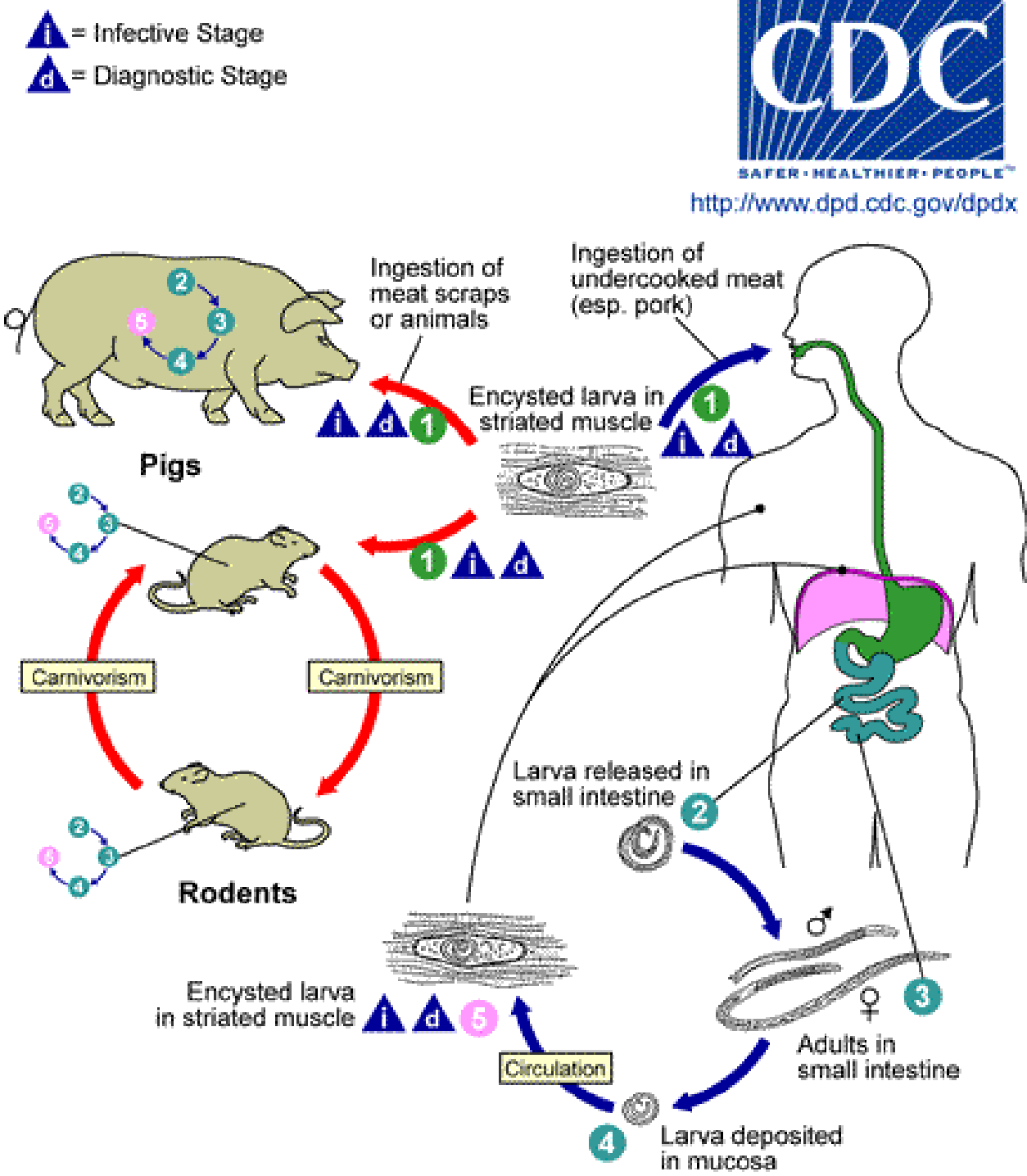
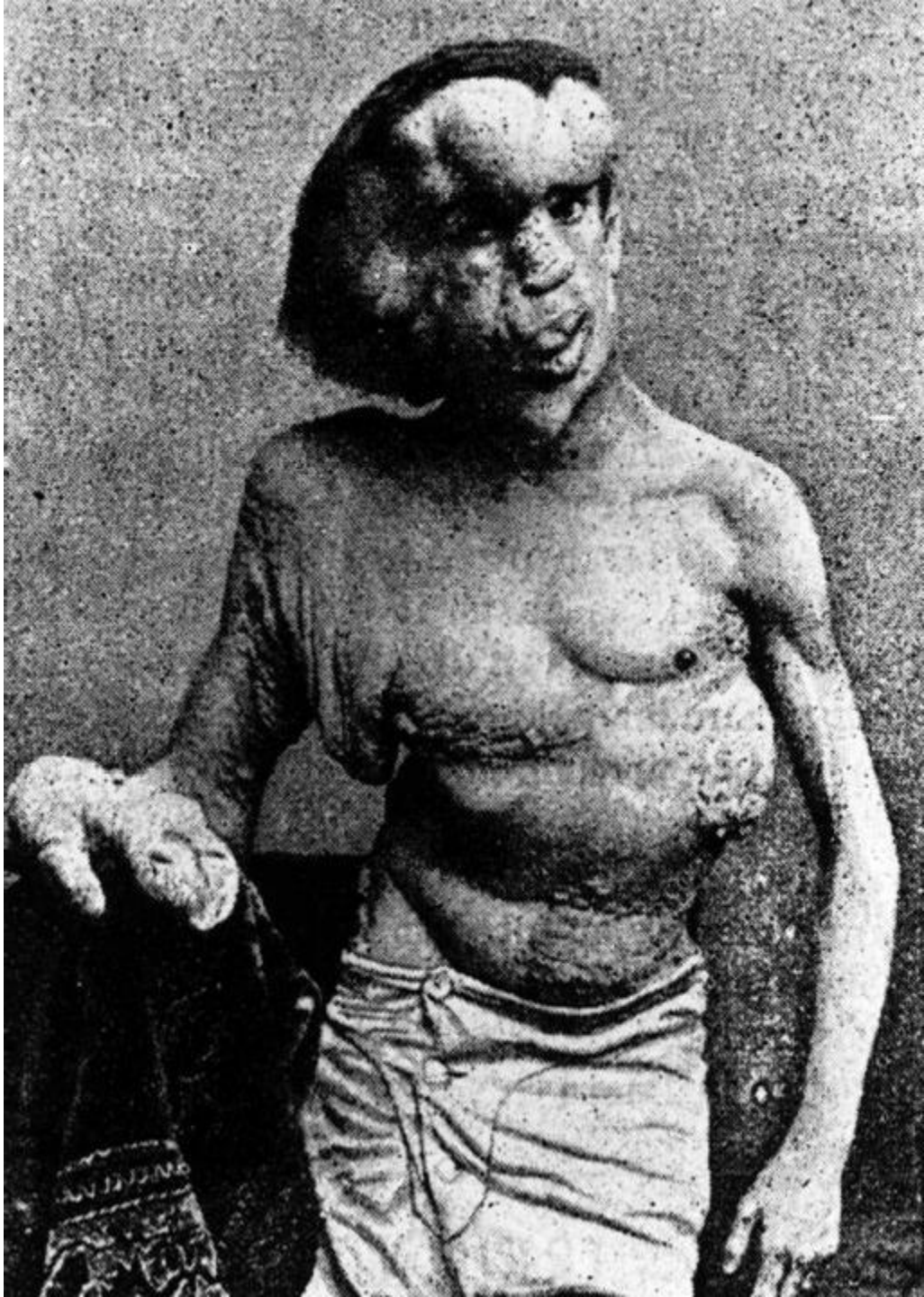
Trichinella in its host's muscles



