Tree of Life III: Eukaryotes (Fungi and Animals)

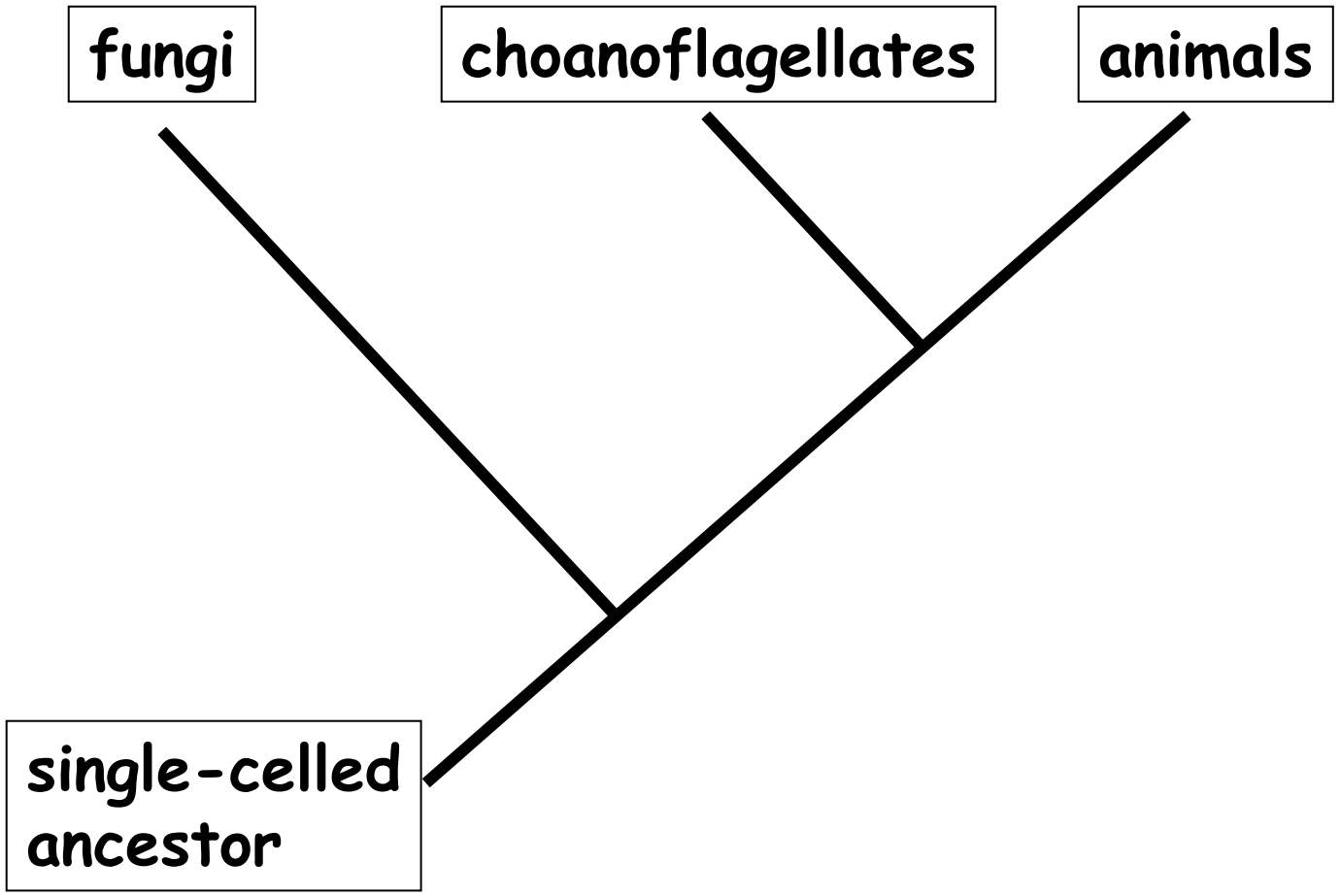
Biology/Env S 304

Spring 2007

TOL III: Fungi and Animals

- Fungi and animals probably share a common ancestor with choanoflagellates (collar-flagellates) based on genetic data
- Cell wall components and other complex biosynthetic pathways are similar between fungi and animals

