ZOO 2700 Midterm STUDY NOTES

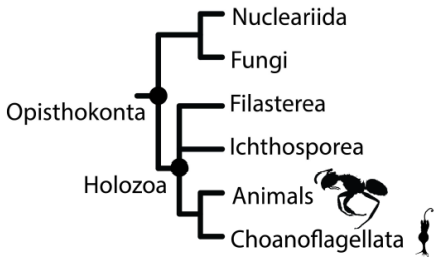
Main themes – unity and diversity among inverts, evolutionary relationships, evolutionary trends, structure/function

Dendrogramma – new genus that could represent a new phylum

Could be classified as an outgroup with ctenophores, or within the ctenophores that are the sister taxa to the cnidarians

86% of species on Earth (91% in the ocean) await description; inverts are >99% of all living animals; inverts are important for health and disease (disease vectors, parasites, medical uses, pharmaceuticals), and economics (food, pollinators, pests, commodities)

INVERTS:



EVOLUTION BY NATURAL SELECTION – A LOGICAL OUTCOME OF 5 CONDITIONS:

1- Variation within populations
2- Variation is heritable
3- Overproduction of offspring
4- Differential survival and reproduction, determined by the environment
5- Result is a change in gene frequencies that correlates with a change in morphology, behaviour, physiology, etc.

Example: *Biston betularia* – 2 types (typica and carbonara) (1), region on chromosome 17 is responsible for peppered moth's melanism (2), ~350 eggs/female (3), strong differential bird predation against typica due to soot on tree trunks (4) → all of which result in a change in gene frequencies that correlates with a change in morphology, etc.

LINNAEAN CATEGORIES	PHYLOGENETICS SYSTEMATICS
Groupings based on similarities and differences	Groupings based on order of dichotomous branchings
Nested hierarchies	Only monophyletic groups are recognized
Typically morphology-based	Often includes molecular data
Linnaean levels emphasized	Linnean levels de-emphasized

Cladistic Analysis – the terms

Apomorphy: a derived character or trait
Synapomorphy: a shared derived character
Monophyletic taxon: includes all the descendants of a single immediate ancestor

Symplesiomorphy: a shared ancestral trait
Paraphyletic taxon: group that includes some, but not all of the descendants of a stem species
Paraphyletic taxon: group that includes some, but not all of the descendants of a stem species
Polyphyletic taxon: group that includes descendants of more than one ancestor
Homology: similarity via common genetic inheritance
Homoplasy: similarity via convergent evolution
Outgroup: close relative of the members of the ingroup that provide a basis for comparison with the others

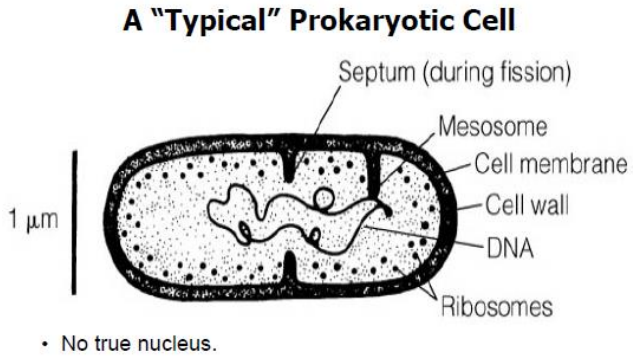
Molecular Data

Degenerate code – redundancy of codons specifying an amino acid (tolerance of point mutations)

Saturation – so many base pair substitutions that the phylogenetic signal is lost

Long branch attraction – rapidly evolving sequences lead to long branches – long branches in a phylogenetic tree tend to cluster together but not due to evolutionary relatedness

Guelph limestone from the Silurian period - ~443-419mya

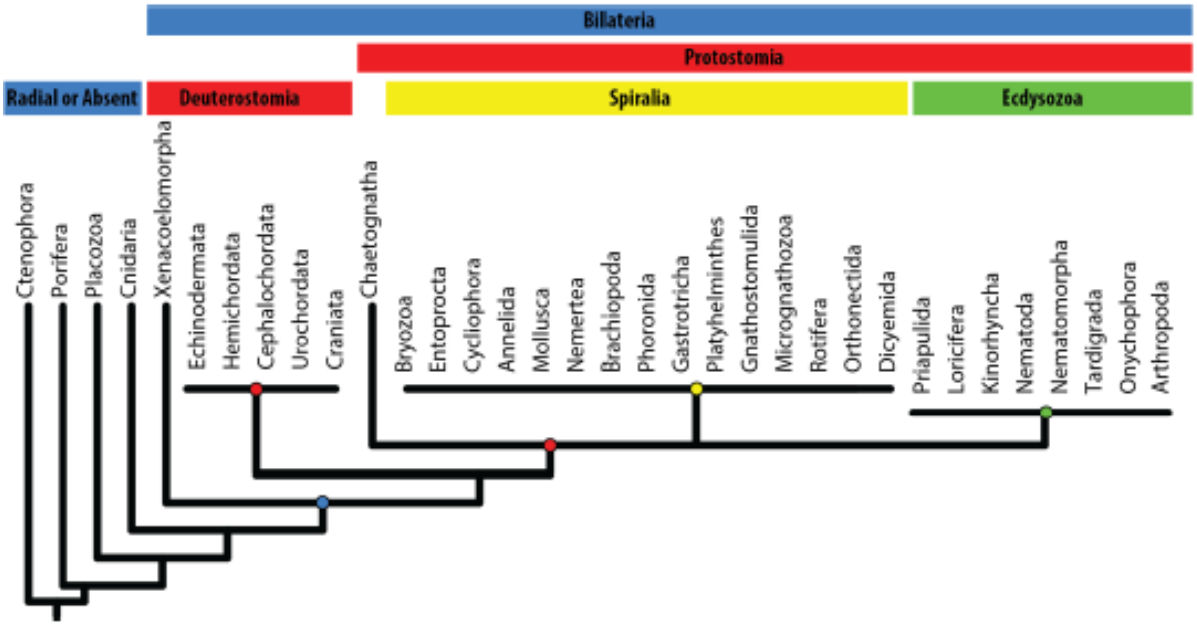


Where did euk. come from?

Prokaryotic ancestor, serial endosymbiosis

Evidence for the endosymbiotic theory:

Mitochondria and chloroplasts have their own DNA
Mitochondria and chloroplasts divide
Different genetic code in mitochondria
Double membranes
rRNA similarities (between mitochondria, bacteria, and chloroplasts)
Recent endosymbiotic events in protists
Facultative endosymbiosis
Secondary endosymbioses



Where did animals come from?

Animals first appeared ~600 million years ago ----- Cambrian explosion

Single-celled eukaryotic ancestor – choanoflagellate

Choanoflagellata

Heterotrophic, single flagellum with collar, suspension feeders, solitary or colonial, sister taxon of Metazoa

Protista

Described as single-celled eukaryotes. They are ecologically important primary producers, consumers (important parts of the food web). Humans greatly affected by parasitic protozoans. Asexual reproduction (replication of chromosomes then splitting of the parent in 2+ parts, binary fission, multiple fission, budding). Methods of mvt was used for group differentiation, but convergent evolution makes this unreliable. VERY divergent group, unsure of ancestral forms.

Protozoa

"First animals", aka animalcules. They are motile, heterotrophic. Can contrast with metazoans. Division of labour within the cell – excretion (contractile vacuoles), locomotion (cilia, flagella, pseudopodia), digestion (oral groove, lysosomes), reproduction (micronucleus), defense (extrusomes), external support (test), internal support (cytoskeleton).

Contains Alveolates, Euglenozoa, Fornicata.

Euglenozoa

Some photosynthetic forms, some can switch to heterotrophic mode of life, flagella used for mvt.

Euglenoida

Autotrophs or heterotrophs (can switch between the two), chloroplasts & pyrenoids (intra-chlorop storage structures), pellicle reinforces cell membrane, 2 flagella present, clonal reproduction. Trailing and leading flagellum, rod organ used in prey capture (can extrude and pull back, made of microtubule bundles).

Kinetoplastida

Heterotrophs, most are parasitic, presence of kinetoplast (large mass of DNA in single mitochondrium), undulating membrane. Includes *Leishmania* (black fever) and *Trypanosoma* (Chaga's disease, African sleeping sickness). Huge number of pellicle-related genes, can change the surface coat in order to survive once immune system is alerted to its presence.

Chagas – caused by the kissing bug, symptoms include fever, swelling, pain, heart failure, death. Transmitted via blood meals.

Chlorophyta

Green algae, close relative to green plants. Volvocida are all flagellated. Can be present in solitary and colonial forms. Reproduction is clonal or sexual. Gonidia → daughter colonies via division of aflagellated cells (found in *Volvox*)

Retortamonada & Axostylata

Retortmonada – includes Giardia (found in contaminated water in mountain streams) which has 2 nuclei, and has secondarily lost mitochondria

Axostylata - have an axostyle, includes Tichomonas, Trichonympha, sexually transmitted disease living in the urinary tract of humans.

Alveolata

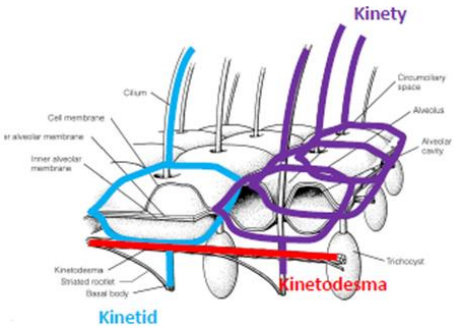
Includes three taxa – Dinoflagellata, Ciliophora, Apicomplexa; presence of unique alveoli – characterized by cortical vesicles that support the cell membrane

Dinoflagellata

Usually has 2 flagella, contains a suculus (longitudinal groove in which one flagellum lies), cingulum (a transverse groove that also has a flagellum), theca (rigid, cellulose, often sculpted skeleton, occurs in the alveoli. Can be autotrophic or heterotrophic, are important primary producers, cause red tides (and can secrete neurotoxins), can bioluminesce, are zooanthellae (critical for coral reefs).

CILIA and FLAGELLA

Kinetid – cilium & basal body (and associated fibres)… A basal body has 9 triplets and a central doublet of microtubules



Ciliophora

Heterotrophic, multiple cilia, alveolar vesicles, mitochondria with tubular cristae, 2 types of nuclei, carbs are stored as glycogen. Presence of somatic and oral ciliature. Have kinetids (cilium with basal body), kinety (row of kinetids), kinetodesma (bundling of basal body fibrils). *metachronal waves (power and recovery strokes). Can have cirri (fused short cilia in a row) that allows for 'walking'.

Paramecium

Osmoregulation is accomplished by contractile vacuoles. Reproduction mechanisms vary with micronucleus (comparable to gonad master copy) and macronucleus (working copies, with millions of copies of certain genes) – asexual fission (transverse, donc fission plane cuts across row of kinetids), sexual conjugation (involves meiosis and exchange of haploid micronuclei bc macronuclei degenerate prior to conjugation)

Several defense mechanisms:

Extrusomes: membrane-bound defensive structures
Trichocysts: long nail-like spikes that are presumably used in defense
Toxicysts: discharge a long thread with a toxic bulb at the base used for defense/prey capture
Mucocysts: release mucus filaments used for defense/prey capture
Haptocysts: harpoon-like structures used by suctorians for prey capture (similar to nematocysts)

Apicomplexa

They are important parasites (malaria or coccidiosis), containing an apical complex. They move via gliding locomotion and do not have cilia.

MALARIA - *Anopheles* mosquito vectored.

Toxoplasma – found in cats and their prey, causes rats to be attracted to cats. Effects on humans may be seen in changes of personality, reduced motor skills (bc it's a dead-end host).

Amoeboid Protozoa

Includes Amebas, Foraminifera, Actinopoda. Sees transition of cytoplasm between stiff clear ectoplasm (gel) and fluid internal endoplasm (sol). Have pseudopodia (lobopodia – blunt, or filopodia – fine), test (protein or siliceous).

Foraminifera

Mostly marine individuals, have reticulopodia, an extracellular test, have diverse fossil fauna, marine deposits and calcareous tests are responsible for the White Dover cliffs.

Actinopoda

Includes Radiolaria and Heliozoa, have axopoda (needle-like pseudopodia used for prey capture, flotation, locomotion or attachment). They are planktonic, benthic.

Radiolaria

Mostly planktonic, have organic or siliceous tests. They are algal symbionts. *marine sediments

Heliozoa

Mostly benthic (some planktonic). Have siliceous spicules, are algal symbionts.

Rhizaria includes Cercozoa, Foraminifera, Radiolaria.

METAZOANS

They are motile, heterotrophic, multicellular animals. They develop from embryos, and have somatic cell differentiation. Have tissues (specialized cells bound together) such as epithelium- sheet of cells, or connective tissue – cells and an ECM. Also have collagen, potentially the most important structural protein in animals.