Life cycle of *Trichinella spiralis*



Joseph Carey Merrick – the ‘Elephant Man’




Parasitic nematodes in
a soybean root

Importance of roundworms

- nematodes are extremely important predators in soil and many aquatic ecosystems
- the roundworm *Caenorhabditis elegans* was the first organism to have its entire DNA sequence mapped

“If all the matter in the universe except the nematodes were swept away, our world would still be dimly recognizable, and if, as disembodied spirits, we could then investigate it, we should find its mountains, hills, vales, rivers, lakes and oceans represented by a thin film of nematodes.”

Phylum Annelida

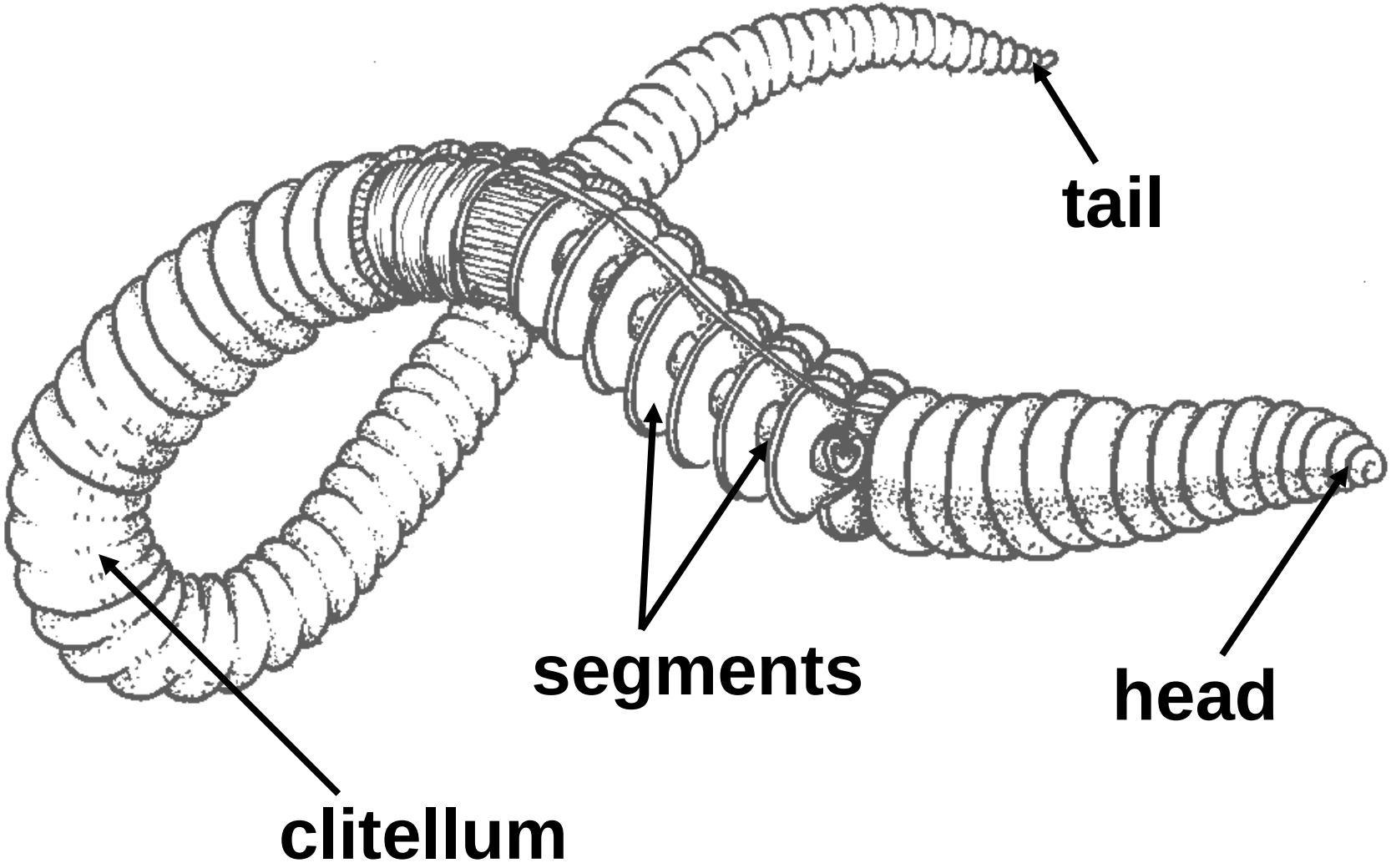
The segmented worms

Phylum Annelida

- 3 embryonic germ layers
- first to have a true coelom
- have a complete gut
- many are free-living, some are external parasites
- both terrestrial and marine species

Anatomy of annelids

- segmented: made of many repeated sections
- some organs are found in each segment, like excretory organs
- other organs pass through the entire animal, like the gut, nervous system, and blood vessels
- segments often have hairs