TOL III: Fungi and Animals



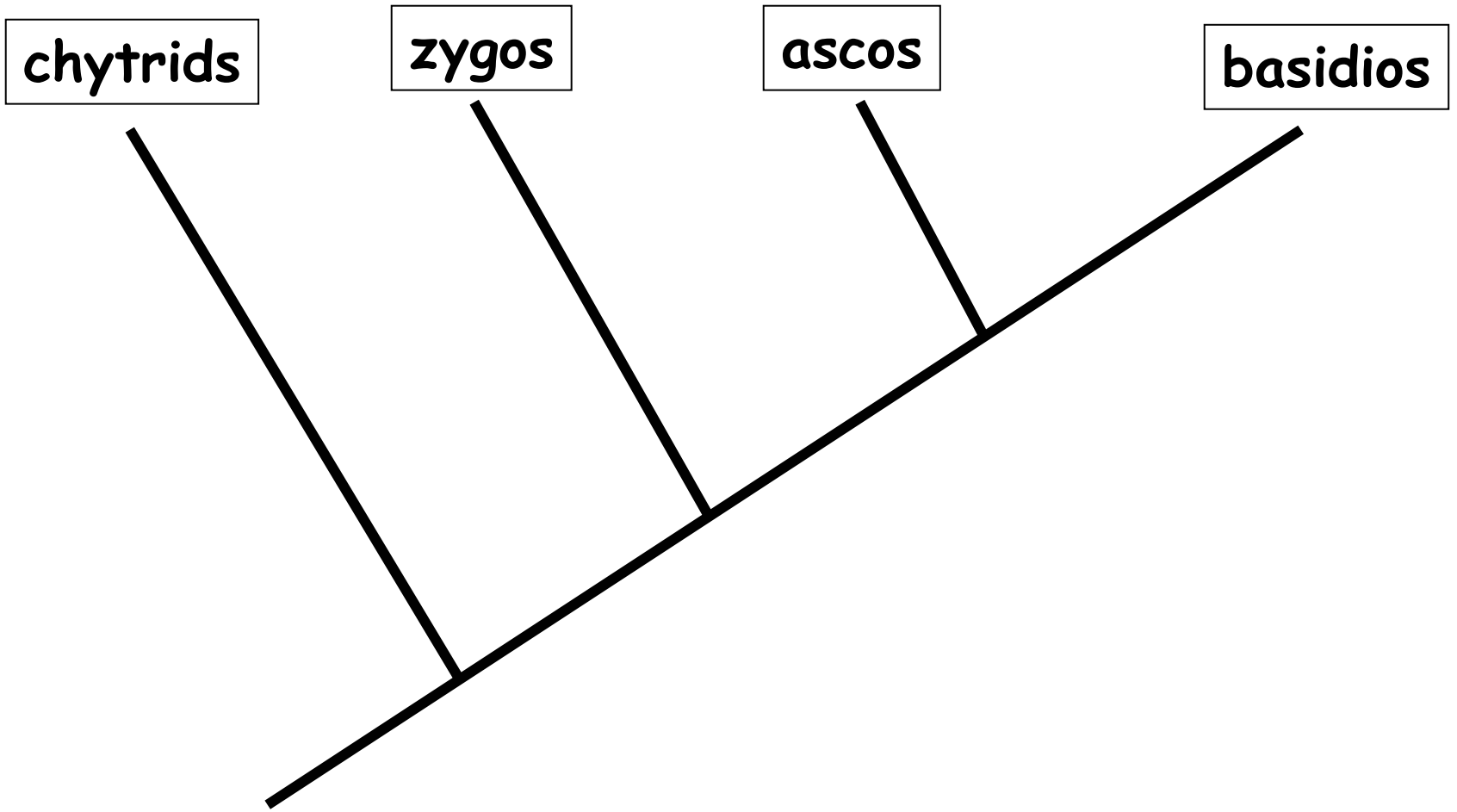
TOL III: Fungi

- Primarily terrestrial
- No motile cells except in reproductive cells of chytrids
- Chitin in cell walls
- Unique features of chromosomes and nuclear division
- Dominant part of life cycle has only one set of chromosomes per nucleus