Advantages of multicellularity: (1) many differences due to SA:V, the surface is the interface between the organism/cell and its environment. How to get oxygen to internal cells? How to void cell waste? Physical limitations that have had enormous effects on directing evolutionary solutions… SA and respiration/water loss/heat loss/strength. Responses to this often involve changing the internal surface area (microvilli, cilia, trachea) or external morphology (2) division of labour (3) efficiency (environmental damage and loss) (4) increase in size (5) ecological advantages – predators (6) metabolic advantages (7) complex tasks (8) information processing (9) biomechanics – speed

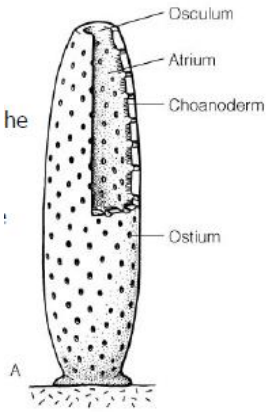
Metazoan origins – colonial theory (derived from a colony of flagellated Protozoa) or syncytial theory (metazoa derived from a multi-nucleate but unicellular like a ciliate protozoan). Colonial theory supported by the fact that Choanoflagellata seem to be the sister taxa to Metazoa. There is a conflict between growth and locomotion, however,…….. centrioles used for mitosis used as flagellar basal bodies; division occurs after the flagella regresses.

1. enlarge existing cells 2. Regress flagella, divide, reassemble flagella 3. Some cells divide while others do not 4. Division of localized cells set aside for growth…. Issues that arise: limits body size, compromises location, permits both therefore best compromise of both.

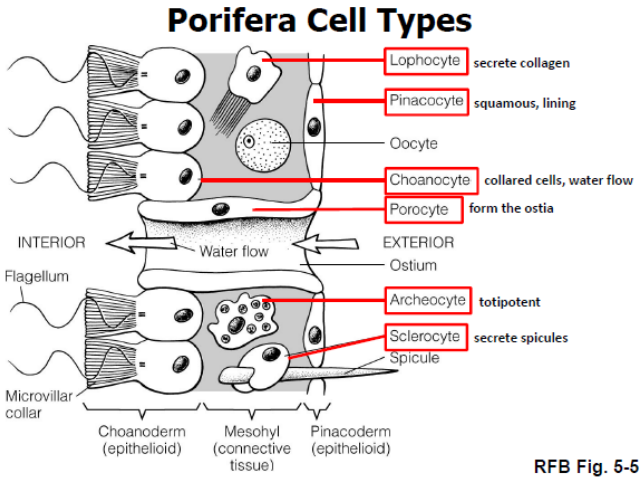
PORIFERA

Apomorphies:

-sessile adults
-pinacocytes (pavement-like cells that cover the body)
-mesohyl (connective tissue layer between the pinacoderm and the choanoderm)
-internal aquiferous system
-archeocytes (totipotent cells)
-sclerocytes (secrete spicules)
-siliceous spicules
-stereoblastula larva



Porifera are suspension feeders, that phagocytise their food through intracellular digestion (food flows into incurrent canals and archeocytes absorb large particles, choanocytes absorb smaller particles (and transfer them to archeocytes in order for digestion to occur)



RFB Fig. 5-5

Sponge phylogeny:

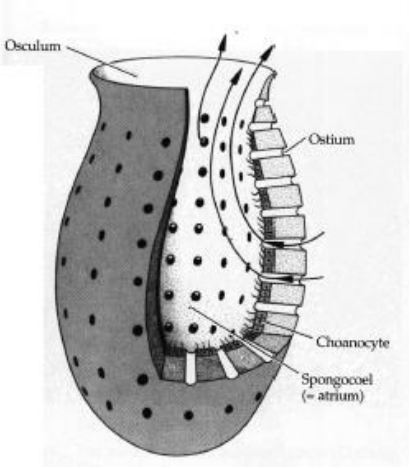
Porifera
- Symplasma (Hexactinellida)
- Cellularia
  - Demospongiae
  - Calcarea

HEXACTINELLIDA (glass sponges) **Apomorphies:** -siliceous spicules (they dissolve in HCl) -6-rayed –syncytium –secondary silification
CELLULARIA **Apomorphies:** -cellular tissues –porocytes –extracellular calcification –Demospongiae and Calcarea

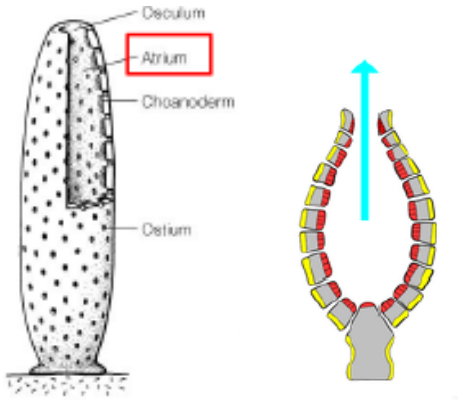
Demospongiae	***Calcarea***
Apomorphies: -siliceous tetraxons –spongocytes and sponging	**Apomorphies:** -calcium carbonate (calcite) spicules that won't dissolve in HCl –large choanocytes –coeloblastula larva (hollow)

AQUIFEROUS SYSTEM
-dermal pores or ostia
-choanocyte chambers
-excurrent canals
-osculum

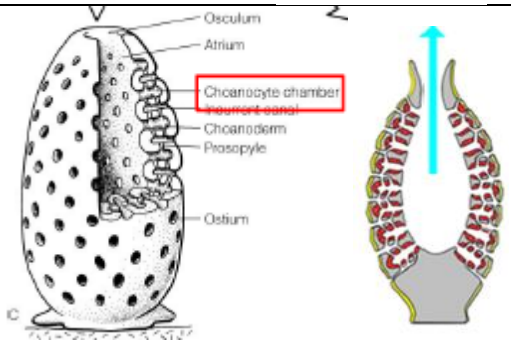
AREA and FLOW
-continuous flow
-flow increases significantly while in choanocyte chambers



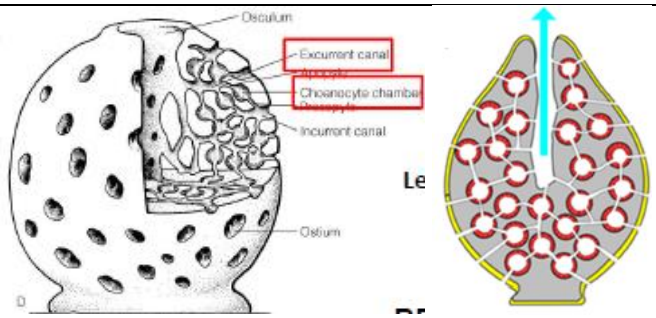
ASCONOID (smallest form)
-hollow cylinder attached to the substratum by its base, body surface covered by a monolayer of pinacoderm, atrium is lined by monolayer of choanoderms, ostia perforate the cylinder wall, large osculum (chimney top)
*limits the body size due to SA:V considerations



SYNCONOID
-increased SA:V
-outpockets of choanoderm are choanocyte chambers , inpockets of pinacoderm are the incurrent canals that discharge into prosopyles (small openings that open into the choanocyte chambers)
Path of water: ostia → incurrent canals → prosopyles → choanocyte chambers → atrium → osculum



LEUCONOID (largest form)
-spherical choanocyte chambers lie at the incurrent and excurrent canals (makes up the aquiferous system
-food-trapping filters are the incurrent canals
-all Demospongiae are leuconoid



Bernoulli's theory allows for a more efficient flow through choanocyte chambers

Boring sponges are responsible for bioerosion. This is accomplished with etching cells (archeocytes). *Cliona celata* is a boring sponge.

Gemmules are dormant structure; clustering of archeocytes that have accumulated nutrients by phagocytizing other cells. They allow for overwintering. *Form of asexual reproduction

Most sponges are hermaphrodites – germ cells embedded in the mesohyl make eggs from archeocytes and sperm from choanocytes. 1-Sperm is released through excurrent canals 2-Phagocytosed by choanocytes (but not digested) 3-Delivered to egg for fertilization 4-Viviparity in most sponges (release of lecithrotrophic larvae)

Development – either coeloblastula (hollow) larvae (different from other metazoans) or lecithotrophic (mobile) larvae

Predatory sponges exist – capture prey on hook-like spicules

Biological associations – hawksbill turtles eat sponges (mostly), filefish, dromiid crabs place sponges on their backs

Placozoa

Have a flattened body, epithelial cells without a basal lamina, ciliated upper and lower cells, fiber-syncytium (contractile), ameba-like motion (non-polarized, can rip itself in two)
Have **lipid spheres** on surface of body – most likely for predator protection because they shimmer

Eumetazoa

A traditional taxon – not in the Dunn or online phylogeny – all animal groups except sponges and placozoa (ctenophores, cnidarians, bilaterans) – characteristics: body symmetry either radial or bilateral, epithelial tissue, have guts, muscles, and nerves

Epithelia – key innovation leading to diversification – allowed for physiological compartmentalization, can allow for evolution into muscle and nerve

1-Polarised (basal facing other cells, apical facing environment) 2-Continuous layer 3-Basal lamina 4-Intercellular junctions

Cnidaria

Cnidarians are diploblasts, metagenesis (alteration between medusa and polyp stages). Unsure if polyps are the original body form or if the polyp stage evolved secondarily.

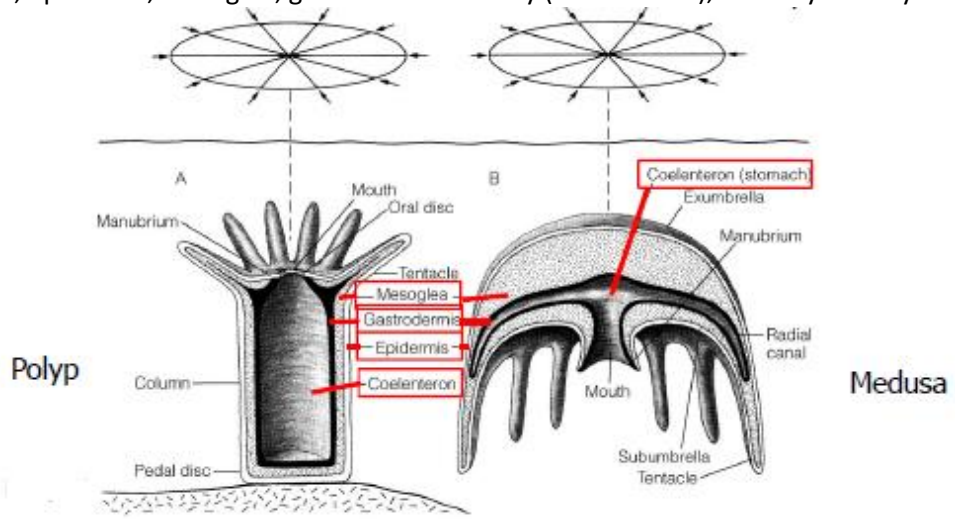
Apomorphies: stinging cells (cnidocytes – not technically a cell, but secreted from a cnidoblast cell), polyp adult and planula larva, nerve nets, longitudinal and circular muscle, endodermal gonads, circular mitochondrial DNA, diploblast (2 layers, endoderm and ectoderm)

Cnidocytes have 2 forms (spirocyst – twirled within the cell, or ptychocyst – wrapped more hapharardly)

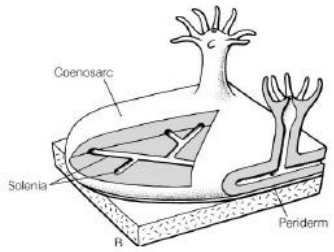
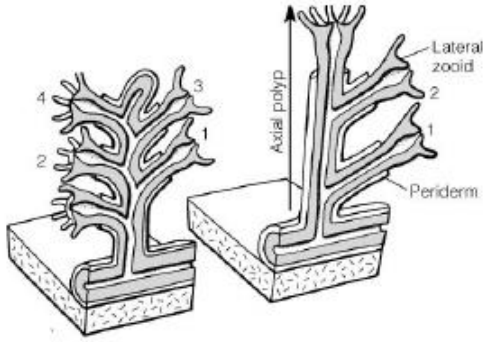
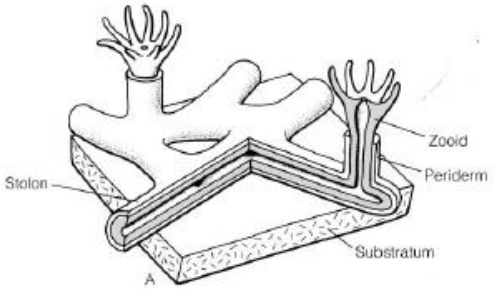
Also, have nematocysts (one of the fastest biomechanical events to inject toxins into prey)

Morphology:

Gastrodermis, epidermis, mesoglea, gastrovascular cavity (coelenteron), radial symmetry.