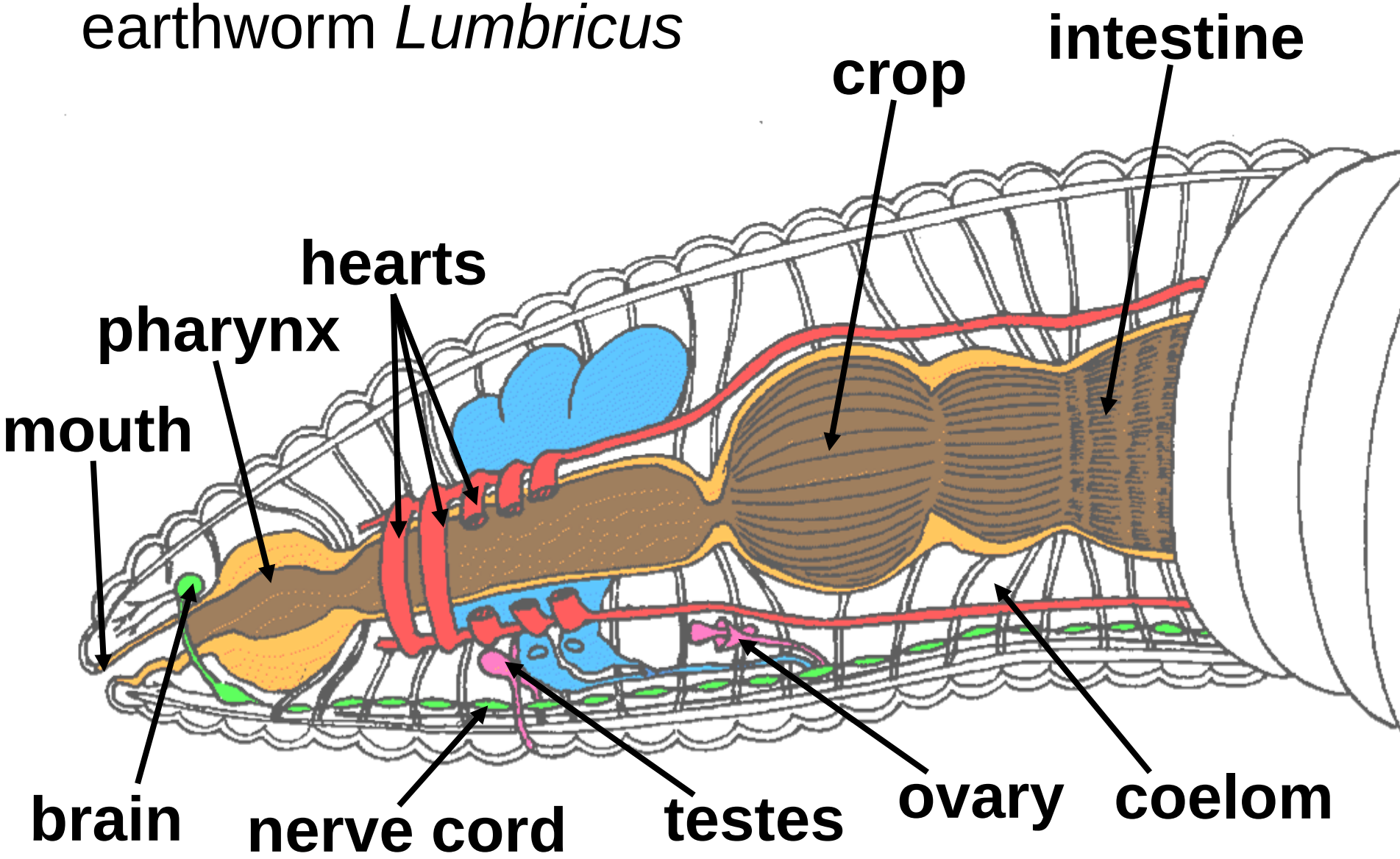

tail
segments
head
clitellum

Organ systems

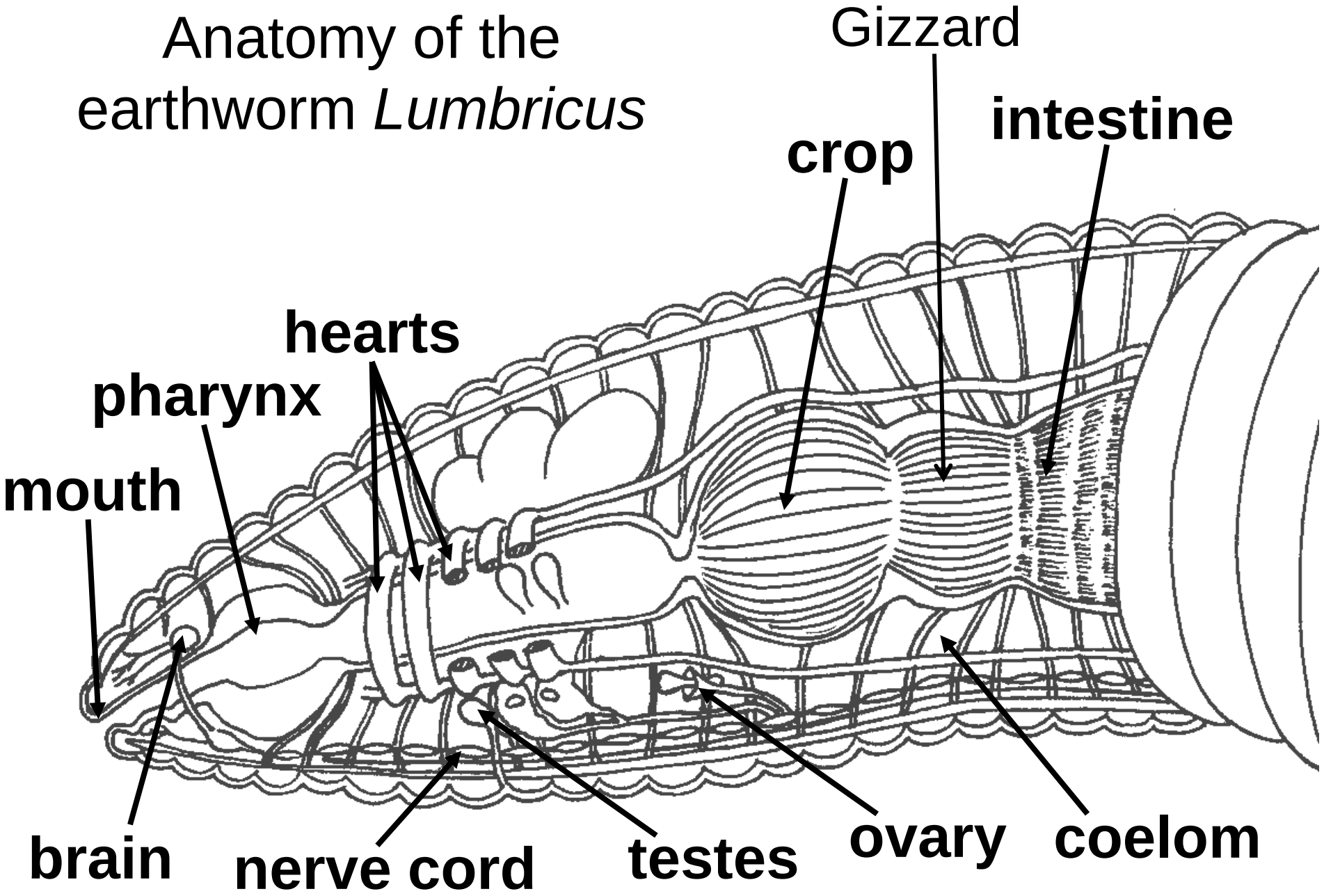
- circulatory system – closed: blood is contained in vessels and pumped by hearts
- nervous system – small brain in the head, with a ventral nerve cord along the body
- excretory system – each segment has its own nephridium:

nephridium = excretory gland, absorbs waste from the coelom and pumps it out the body through a small pore

Anatomy of the earthworm *Lumbricus*



Anatomy of the earthworm *Lumbricus*



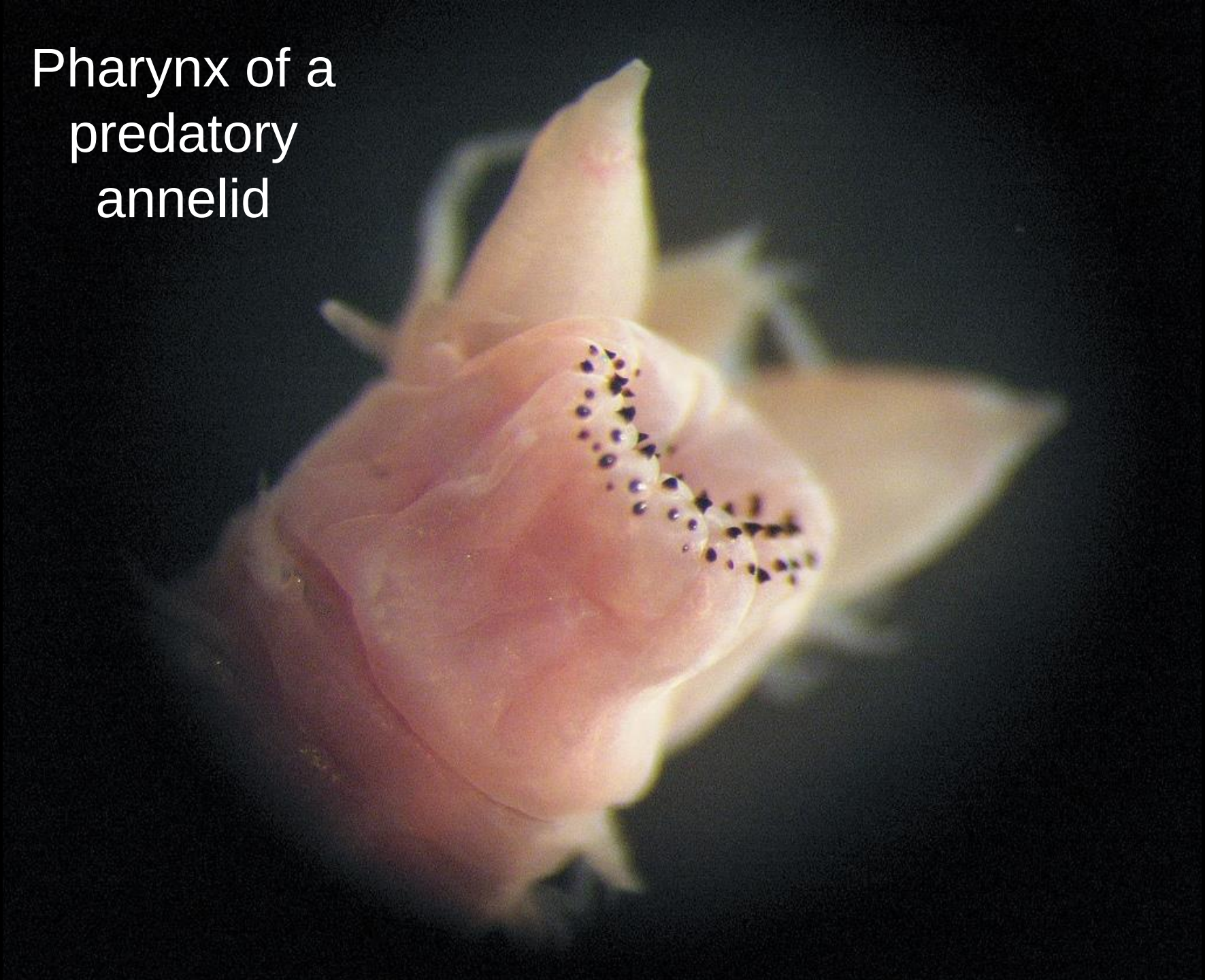
Circulation animation

Animation is loading

Feeding in segmented worms

- most annelids feed by swallowing food into a muscular pharynx
- some marine annelids are filter feeders, their pharynx is branched to trap small food particles in the water

Pharynx of a predatory annelid



Pharynx of a filter-feeding annelid

Annelid reproduction

- some are hermaphrodites
- specialised segments called the clitellum create a mucous ring into which the eggs and sperm are released for fertilisation
- this ring falls off and forms a cocoon around the eggs until hatching