TOL III: Fungi

- Most are filamentous, multicellular; a few are unicellular (chytrids, yeasts)
- Oldest fossils 450-500 million years ago
- About 70,000 species described; estimated to be up to 1.5 million
- 4 lineages: chytrids, zygomycetes, ascomycetes, basidiomycetes

TOL III: Fungi



TOL III: Fungi

- Consumers by absorption
- In addition to natural sources of organic matter, can obtain nutrition from a wide variety of man-made substrates (cloth, paint, leather, waxes, jet fuel, photographic film, etc.)
- Food-obtaining strategies: decomposers, parasitic, predaceous, symbiotic

TOL III: Fungi

1) Decomposers: use dead organic matter through excretion of digestive enzymes
2) Parasitic: obtain organic matter from living cells; many cause disease this way (pathogens)
3) Predaceous: trap and kill small organisms (nematodes, protozoans)
4) Symbiotic: form mutualistic relationships with other organisms (lichens, mycorrhizae)

TOL III: Fungi

Structure, Growth and Reproduction

-usually consist of hyphae (thread-like filaments)

-mass of hyphae = mycelium

-grow under a wide range of conditions

-reproduction mostly sexual by spores; but asexual reproduction is common

TOL III: Fungi

fungal mycelium on wood

TOL III: Fungi

fungal fruiting bodies (composed of organized hyphae)

TOL III: Fungal Diversity (chytrids)

- Mostly aquatic
- Reproductive cells with a characteristic flagellum
- Unicellular or multicellular with a mycelium
- About 750 species
- One cause of frog die-offs

TOL III: Fungal Diversity (zygomycetes)

- Mostly decomposers, a few parasitic
- Multicellular, filamentous
- About 600 species known
- Best known as the bread molds
- About 100 species form mycorrhizae with plant roots

TOL III: Fungal Diversity (ascomycetes)

- Filamentous except for yeasts (unicellular)
- Mostly decomposers or parasitic, some predaceous or symbiotic
- Over 30,000 described
- Includes most Fungi Imperfecti (e.g., penicillium)
- Economic importance: yeasts (bread, beer, wine); Dutch elm disease, chestnut blight, ergots; edible fungi (truffles, morels); antibiotics

TOL III: Fungal Diversity

ascomycetes

Cordyceps

scarlet cups

ergot on rye

yeast

truffles

morels

TOL III: Fungal Diversity (basidiomycetes)

- Mainly decomposers and pathogens
- About 25,000 species described
- Ca. 5,000 species involved in mycorrhizal associations
- Economic importance: edible (mushrooms, corn smut); poisonous; pathogens (rusts, smuts); decomposers (woodrotters)

TOL III: Fungal Diversity

pathogenic basidiomycetes

blackberry rust

cedar apple rust

corn smut (also edible)

TOL III: Fungal Symbionts

- Lichen = symbiosis with a green alga or cyanobacteria
- Fungal partner usually an ascomycete, usually about 90% of the lichen biomass
- Have a unique biology
- Close to 17,000 species

TOL III: Fungal Symbionts

- Mycorrhiza = symbiosis between a fungus and a plant root
- Important in evolution of plants and fungi; allowed exploitation of many more habitats for both partners
- At least 85% of plants form mycorrhizae
- Involves zygomycetes (endomycorrhizae) and basidiomycetes (ectomycorrhizae)

TOL III: Mycorrhizal diversity

endomycorrhizae
(zygomycetes)

ectomycorrhizae
(basidiomycetes)

TOL III: Animals (Metazoa)

- Multicellular consumers by ingestion
- Storage product is animal starch (glycogen)
- Most have nervous tissue and muscle tissue (which are unique to animals)
- Most are mobile

TOL III: Animals

- Gas exchange through aqueous medium surrounding the organism or through specialized gas exchange structures (e.g., gills or lungs)
- Some kind of internal circulation system present (food, gases, maintenance of proper water and mineral concentrations, waste elimination)