Cell types: cnidocytes, muscle, nerve, glandular, interstitial, ciliated, sensory, germ

Colonial forms:	**Skeleton:**
Coenosarcal: stolonate mat, continuous  	Chitin (hydroids) Calcium carbonate (brain coral) Spicule endoskeleton (sea plumes) Hydrostatic (fluid-filled cavity surrounded by muscles) Foreign material (zooanthellae and zoochlorellae gave 90% of nutrition)
Fruiticose: generated by two different kinds of budding of polyps from other polyps  	**Musculature:** Polyps have antagnonistic sheets of smooth muscles. Epidermal is longitudinal (shortening of body) and gastrodermal is circular (elongation) Medusae have a ring of muscles called coronal muscle, which are antagonized by the elastic mesoglea
Stolonate: like a strawberry runner  	**Nervous System:** Have sensory neurons, motor neurons, and interneurons. One nerve net just under the gastrodermis, another just under the epidermis, but both are connected to each other. There are simple nerve nets, but also have ganglia. Nerve rings are concentrations of neurons that innervate the coronal muscle.

Phylogeny:

Anthozoa (sea anemones, corals, sea pens)		
'Medusozoa' (jellies with medusa stage)		
Schyphozoa (jellyfish, medusa with rhopalia)	**Cubozoa** (jellyfish, medusa with box-like body)	**Hydrozoa** (greater representation of the polyp morph, medusa with velum)

ANTHOZOA

Corals (ie Scleratinia), sea anemones (ie Actinaria), sea plumes/sea whips/sea fans (ie Gorgonacea, Holaxonia, Pennatulacea) – **polyploid form only**

Apomorphies: polyps with pharyns (siphonoglyph [ciliated grooves]), 3 cnidocytes, septa (division of coelentron into vertical partitions), septal filaments

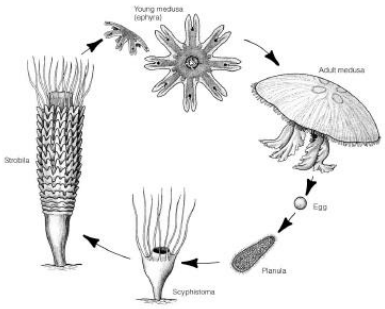
'MEDUSOZOA'

Apomorphies: medusa stage, linear mitochondrial DNA

Reproduction: medusa → planula → polyp → medusa

SCHYPHOZOA

Apomorphies: Medusa with rhopalia (sense organs) [mesogleal, gastrodermal and epidermal components; gastrodermal statocyst, mechano-, photo- and chemoreceptor], gastric filaments (bears nematocysts and digestive cells), strobilation



CUBOZOA

Apomorphies: small polyps lacking septa, cubic medusa, tentacles on pedalia at four corners of the bell, four rhopalia with ocelli, velarium (developmentally different from the velum; ring of tissue that extends around the bottom inside of the bell that contracts during swimming, increasing thrust… increases the efficiency of the jet propulsion & increases swimming speeds), highly venomous

HYDROZOA

Apomorphies: medusa with velum (ring of tissue that directs the flow of water out of the bell), endodermal cnidocytes are absent, nerve rings with gap junctions

Ctenophora

Apomorphies: biradial symmetry (pharyngeal and tentacular plane), aboral organ (rudimentary brain controlling the comb rows, gravity-sensing), ciliary rosettes (transport nutrients to the mesoglea), photocytes, ctene rows (eight rows), collocytes (cells that secrete a sticky substance for prey capture on epidermis and tentilla, 'spin-capture')

Ctenophore nervous system: many genes controlling the neuronal fate and patterning are absent in the ctenophores, they lack components for synaptic functions in eumetazoans, they don't use the typical intercellular messengers. They lack neuron-building genes. Donc, evolution took place in two separate lineages (one led to ctenophores, the other to all other animals with a nervous system).

Musculature: coronal muscle and mesoglea

Bilateria

LITERALLY EVERYTHING ELSE IS PART OF THIS GROUP.

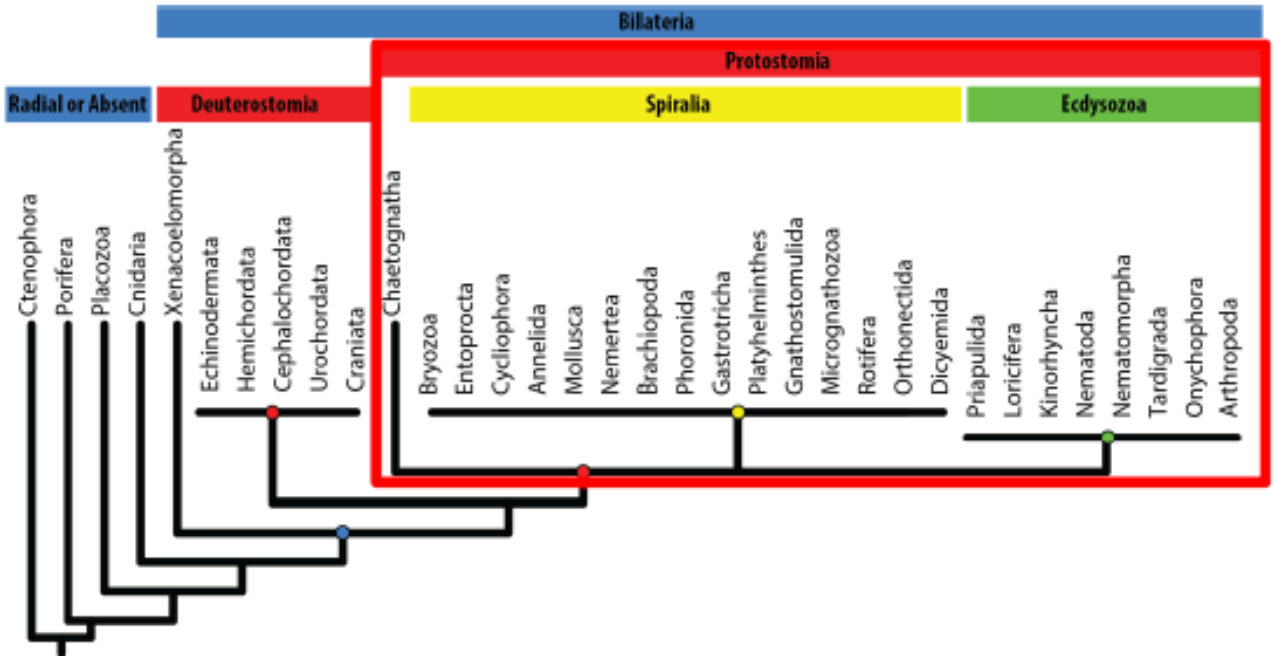
Apomorphies: bilateral symmetry (midsaggital plane, L/R mirror images), dorsal and ventral sides, cephalization, filtration excretory organs

Symmetry – anterior/posterior, dorsal/ventral, importance of gradients (radial symmetry works best for sessile suspension feeders).

Significance of bilateralism → perpendicular to environmental gradients, feeding (patchy), swimming, reproduction, differentiation; it is synonymous with **cephalization** (anterior end, sensory information, information processing, feeding, sessile vs. motile)

Secondary radial symmetry → directionality – food in all directions therefore no polarisation necessary

Primary division into Protostomes (blastopore becomes the mouth, coelom formed from splitting of the mesoderm [schizocoeleous]) and Deuterostomes (blastopore becomes the anus, coelom formed from folds of archenteron [enterocoelous])



Protostomia

Apomorphies: blastopore becomes the mouth, schizocoely (coelom [body cavity] is formed by splitting the mesodermal embryonic tissue)

Divided into Spiralia (='Lophotrochozoa'), Ecdysozoa

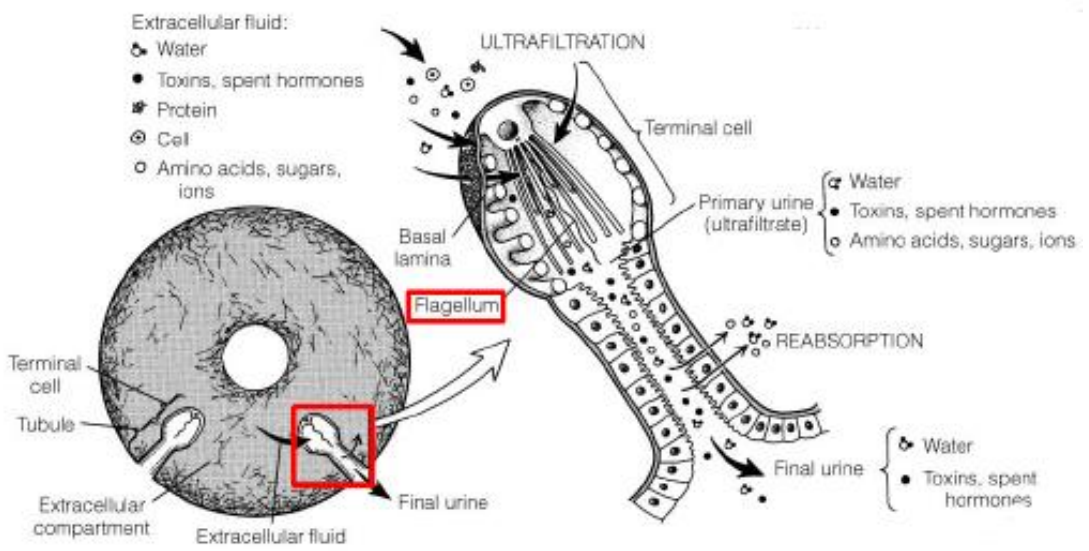
Ecdysozoa

=Moulting animals, composed of arthropods, nematodes

Spiralia

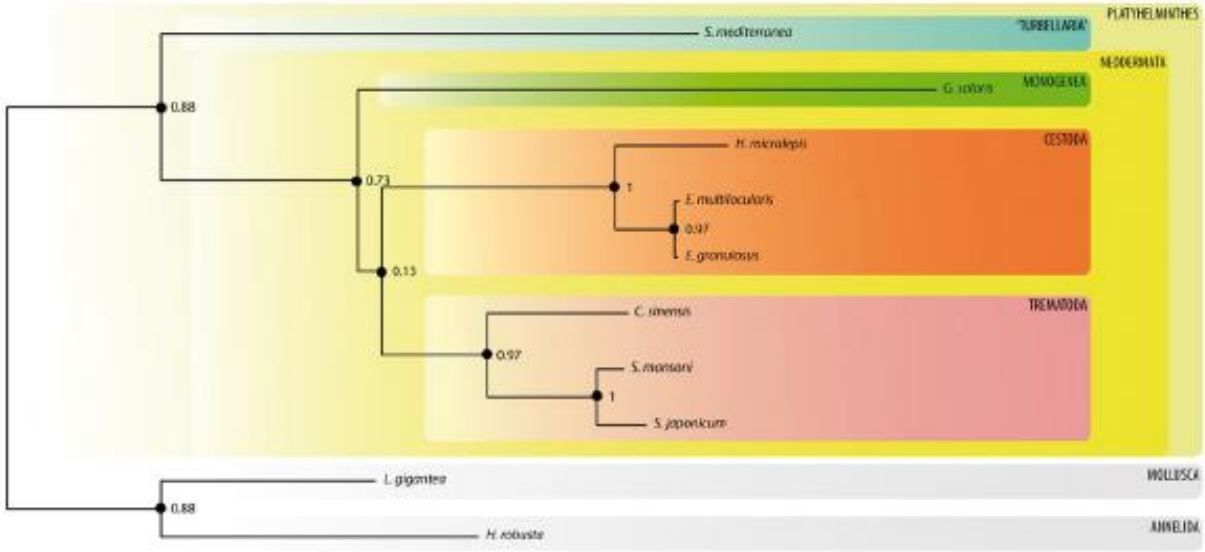
='Lophotrochozoa', composed of annelids, mollusks, bryozoans, chaetognaths, rotifers, etc.

Apomorphies: larval protonephridia (face outwards to the environment), chaetae (stiff bristles), beta chitin



*How are the larval protnephridia similar to ctenophores' ciliary rosettes? (Homology? Convergence?)