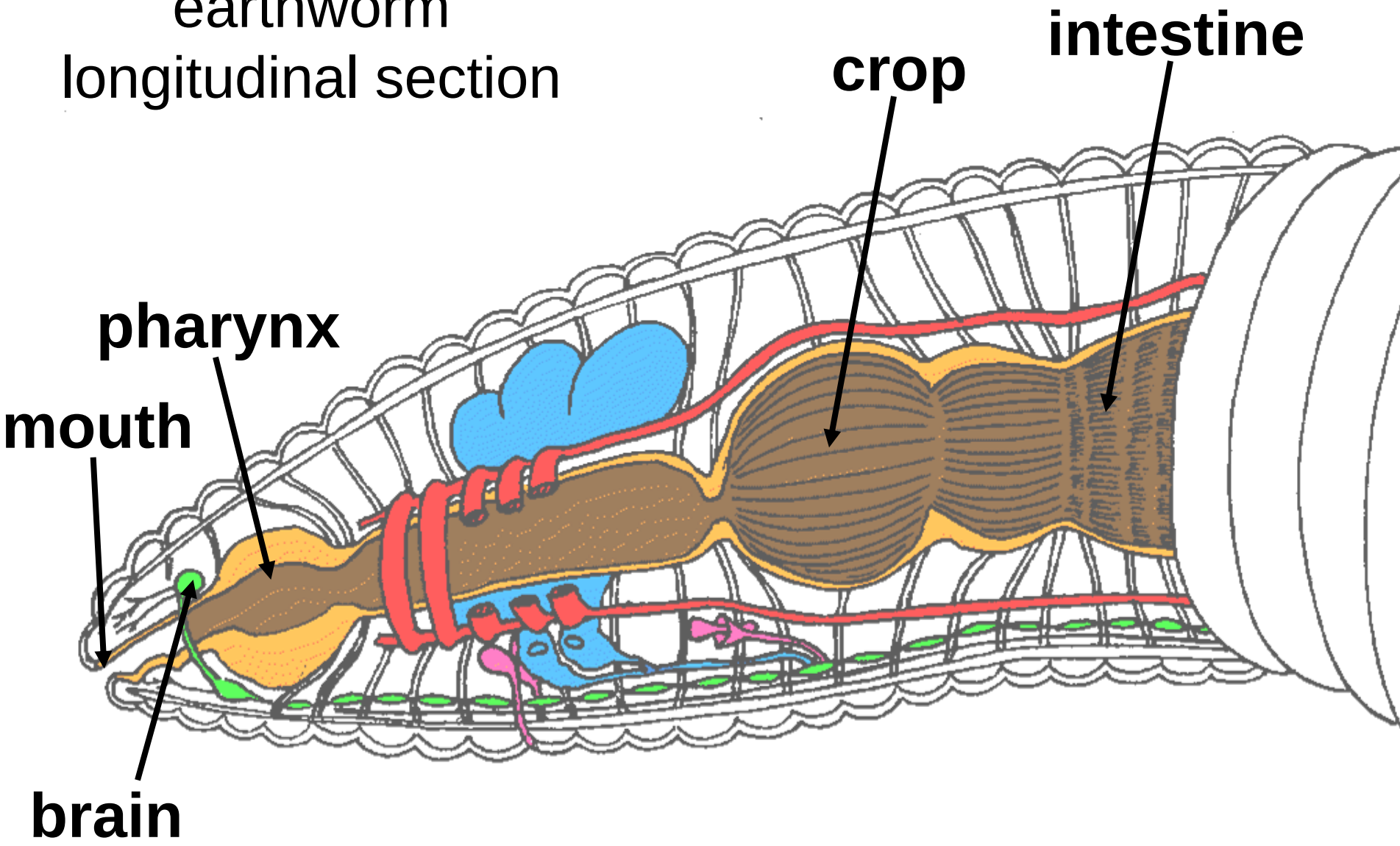
pair of earthworms mating


earthworm cocoons

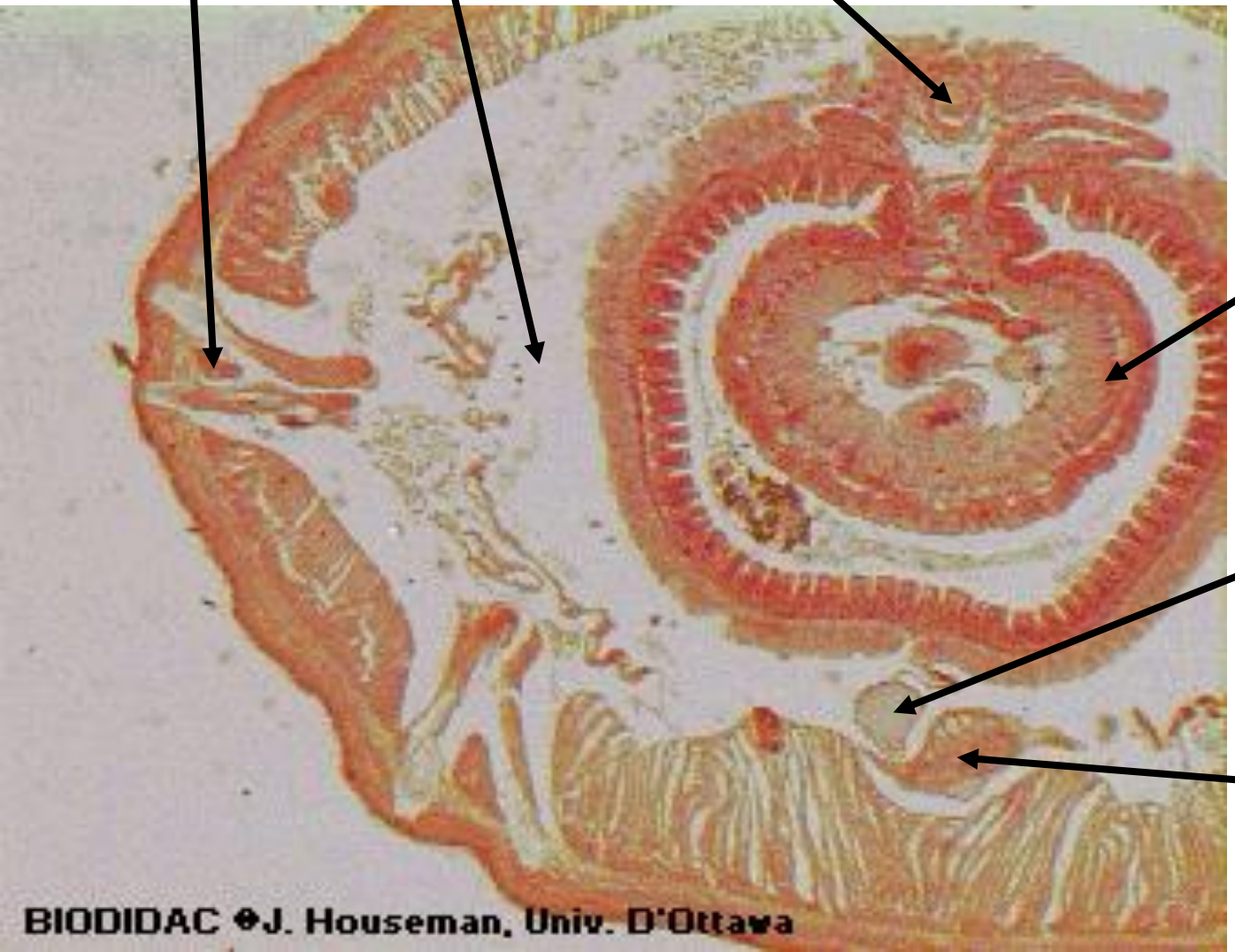
Phylum Annelida observation

1. earthworm longitudinal section
   - mouth, pharynx, crop, intestine, brain
2. earthworm cross section
   - intestine, ventral nerve cord, dorsal and ventral blod vessels, coelom, bristle
3. earthworm nephridium
   - nephridium
4. *Nereis* parapodium
   - parapodium, bristles

Drawing 1:
earthworm
longitudinal section

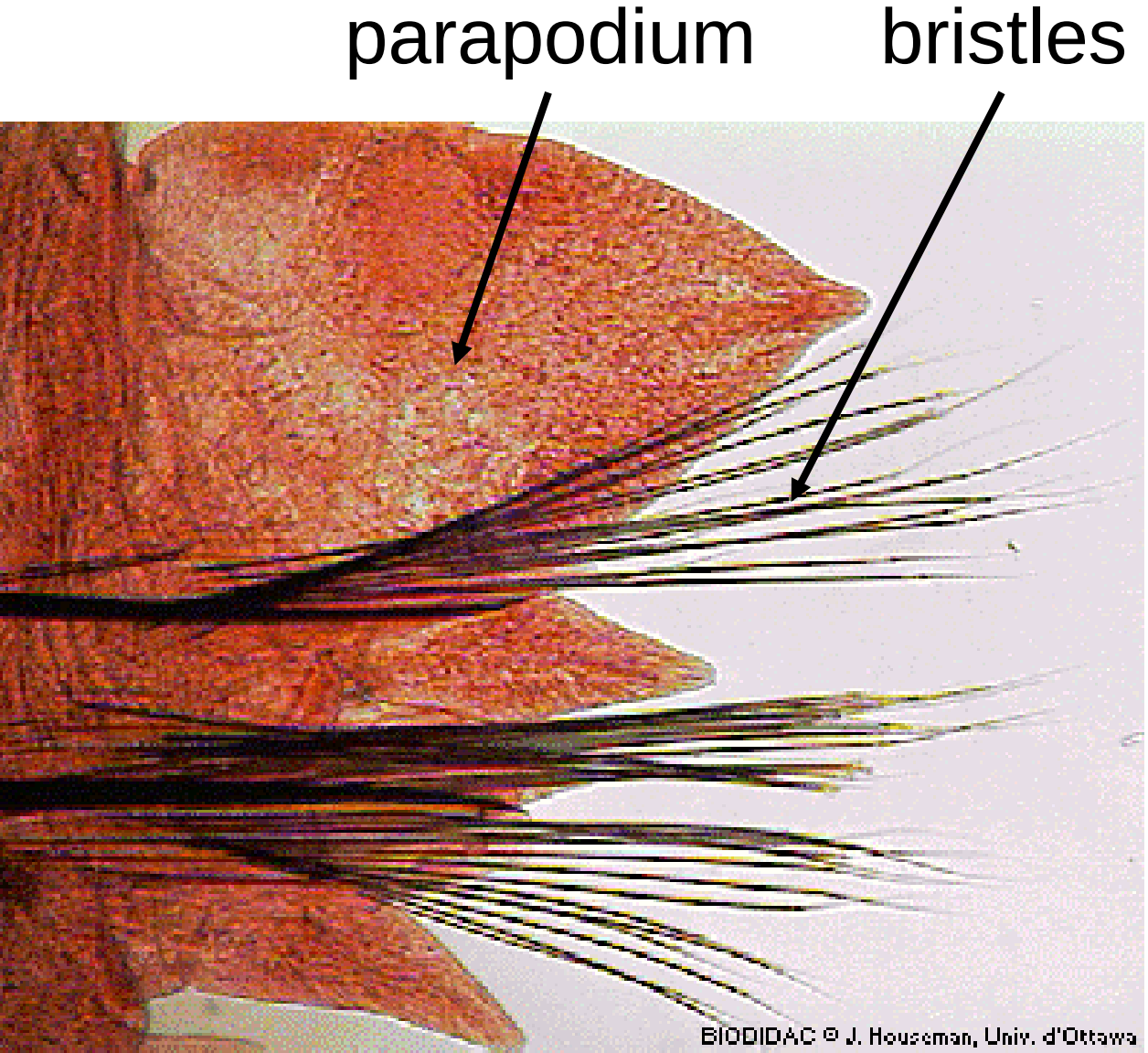


Drawing 2:
earthworm cross
section



Drawing 3:
earthworm
nephridium

Drawing 4: *Nereis* parapodium

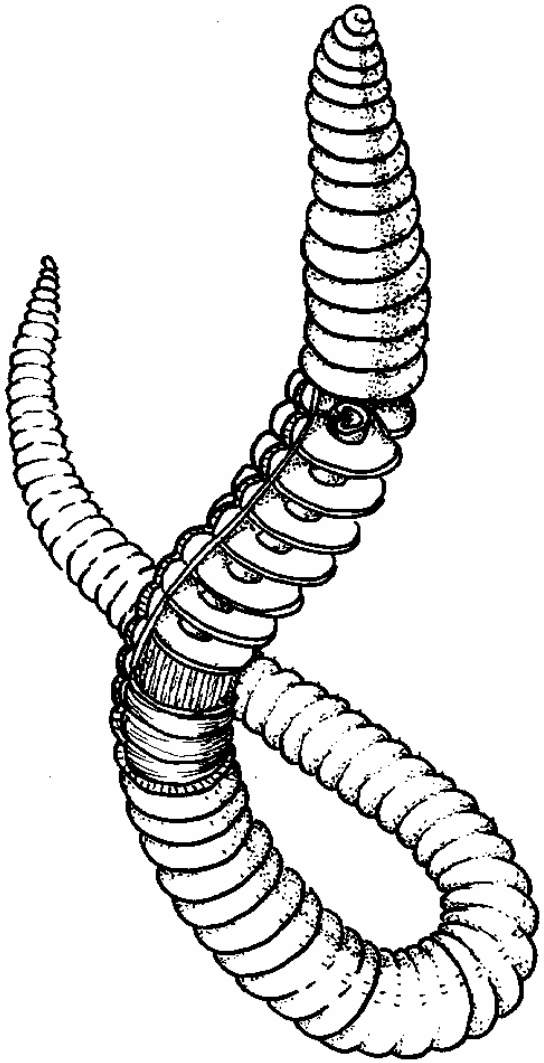


Annelid diversity

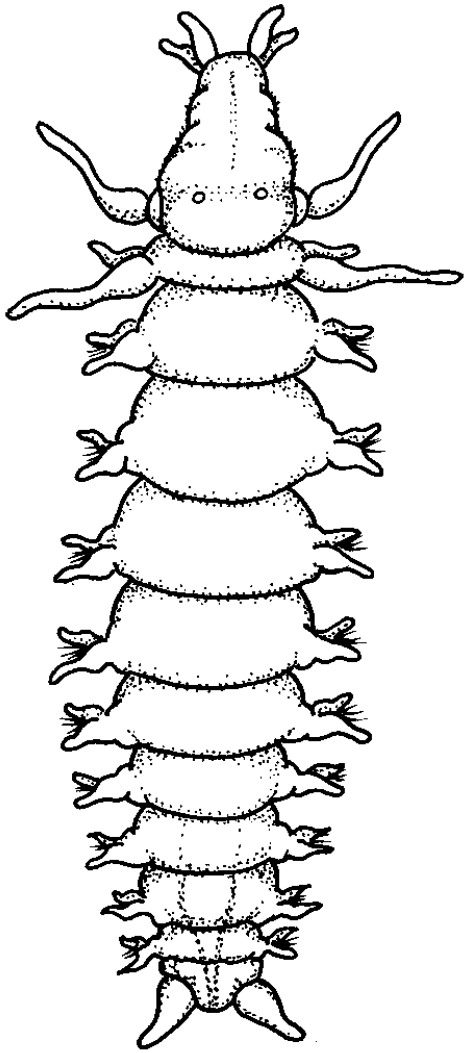
Annelid diversity