- Spiralia = Lophotrochozoa
  - **Platyhelminthes**
  - Rotifera
  - Bryozoa
  - Chaetognatha
  - Nemertea, Phoronida, Brachiopoda, Annelida, Mollusca…



Platyhelminthes

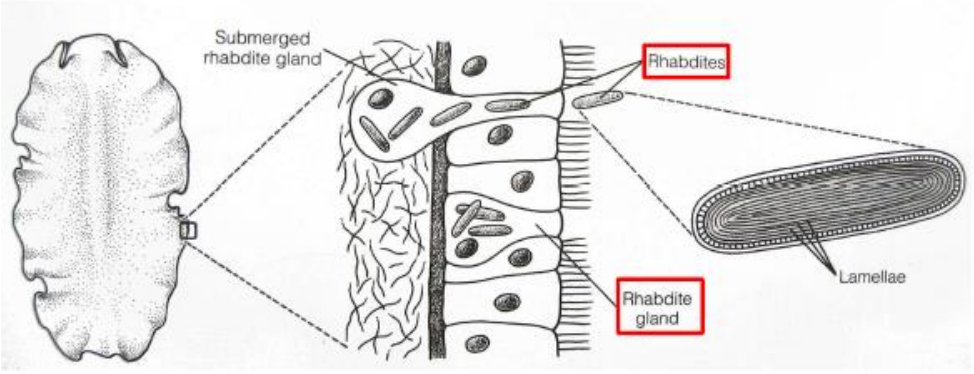
Subclassification of Spiralia; contains Trematoda, Cestoda, Monogenea, 'Turbellaria'

Apomorphies: multi-ciliated epidermis and gastrodermis, two cilia per protonephridial terminal cell (negative pressure, flame cell: characterized by two cilia or more – flatworms only have two, solencyte: terminal cell with one flagellum) *see protonephridia diagram in spiralia

'Turbellaria'

Diverse, free-living, no cuticle, NOT AN ACCEPTED GROUP

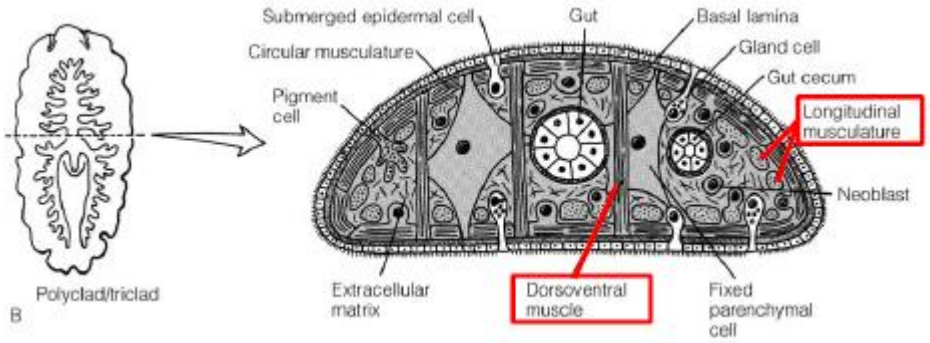
Body wall: contains rhabdites (rod-shaped secretions of the epidermal glands to produce slime for predator repellant, cocoon formation)



Some species have calcerous skeleton under epidermis

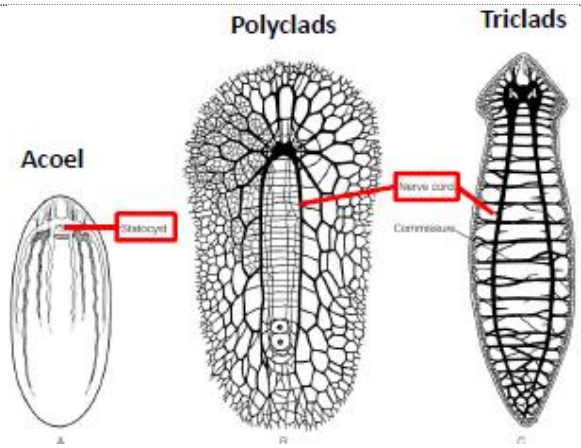
Also have duo glands – adhesion in marine species, comprised of two parts: viscid glans (adhesive function) and releasing gland (de-adhesive function)

Musculature: circular, longitudinal, dorsoventral muscle; muscular waves allows swimming (however, smaller species primarily use cilia for locomotion)



Regeneration in *Planaria* – terminally differentiated cells can be reprogrammed (good insight into stem cell research – animal model)

Nervous system:
Nerve cords
Nerve nets
Statocysts (gravity receptor)
Ciliary receptors (mechanoreceptor)
Chemoreceptors
--
Pigmented eye spot
Photoreceptors (strongly phototactic)



Digestive system: mouth, no anus, lateral branches, phagocytic, gland cells, gastro-vascular

Platyhelminthes

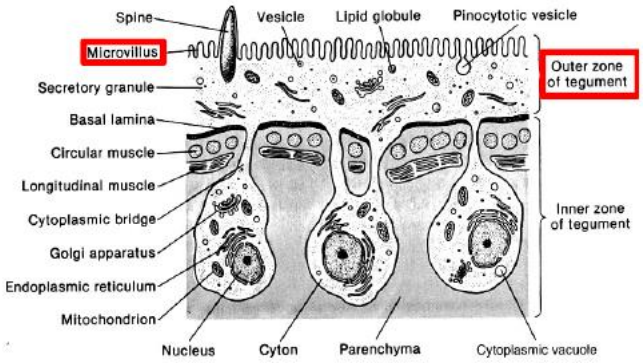
Subclassification of Spiralia; contains Trematoda, Cestoda, Monogenea, 'Turbellaria'

Apomorphies: multi-ciliated epidermis and gastrodermis, two cilia per protonephridial terminal cell (negative pressure, flame cell: characterized by two cilia or more – flatworms only have two, solencyte: terminal cell with one flagellum) *see protonephridia diagram in spiralia

Neodermata

Contains Monogenea, Cestoda, Trematoda

Apomorphies: neodermis (tegument; an adaptation to parasitic lifestyle – offers protection from gut enzymes, allows for nutrient absorption from the host, it is non-ciliated, syncytial



Syncytial = multinucleated mass of cytoplasm that is not separated into individual cells

Syncytial neodermis is composed of a distal anucleate cell layer, cell bodies containing the nuclei (cytons) lie beneath a superficial layer of muscles, connected to the distal cytoplasm by way of bridges (internuncial processes)

'Cercomeramorpha'

= Cestoda & Monogenea (polyphyletic group), characterized by anchoring hooks on modified posterior end

Trematoda

Apomorphies: flatworms/flukes, larval epidermis is a combination of ciliated cells and syncytial neodermis, molluscs are the primary hosts (*flukes are a big deal in human health)

Aspidogastrea

Found within the Trematoda group

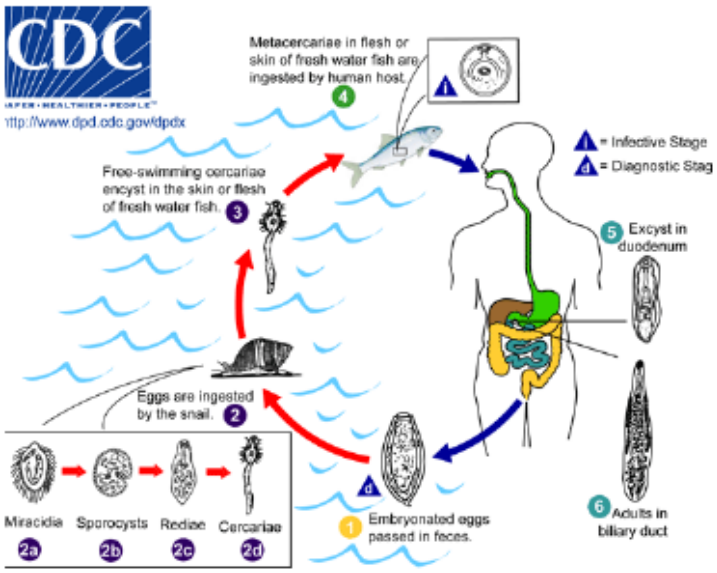
Apomorphies: large & complex ventral sucker, (aspido = shield), mostly preys upon fish and turtles

Digenea (flukes)

Has an oral sucker for feeding, a ventral sucker for attachment, a bulbous pharynx, circular & longitudinal muscle

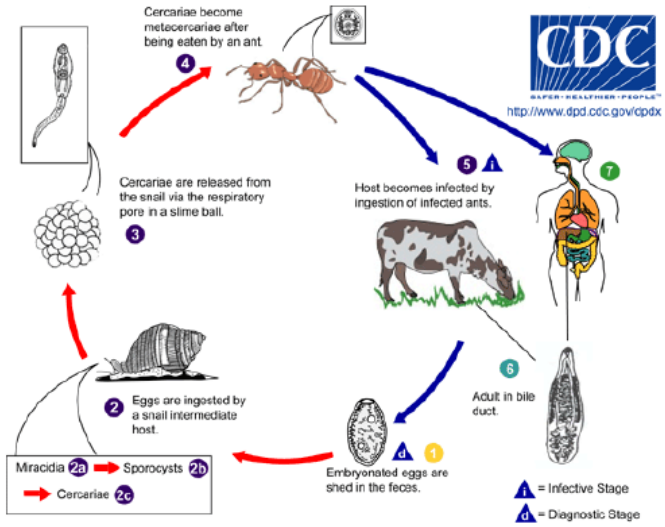
Apomorphies: miracidium larva with transverse bands of ciliated cells, intermediate mollusc hosts and definitive vertebrate hosts

Chinese liver fluke (*Clonorchis sinensis*) has multiple asexual phases, parasitized 3 different species. (1) Embryonated eggs passed in feces (2) Eggs ingested by the snail [1st intermediate host] (3) Free-swimming cercariae encyst in the skin or flesh of freshwater fish [2nd intermediate host – can be fish or arthropod] (4) Metacercariae in flesh or skin of freshwater fish are ingested by the human host [definitive host] (5) Encysts in the duodenum (6) Adults in the biliary duct



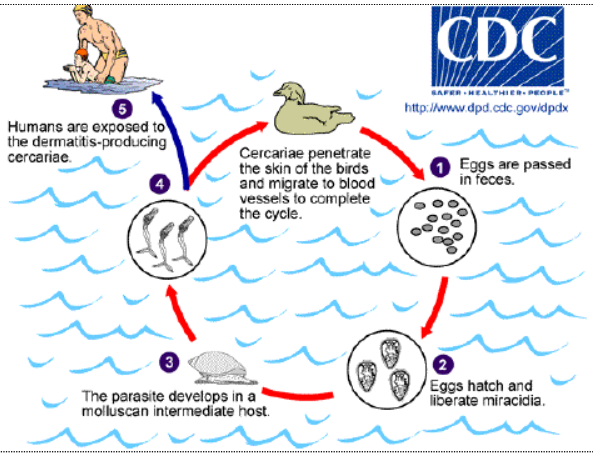
Lancet liver fluke (*Dicrocoelium dendriticum)* – zombifies ants

(1) Embryonated eggs are shed in feces (2) Eggs are ingested by a snail – intermediate host where miracidia → sporocysts → cercariae (3) Cercariae are released from the snail via the respiratory pore in a slime ball (4) Cercariae → metacercariae after being eaten by an ant (5) Host becomes infected by ingestion of infected ants – in the case of cows (6) Adults in bile ducts of either cows or humans

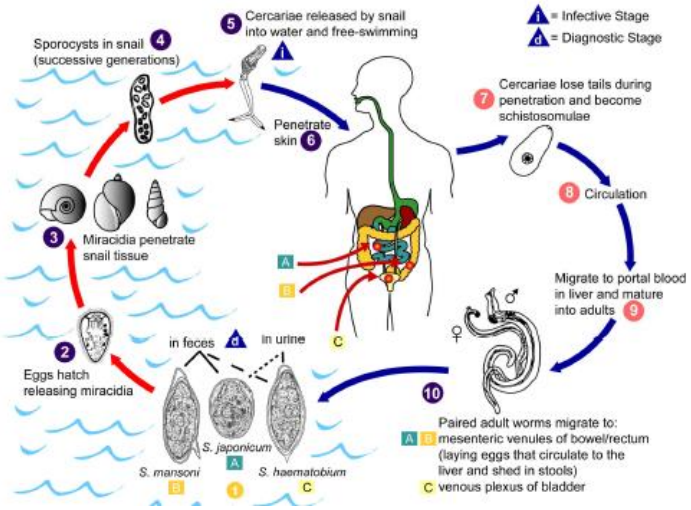


Trichobilharzia – causes Swimmer's Itch

(1) Eggs passed in feces (2) Eggs hatch and liberate miracidia (3) The parasite develops in a molluscan intermediate host (4) Mature into cercariae (5) Humans are exposed to the dermatitis-producing cercariae



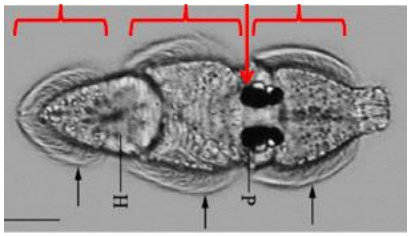
Schistosoma (2nd most devastating parasitic disease)
(1) Found in feces/urine (2) Eggs hatch releasing miracidia (3) Miracidia penetrate snail tissue (4) Sporocysts in snail [successive generations] (5) Cercariae released into water & are free-swimming (6/7) Penetrate human skin & loses tail to become schistosomulae (8/9) Enters into circulation, migrates to portal blood in liver & matures into adults (10) Paired adult worms travel to bowel/rectum or bladder



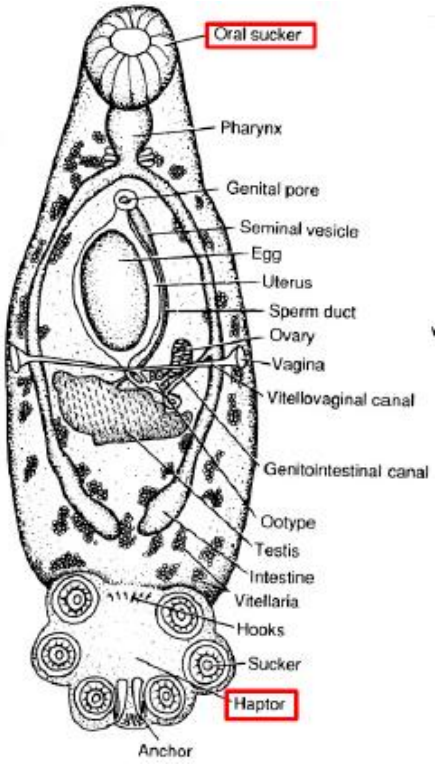
*Prevention of *Schistosoma* – access to safe drinking water and improved sanitation, vigorous towel drying after any accidental water exposures.