There are three main groups of annelids:

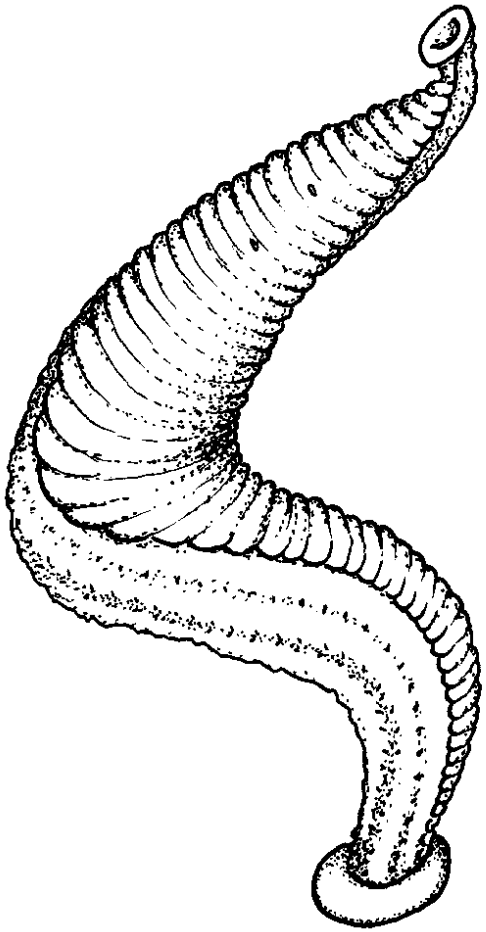
1. Class Oligochaeta – terrestrial and aquatic, mostly detritus feeders
2. Class Polychaeta – all aquatic, mostly marine predators and filter feeders
3. Class Hirudinea – terrestrial and aquatic, mostly predatory, few are parasitic