Monogenea

Apomorphies: onchomiracidium larva with three widely separated bands of ciliated cells, has a pair of pigment cup ocelli



Monogeneans (within the Neodermata grouping) are ectoparasites with well-developed dorsoventral muscles, with only one host – an aquatic vertebrate host. No asexual stage. Has an oral sucker (mucus and scraping from the host) , and a haptor (posterior attachment organ), and is transmitted at the larval stage



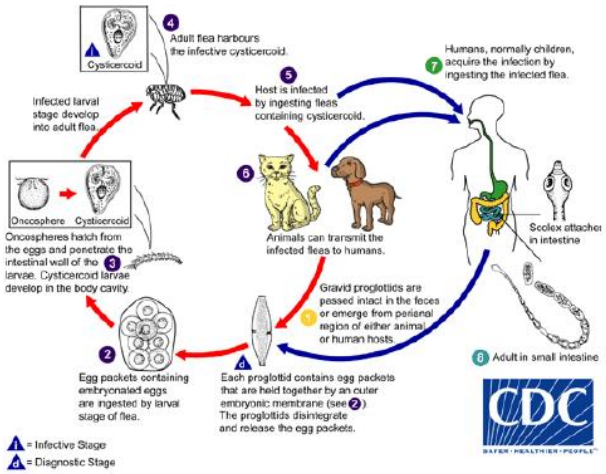
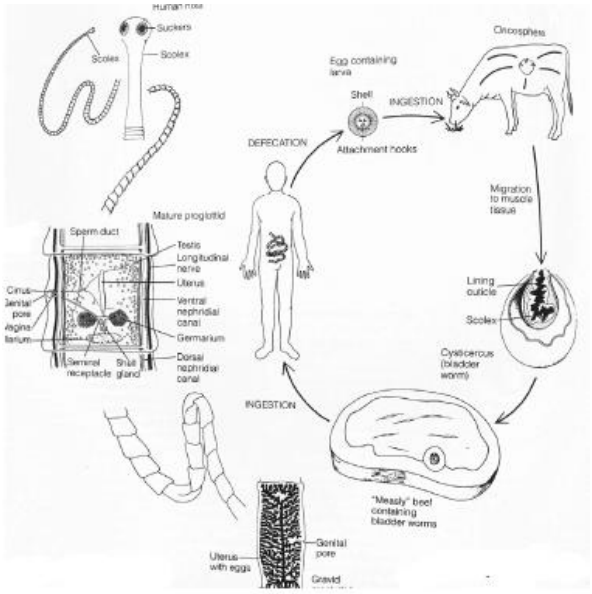
Pseudodiplorchis americanus is transmitted from one toad to another, transmission (invade via the nostrils) can occur a maximum of 7 hours over 1-3 nights; in some years, <u>all</u> toads are infected which indicates a synchronization of life-cycles

Cestoda

(=tapeworms)

Apomorphies: absence of a gut, ciliated larval epidermis syncytial

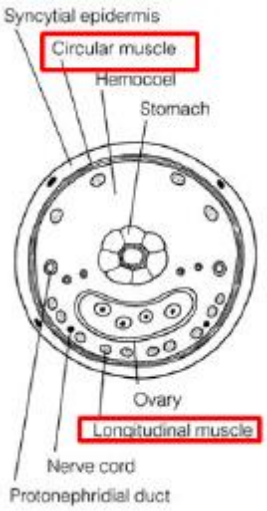
Presence of a scolex, neck, strobila (with proglottids – segments of eggs), neodermis (non-ciliated syncytial endodermis – epidermis is replaces during development, no inter-cellular space, exchanges of substances through body wall is regulated). *Entire body functions as an inverted intestine

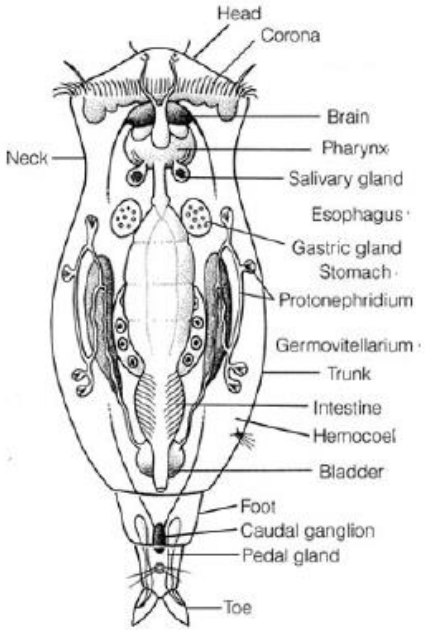
Canine tapeworm (*Dipylidium caninum*) (1) Gravid proglottids are passed intact in the feces or emerge from perianal region of either human/animal hosts (2) Egg packets containing embryonated eggs are ingested by larval stage of the flea (3) Oncospheres hatch from the eggs and penetrate the intestinal wall of the larvae & cysticercoid larvae develop in the body cavity (4) Adult flea harbours the infective cysticercoid (5) Host ins infected by ingesting fleas containing cysticercoid (6) Animals can transmit infected fleas to humans (7) Humans (kids, mostly) acquire the infection by ingesting the infected flea (8) Adult in small intestine	
Beef tapeworm – Humans are the definitive host, intermediate host is the cow 	Oncosphere: ciliated "egg" containing many cells Found in aquatic cestodes, transmitted by copepods (small crustaceans), enters fish gut after ingestion of copepod Has three pairs of small hooks on the surface

Rotifera

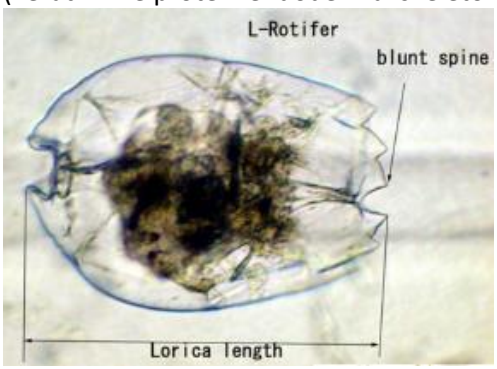
Apomorphies: ciliary corona on head (wheel organ), unpaired retrocerebral gland (secretes mucus to lubricate the wheel), female has vitellarium (syncytial structure produces eggs)

Morphology: Transverse rings, circular and longitudinal muscles, hemocoel



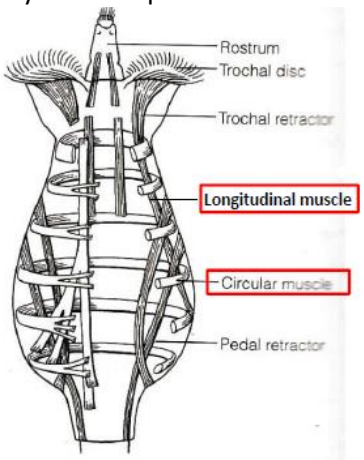


Body wall: syncytial epidermis, cuticle, lorica (keratin-like protein endodermal skeleton)



Reproduction: gonochoric (aka not hermaphroditic), parthenogenic (an unfertilized egg develops into a new individual), hypodermic impregnation (injection of sperm into coelom), heterogony (alteration of sexual and asexual)

Locomotion and feeding: contraction of circular muscle to elongate the body & stretch out the relaxed longitudinal muscle, the pseudocoel acts as a hydrostatic skeleton (permits mutual antagonism of circular and longitudinal musculature through generation of temporart increase in hydrostatic pressure



They swim, crawl, inchworm or telescope. Are suspension feeders, raptors or omnivores

'Lophotrochozoa'

(='Lophophorata') Groups together Bryozoa, Brachiopoda, Phoronida

Lophophore: Crown of hollow, ciliated tentacles encircling the mouth – upstream collection system for suspension feeding (water pulled down into center of lophophore via ciliary action, expelled between

adjacent tentacle after frontal cilia have removed food particles), used for gas exchange, hollow space in tentacle is part of coelomic space

Other features of this group: sessile or sedentary suspension feeders, employ lophophore cilia to capture phytoplankton and small planktonic organisms, no distinct head

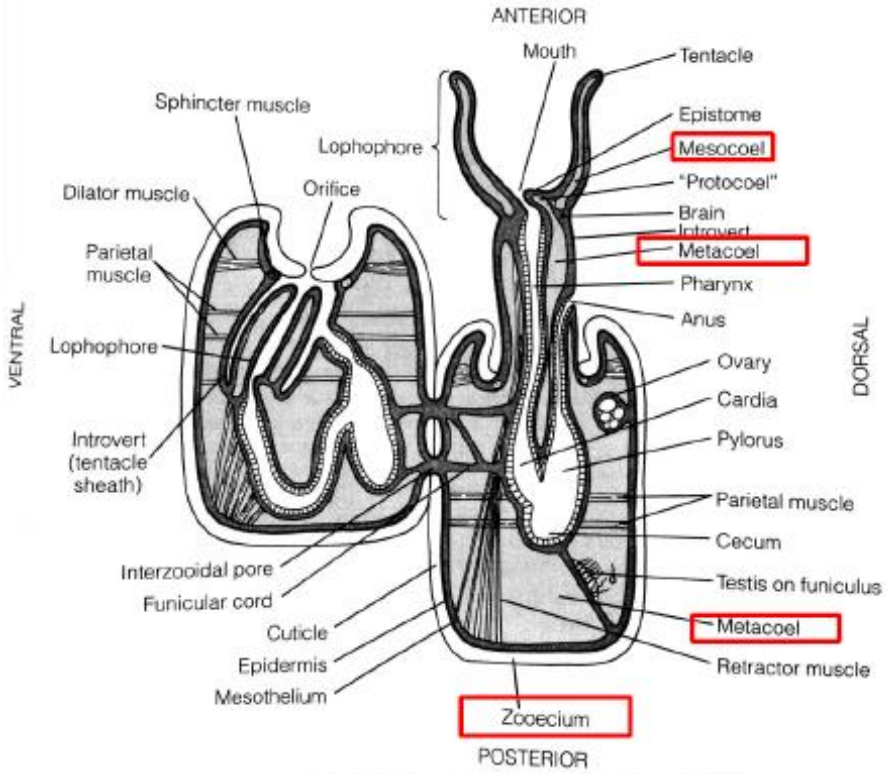
Bryozoa

(=moss animals), freshwater and marine

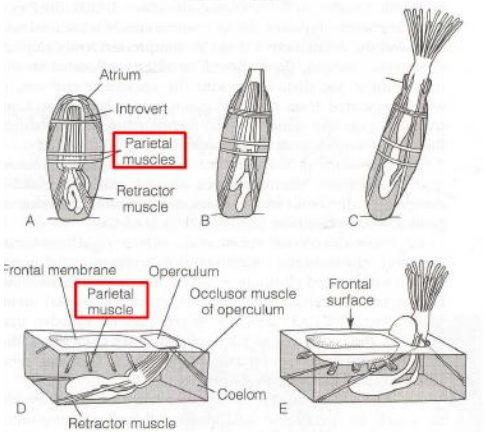
Apomorphies: Introvert (anterior part of the body forms an introvert, within which the lophophore and tentacles can be withdrawn), funicular system, colonial, multiciliated cells, coelomopores (a ciliated groove in the mesothelium along which eggs move to be released to the environment

Musculature: funiculus is a 'ligament'/a tendon that connects the stomach to the bottom of the body wall

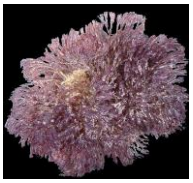
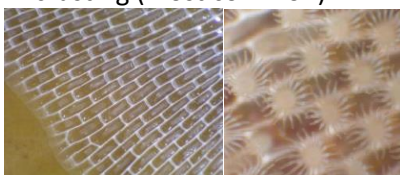
Lophophorate body: mesosome (coelom containing lophophore), metasome (most of the body), zooecium (='animal house', exoskeleton secreted by the metastome), coelomopores, lophophore (crown of ciliated tentacles around the mouth, funiculus (nutrient transportation and sexual – intra-zooid), colonial interzooidal pores, multiciliated cells,



Lophophore eversion
Caused by the contraction of parietal muscles – it increases coelomic pressure and everts the lophophore

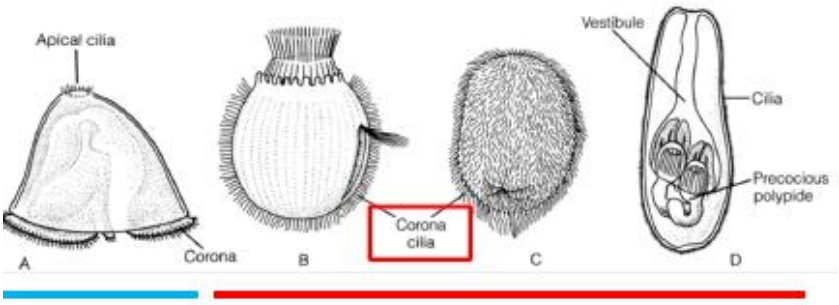


Bryozoan colonies – physiologically and physically integrated zooids (integrated coelom), form depends on pattern of asexual budding, modular

Stolonate: hydroid shaped	Foliaceous: leaf-like	Fruticose	Encrusting (most common)
			

Zooids (polymorphism) – in some groups, **eurystomes**; **autozooids** (feeding zooids); **heterozooids** (non-feeding zooids)→ **avicularia** (jaw-like mechanism used for defense), **vibracula** (large cilia-like structure used to keep colony clean/for locomotion)

Bryozoan larvae – either planktotrophic (functioning gut and actively feeding before settling) or lecithotrophic (nutrition not required before settling)

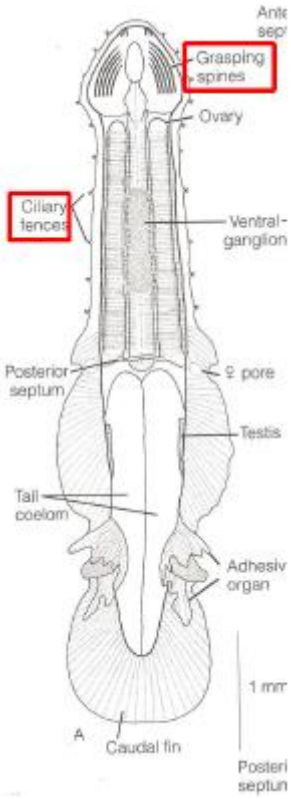


Corona: ciliary band for swimming and locomotion
Cyphonautes larvae: long-lived (A)
Brooding
Metamorphosis: larval rudiment develops into a zooid

Statoblast formation: each colony arises by asexual bussing from the first settling zooid (ancestrula), formed by the metamorphosis of a sexually produced larva or from a resting bud (statoblast – comparable to poriferan gemmules), travel long distances

Chaetognatha

Apomorphies: grasping spines (alpha-chitin, hollow, prey capture, envenomate, encapsulated in a hood), ciliary fences, double-walled lateral fins, stratified epidermis (chitinous cuticle occurs at the head; along the rest of the 'torpedo' epidermis is 3-5 layers thick), hood



Found in all marine environments, major predators, present in the fossil record since the Cambrian explosion

Feeding: sit and wait predators

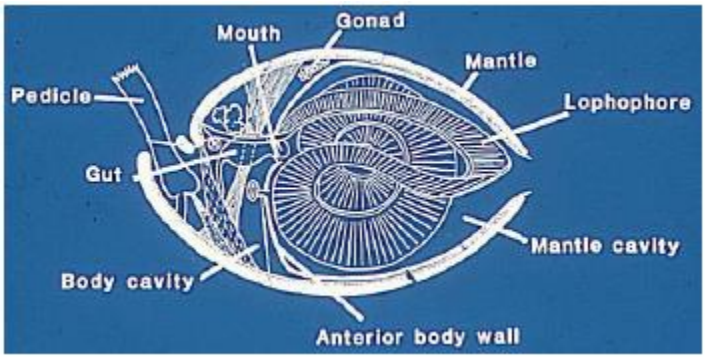
Brachiopoda

(='arm-footed'), marine benthic suspension feeders, live attached to rocks, large lophophore, superficial resemblance to bivalves. Bivalve mollusc (valves are lateral (left and right, plane of symmetry runs along hinge line), brachiopod (valves are dorsal and ventral, plane of symmetry runs perpendicular to the hinge)

Apomorphies: Bivalve shell & mantle, brachia (calcerous lophophore support), dorsal heart, digestive ceca

Adductor muscle contraction pulls valves together and closes shell, abductor (diductor) muscle contraction opens the valves, pedicle (extension of the body wall) connects to substrate

Morphology: Valves are dorsal and ventral, Inarticulata and Articulata (presence or absence of hinge teeth and sockets, most modern ones are Articulata, hinge that holds two valves together is more developed in Articulata), large lophophore, shell secreted by outer mantle edge, pedicle (attachment stalk)



Positions itself perpendicular to the water flow so currents aid ciliary current of lophophore; burrowing using pedicle with scissor-like movements to burrow into sand

Brachiopod chaetae – series of small bristles extending from grooves at the valve and mantle edges that serve as tactile sensory devices

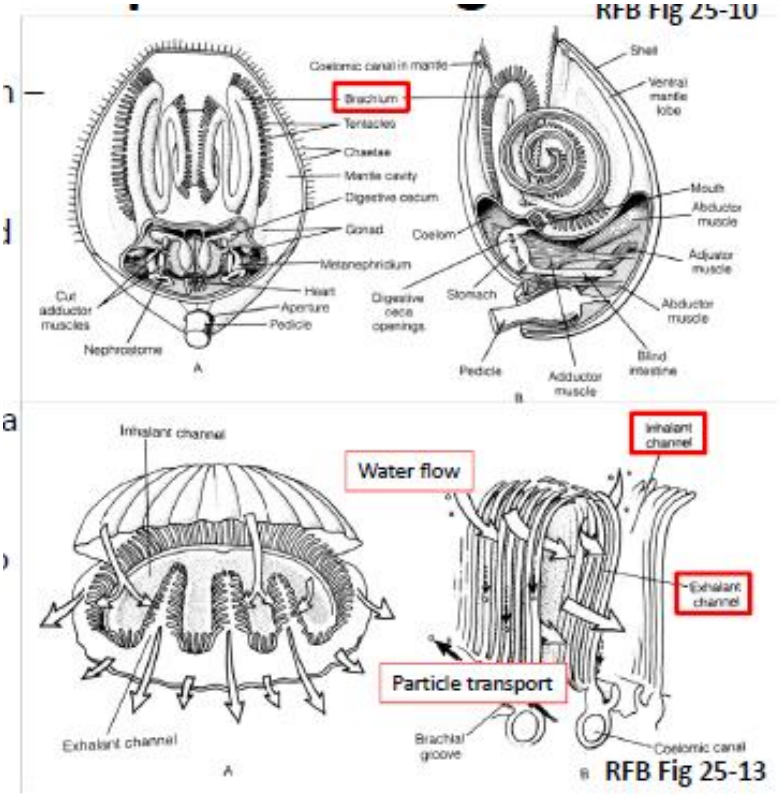
Brachiopod feeding:
Lophophore extension via brachia

Increased size offers enhanced feeding and respiration efficiency

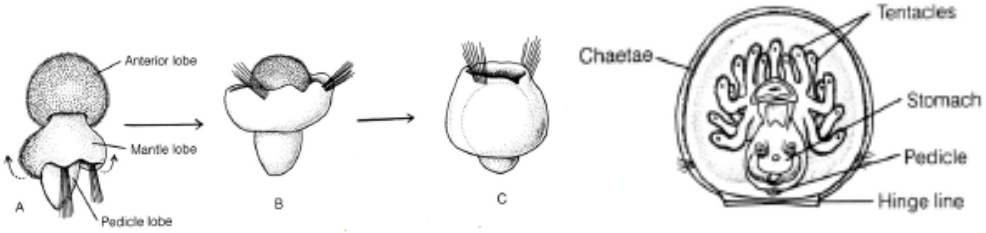
Upstream particle collection system (suspension feeding via specific channels)

Brachial groove (transports particles to mouth)

Rejected particles removed through exhalant channel



Reproduction and Development
Mostly gonochoric (separate sexes), free spawner – fertilization in water column, brooding and viviparity also occurs (within mantle cavity), larva undergo metamorphosis
**Sexual reproduction



Phoronida

Marine sessile and benthic, live in permanent chitinous tubes, lophophore is the only external feature, molecular evidence groups them closely with Brachiopoda, externally bilateral symmetry, internally asymmetrical (left side dominance)

Lophophore coiling, tentacle number, SA is correlated with body size (circular lophophore → horseshoe → simple spiral → complex spiral)

Apomorphies: corpuscular hemoglobin in hemal system (an adaptation to life in anoxic or hypoxic conditions; lophophore extends up into the oxygenated water, but this water is not circulated to the remainder of the organism in the tube), actinotroch larva (free-swimming and feeding on plankton), loss of chaetae (compared to brachiopoda)

> Hemoglobin issues: extracellular HG is large, intracellular HG is small; at equal [c]s, small molecules bind more oxygen since they have greater SA, however many small molecules can increase osmotic pressure - nucleated RBCs circulating in body fluids are encountered in only five invertebrate phyla

Morphology: secrete chitinous tubes (sediment particles are incorporated into the tube), never leave the tube (closed posterior), anterior lophophore, swollen posterior ampulla, coelom created hydrostatic skeleton, muscle fibers allow movement inside the tube, uses upstream collection feeding system, lophophore can be autotomized

Development – Actinotroch larva: upon settling, the gut rapidly changes from linear to U-shaped, settles to bottom, and secretes a tube to become a benthic adult

Annelida

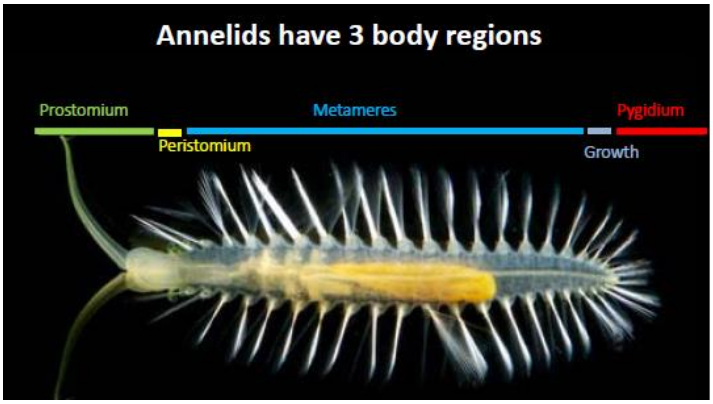
Two major clades within Annelida – Errantia (appendages, parapodia, nuchal organ) and Sedentaria (clitellum, cocoons, no appendages)

Apomorphies: metamerism (segmentation) – septa divides fluid-filled coelom, added sequentially (youngest is furthest back), Echiura's apparently unsegmented body in fact represents a series of fused segments; chaetae (cuticular structures produced by epidermal cells, four bundles of simple chaetae per segment, chaetae made of beta-chitin, used for traction and other tasks

Chaetae vs. Setae – chaetae are made of beta-chitin (adjacent parallel molecules of same polarity, tough and flexible, found in annelids), setae are made of alpha-chitin (adjacent parallel molecules with opposite polarity, hard and stiff, found in arthropods)

Metamerism: structural plan in which the body is differentiated along its longitudinal axis into a series of units or segments, each containing elements of the chief systems of organs

Growth zone contains ectoderm and mesoderm teloblast cells that form each segment



Metameres contain: a pair of mesodermal somites with coelomic spaces; a pair of nephridia (excretion); pair of coelomoducts ('nephrostome' ciliated excretory and reproductive channels); pair of ganglia on a ventral nerve cord; pair of appendages

*No perfect example of a series of metameres – some structures span segments (ie. Nervous system, musculature, digestive system

Segmentation vs. Metamerism:

Segmentation	Metamerism
Derived from the ectoderm	Derived from the mesoderm
Can be confined to only ectoderm	Confined to ectoderm and mesoderm (doesn't apply to endoderm)

Advantages of metamerism: build a large organism from a simple plan, effective servicing of major systems, enables flexible and/or complex movements, loss of parts is not fatal, opportunities for specialization

Serial homology: specialization of appendages and other structures for different functions; refers to structures which (though different) have the same segmental, embryonic, and evolutionary origin; refers to segments and appendages

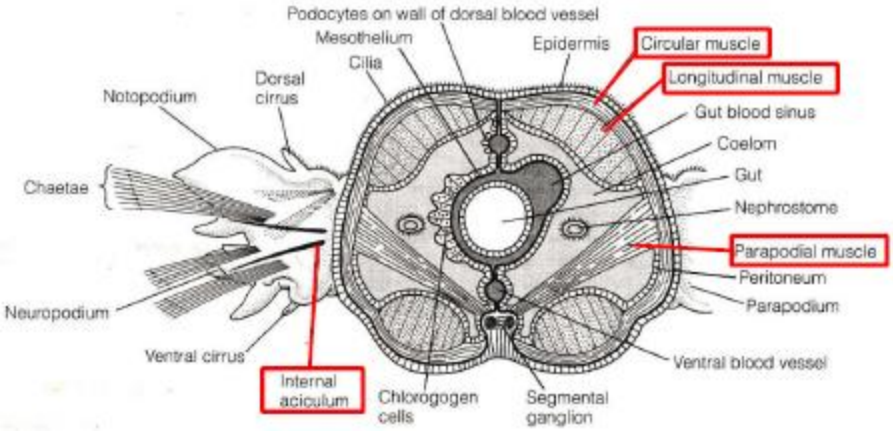
Tagmatization: metameres are sometimes grouped into tagmata – they are structurally differentiated groups of segments specialized to perform specific functions for the whole organism (some Polychaetes, but reaches greatest extent in Arthropoda – head, thorax, abdomen)