Class Oligochaeta



Class Polychaeta



Class Hirudinea

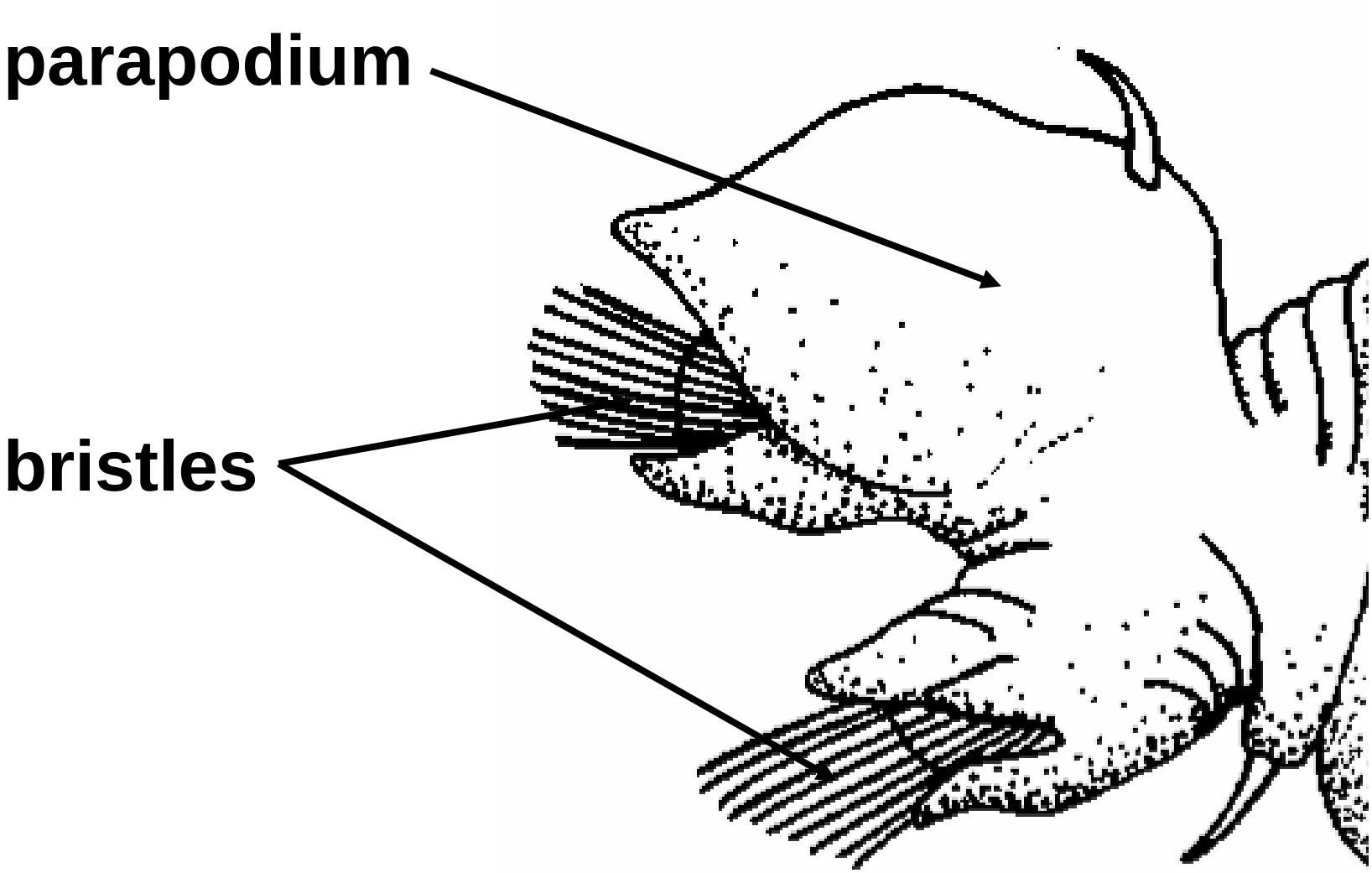
Class Oligochaeta

- segments are smooth and have only a few bristles (<12)
- head lacks sensory organs
- burrowing species are decomposers, feeding on organic matter in the soil
- earthworms are crucial for healthy soil: creating humus and organic nutrients, and aerating ground with their burrows


giant Gippsland earthworm

Class Polychaeta

- each segment has a pair of appendages called parapodia, each of which carries bristles
- these parapodia are used as gills as well as for locomotion
- head has tentacle-like sensory appendages



Parapodium of *Nereis*

clam worm *Nereis*, a polychaete

polychaete living in a clam

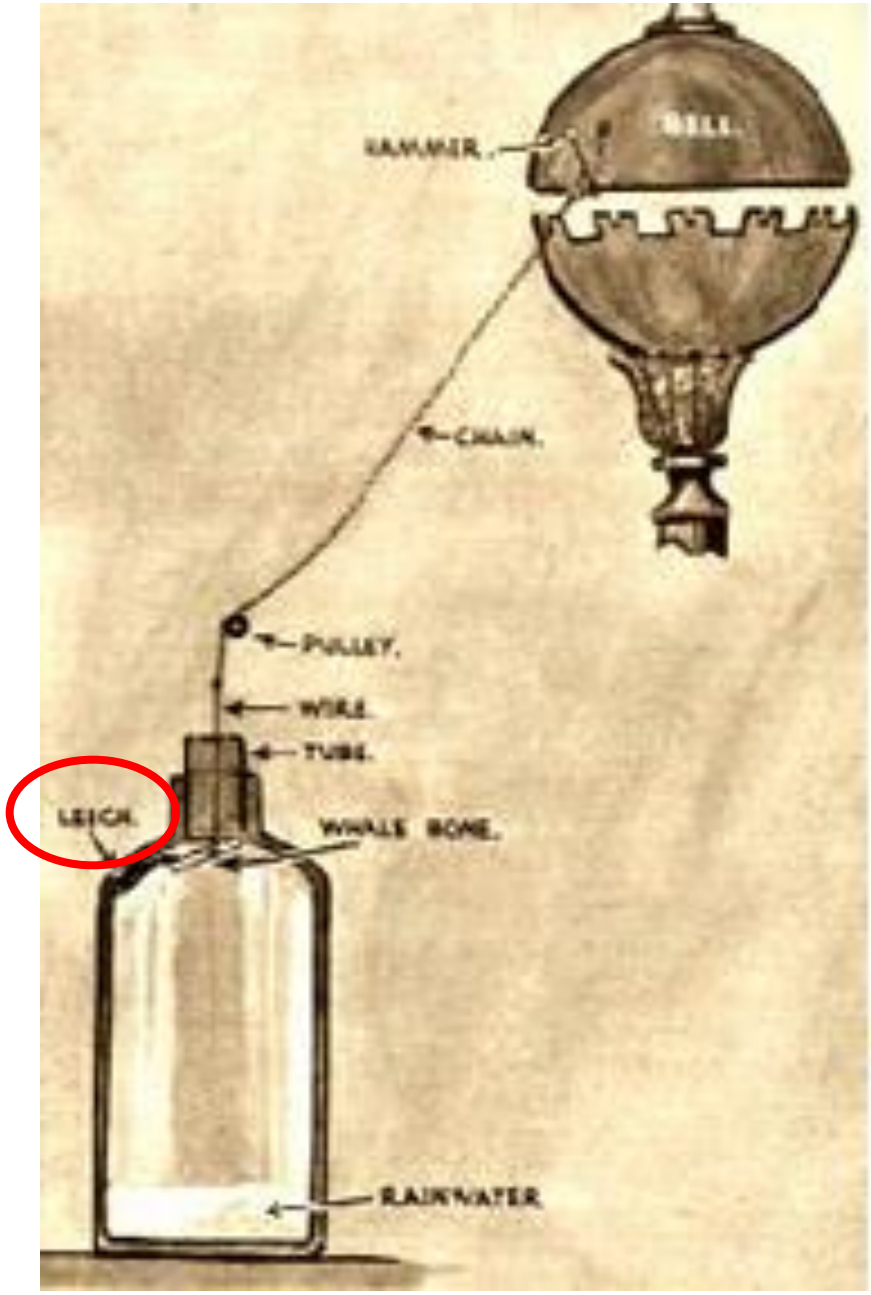
deep sea tube worm - *Lamellibrachia*

bone decomposing worm - *Osedax*

Class Hirudinea

- segments smooth, without bristles
- parasitic leeches feed on the blood of large vertebrates
- saliva contains chemicals which dull pain and prevent blood from clotting
- medicinal leeches are still used to safely relieve swelling in hospitals

Medicinal leech *Hirudo*



George Merryweather's "Tempest Prognosticator"

The medicinal leech

Earthworm observation