Errantia "Polychaeta"

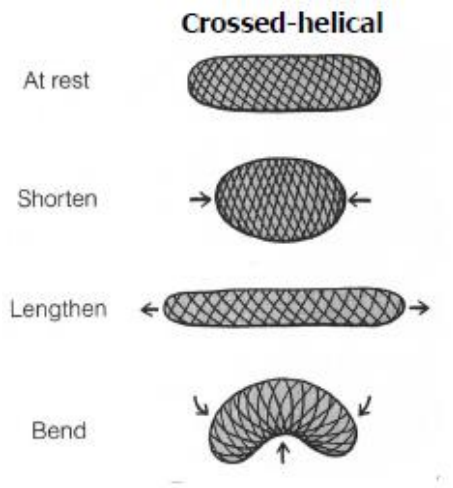
Apomorphies: parapodia (each of a number of paired muscular bristle-bearing appendages used in locomotion, sensation, or respiration), nuchal organs (chemoreception ciliated pit or grove, light detection, food detection), pedal ganglia (control parapodial movements), pair of pygidial cirri (sensory appendage)

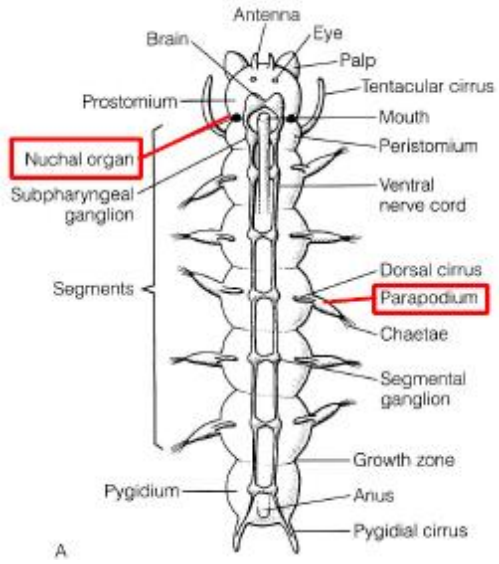
Three major lifestyles for this phylum – burrowers, crawlers, swimmers

Musculature: Circular, Longitudinal, Acicular/parapodial (chitinous skeletal rod)



Body wall: made up of fibrous cuticle (reinforces and prevents bulging when hydrostat is pressurized), and collagen fibres in cross-helical arrangement (prevents kinking)





Many sedentary polychaetes secrete tubes, built from a variety of materials such as fibrous protein, mucus, calcium carbonate, etc.

Locomotion: Swimming is the fastest mode of locomotion, followed by undulatory walking, then walking is slowest

Guest lecture

Researching the Evolution of Invertebrate Biodiversity

-Aim to understand the processes involved in the evolution and maintenance of biodiversity across spatial and temporal scales

-Tagmatization** (differentiation of structure and function of limbs along the body axis

-Since the Cambrian, there has been an increase in average complexity in Crustacea – due to a small number of clade extinctions and originations, or does this represent a pervasive evolutionary trench across multiple lineages

-Ancient Lake Titicaca is an ideal study system for mechanisms of diversification; allopatric divergence and biotic interactions may both be important in diversification

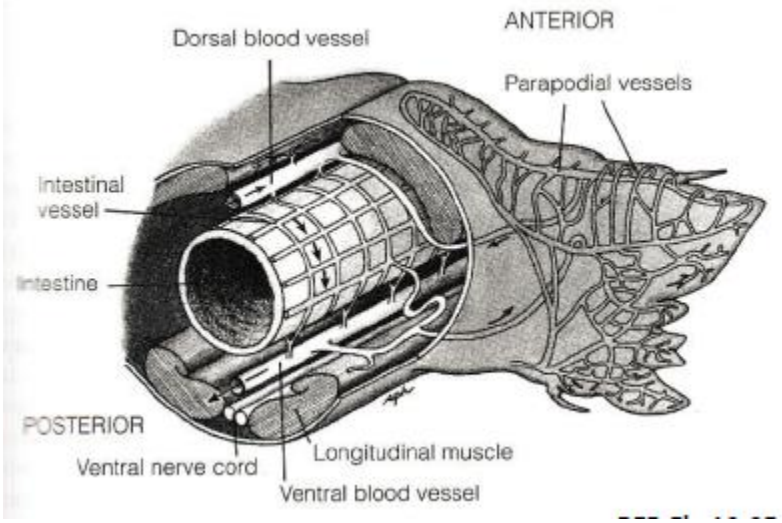
Errantia "Polychaeta" (contd.)

Nervous system: anterior dorsal 'brain', ventral pair of nerve cords, parapodial ganglia, eyes (modified protostomial occeli – image formation?), nuchal organs, **giant axons** (specialized for rapid transmission, large diameter = low resistance + rapid impulse conduction, escape response

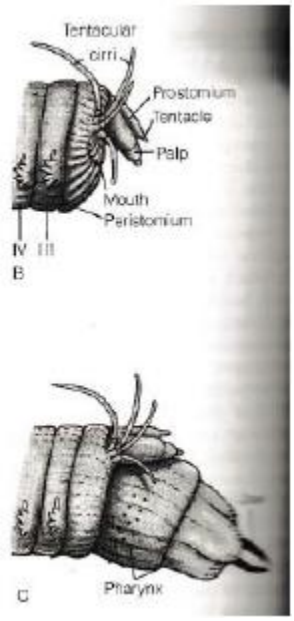
Nutrition: Deposit feeders, either direct (ingest sediment) or indirect (collect organics and transmit to mouth); suspension feeders or predators

Suspension feeding: Feather duster or sabellid worms are able to construct membranaceous tube, captures particles with mucus web

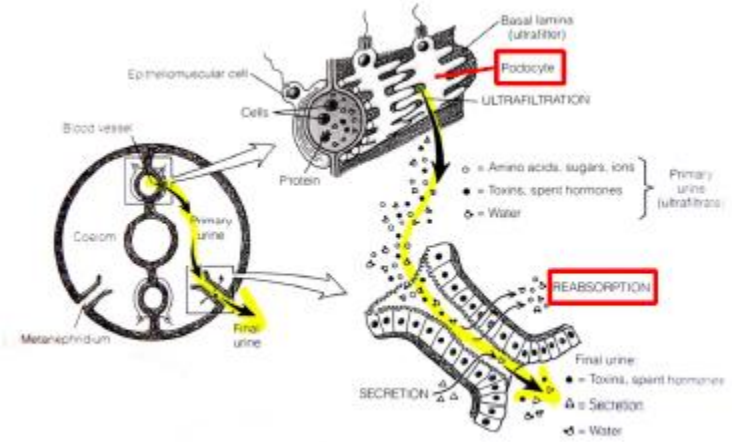
Circulation: hemal system with dorsal (moves anteriorly) and ventral (moves posteriorly) vessels, muscular pumps & peristalsis, gills associated with the parapodia, coelomic circulation as well (in particular for very small species); They have ¾ animal respiratory pigments (Hemoglobin, Chlorocruorin, Hemerythrin)



Predators: everted pharynx can be used as a grasping tube, pharynx everted through contraction of body-wall muscles and subsequent increase in coelomic pressure



Excretion: proto- and meta- nephridial system. The protonephridial system acts as the coelomic system, metanephridial system acts as the hemal system. The circulatory system provides the driving pressure for filtration, blood gets filtered across podocytes into the coelomic cavity (ultrafiltration), then through a metanephridium into the exterior (protonephridia is driven by the beating of a flagellum.



Reproduction: gonochoric, sexual reproduction, gametes are stored in the coelom, external fertilization, trochophore larva (planktonic with several bands of cilia), **epitoky** (pelagic form of sexual reproduction) sexual maturity from an atoke – gametes inside epitoke, synchronised release, morphological adaptations for pelagic

Errantia: Pogonophorans – tube worms within chitin-protein tubes, up to 3m in length, no mouth or anus, chemosynthetic bacteria ensure their survival

Sedentaria

Clitellata

Apomorphies: lack parapodia, clitellum (series of anterior segments enclosed in thick, glandular epidermis – girdle – reproductive structure)

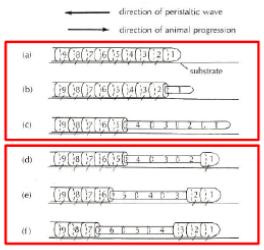
Oligochaeta

=earthworms

Musculature: similar to polychaetes, circular and longitudinal muscle, chaetal pro- and retractors.

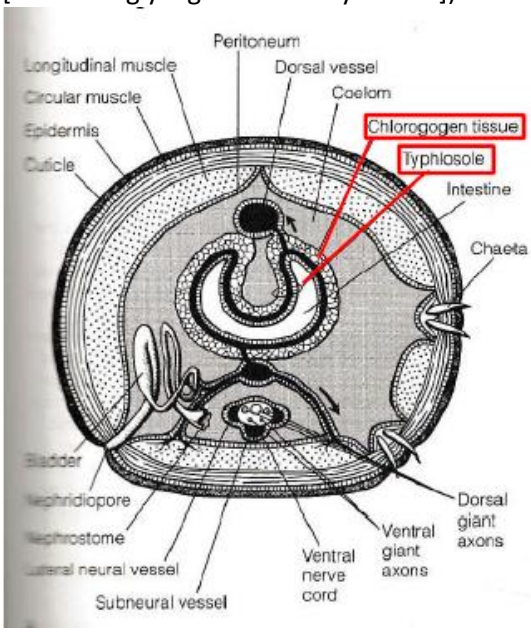
Nervous system: brain more posterior (seen in all oligochaetes), single ventral nerve cord (giant axons), photoreceptors (no eyes; unicellular and distributed around the body), chemoreceptors (tubercles)

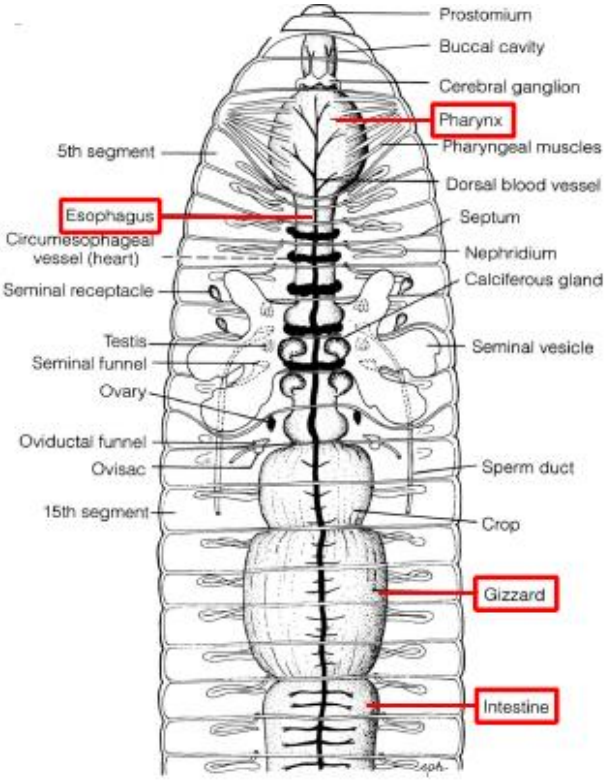
Peristaltic:



- Alternating action of circular muscles and then longitudinal
- a-c : contraction of circular muscles from anterior to posterior
- d-f: contraction of longitudinal muscles from anterior to posterior
- Chetae anchor

Digestive system: muscular pharynx, esophagus (gizzard [chitinous projections for grinding] and crop [storage]), intestine (typhlosole [U-shaped folding for increased SA], chlorogogen tissue [center of glycogen and fat synthesis])

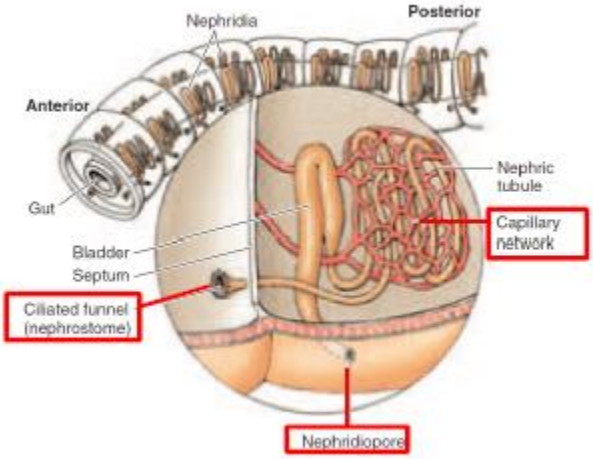




Circulation/gas: similar vasculature to polychaetes, hemoglobin in blood, hypoxia tolerant

Sewer worms (*Tubifex*) have hemoglobin-rich tips, can tolerate very low oxygen, live in lake bottoms and stagnant mud

Excretion: metanephridia in each segment, wastes drawn into ciliated nephrostom, passed through loops of nephridium, expelled through the nephridiopore of next segment [don't deal well with dehydration]



Reproduction: simultaneous hermaphrodites, copulation (exchange of sperm), egg case secreted by clitellum, egg/sperm injected into egg case

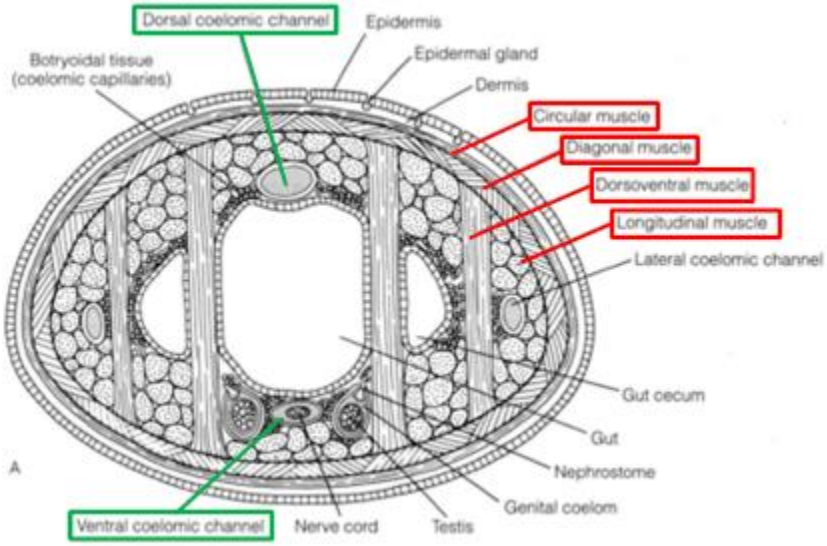
Clitellum: a series of anterior segments enclosed in thick, glandular epidermis – girdle – reproductive structure; secretes mucus for copulation, nutrients for eggs and cocoon.

Hirudinidae

Includes leeches

Apomorphies: posterior sucker (dorsal anus to sucker), superficial annulations (un-segmented body with superficial marks), no chetae, unpaired midventral gonopore, ectoparasitic (lives on surface of host), sensory papillae (specialised sense organs – small projecting disks in a ring around one annulation)

Body walls & muscles: 4 major muscle groups (reduction in coelom and septa), coelom is continuour and has become the hemal system (powered by muscular contractions)



Locomotion: crawling, swimming

Nerves and segments: brain in segment 5 (subpharyngeal ganglion – joining of prostomial & peristomial ganglia), ventral nerve cord, segmental ganglia, chromatophores (unknown reason), pigment cup ocelli, small number and large size of neurons

Excretion: coelomic cavity (acts as the circulatory system), 10-17 pairs of metanephridia (1 pair per segment – embedded in connective tissue, not septa), nephrostome (not excretion, but contains phagocytes = immune function)

Reproduction: simultaneous hermaphrodites, no asexual reproduction or regeneration, internal fertilization, ventral surface of clitellar surface come together, some leeches brood their young (until they can feed on a specific species of prey)

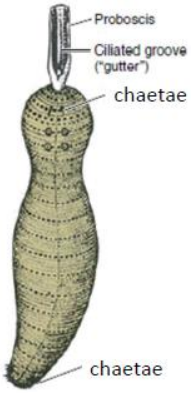
Digestion: anterior sucker/jaws (protrusible or non-protrusible pharynx), lateral ceca (up to 11), lack most digestive enzymes (rely on symbiotic bacteria)

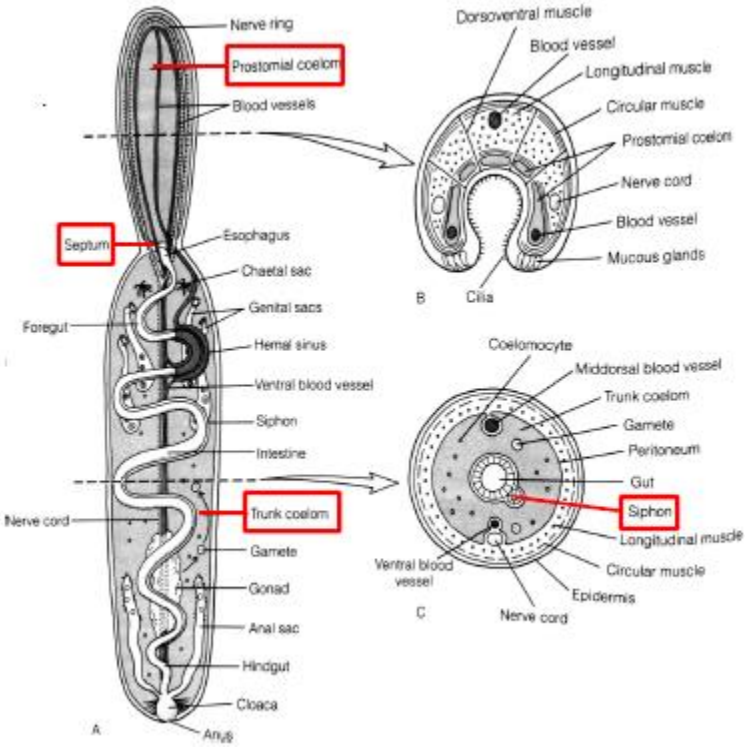
Medicinal use: post surgety, hirudin (anti-coagulant) – leech secretions provide anaesthesia, antibacterial action, increased blood flow

Eichura

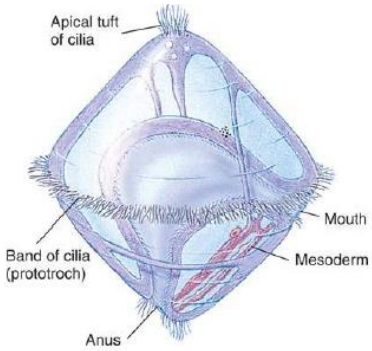
=spoonworms ('serpent-like')

Apomorphies: pair of anterior ventral chaetae, 2 posterior rings of chaetae (beta-chitin, used for digging), apparent unsegmented body is actually a series of fused segments, prostomium, prostomial and trunk coeloms (like sipunculans), intestinal siphon (accessory gut – water bypasses the main gut)





Reproduction: external fertilization, trochophore larva (any that land on another female becomes a male)



Lifestyle: marine, U-shaped burrows/crevices, deposit or filter feeders

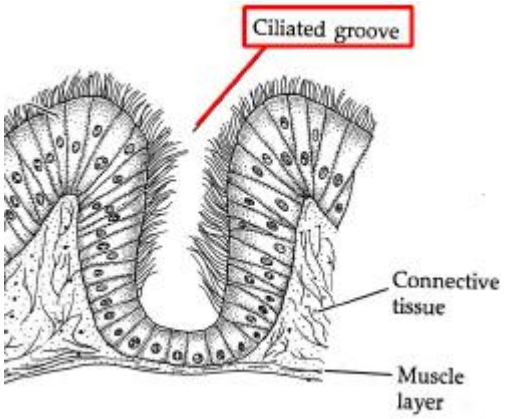
Internal systems: prostomial ring, ventral nerve cord, long coiled gut & siphon, simple hemal system

Morphology: prostomium and trunk, hooked chaetae (beta-chitin), 3 muscular layers (outer to inner: circular, longitudinal, cross-helical);;; male is a miniature ciliated individual that lives in the genital sac of the female

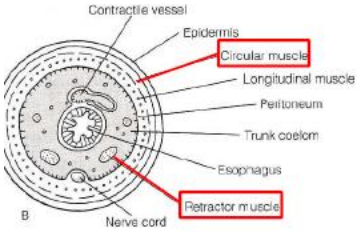
Sipuncula

=peanut worms ('little tube')

Apomorphies: introvert (eversible through circular muscles, introvert retractor muscles), tentacles (with tentacular coelom), J-shaped intestinal tract, intestinal ciliary groove (water shunt), cuticle with scattered hooks, hemerythrin in cells

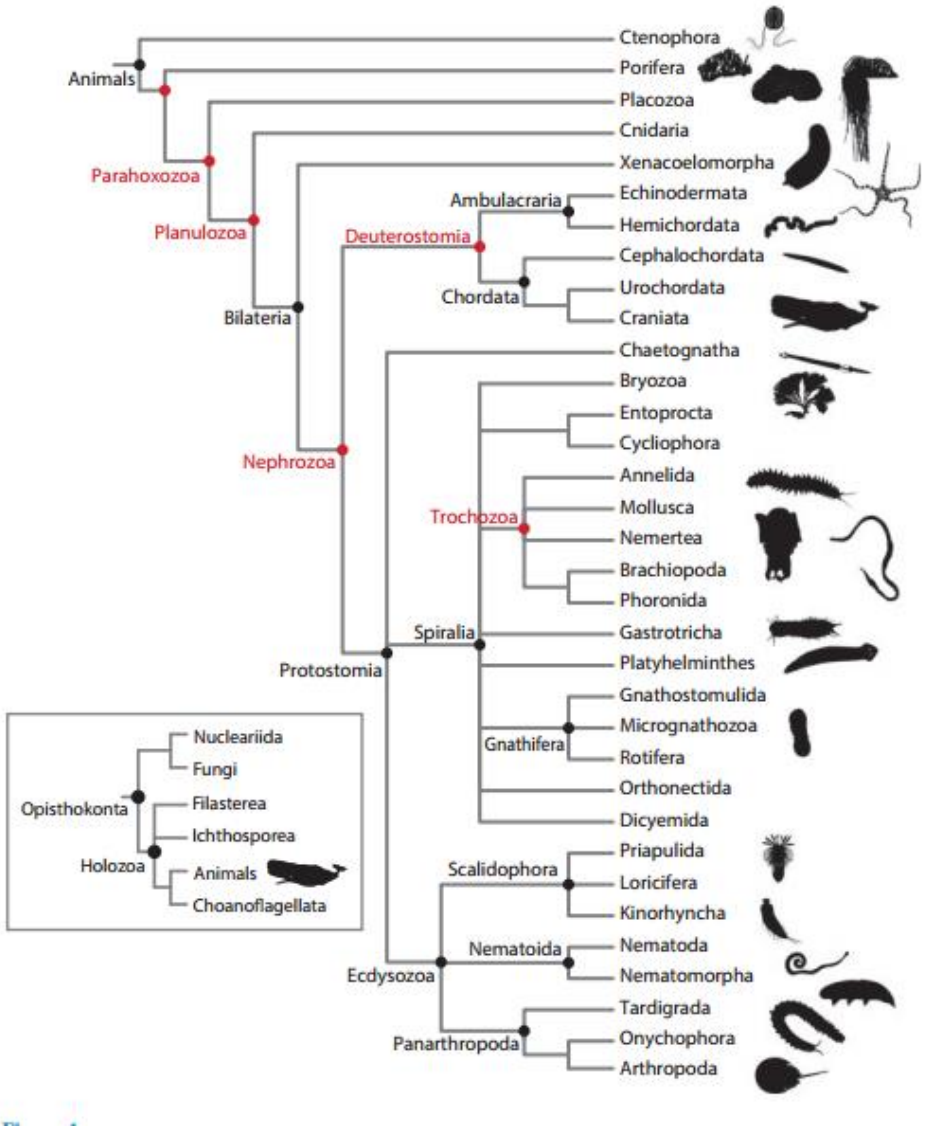


Lifestyle: marine, blind burrows/crevices, suspension or deposit feeders, tentacles, some are boring



/end midterm material

Symmetry Q: Different forms of symmetry are seen amongst invertebrates, often in closely related taxa. These different symmetries each have their advantages and disadvantages. Name the different types of symmetry and list advantages and disadvantages of each. What is the evolutionary significance of polarization? Give possible explanations for the occurrence of a reversion to a more basal symmetry within a phylogenetic lineage.


Ctenophora
Porifera
Placozoa
Cnidaria
Xenacoelomorpha
Echinodermata
Hemichordata
Cephalochordata
Urochordata
Craniata
Chaetognatha
Bryozoa
Entoprocta
Cycliophora
Annelida
Mollusca
Nemertea
Brachiopoda
Phoronida
Gastrotricha
Platyhelminthes
Gnathostomulida
Micrognathozoa
Rotifera
Orthonectida
Dicyemida
Priapulida
Loricifera
Kinorhyncha
Nematoda
Nematomorpha
Tardigrada
Onychophora
Arthropoda
Animals
Parahoxozoa
Planulozoa
Bilateria
Nephrozoa
Deuterostomia
Ambulacraria
Chordata
Trochozoa
Spiralia
Gnathifera
Protostomia
Scalidophora
Nematoida
Ecdysozoa
Panarthropoda
Nucleariida
Fungi
Opisthokonta
Filasterea
Ichthosporea
Holozoa
Animals
Choanoflagellata