TOL III: Animals

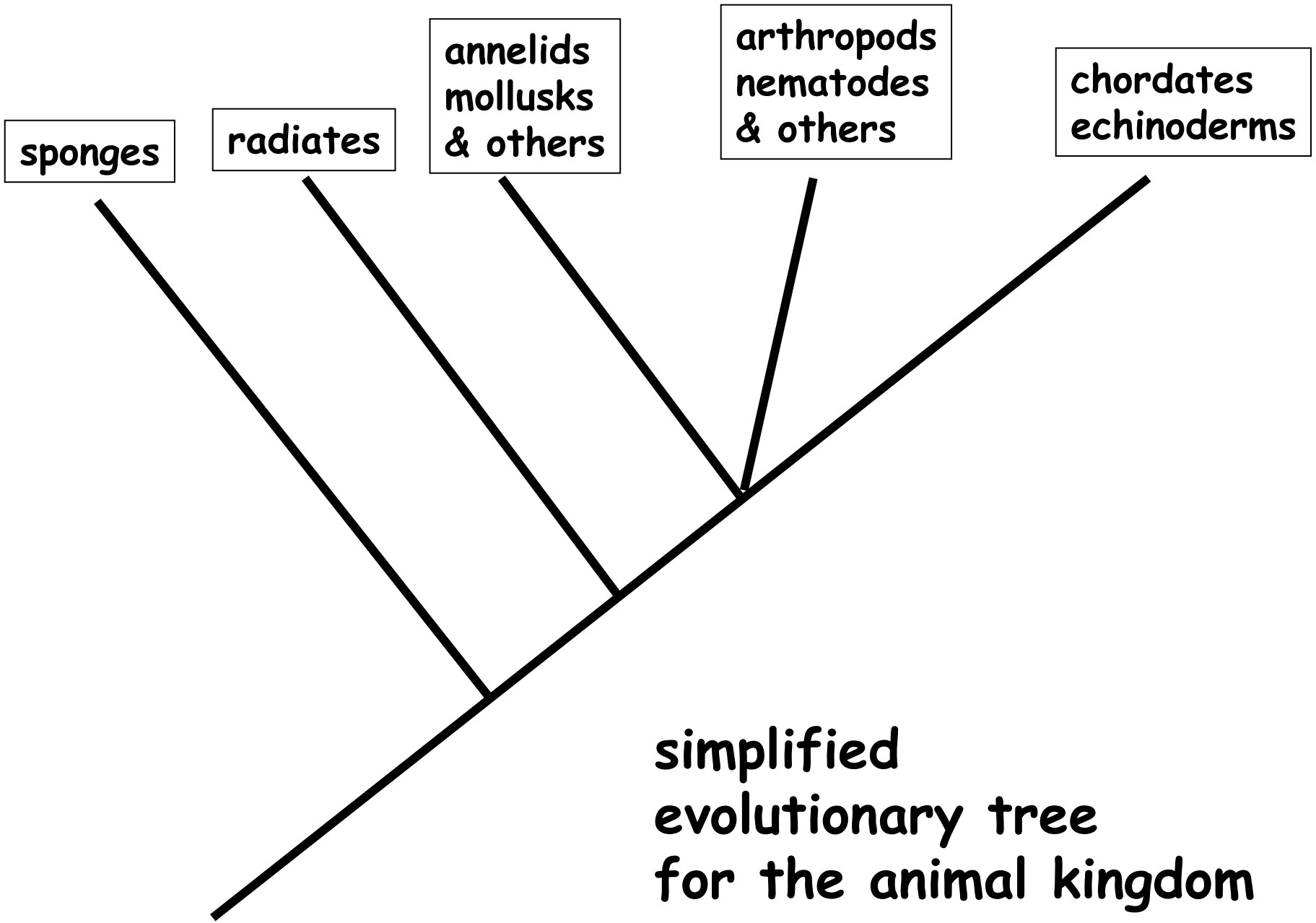
- Animals arose in the oceans from single-celled protistan ancestors
- The earliest animals appeared at least 1 billion years ago
- Most modern groups of animals appeared around 600 million years ago (the Cambrian explosion) in the oceans

TOL III: Animals

- About 35 major modern lineages (phyla) and several fossil lineages of animals are known
- In contrast, protists have at least 16 major lineages, plants have 12 modern and 5 fossil lineages, and fungi have 4 modern lineages
- Over 1 million species of animals are known; >75% of these are insects

TOL III: Animals

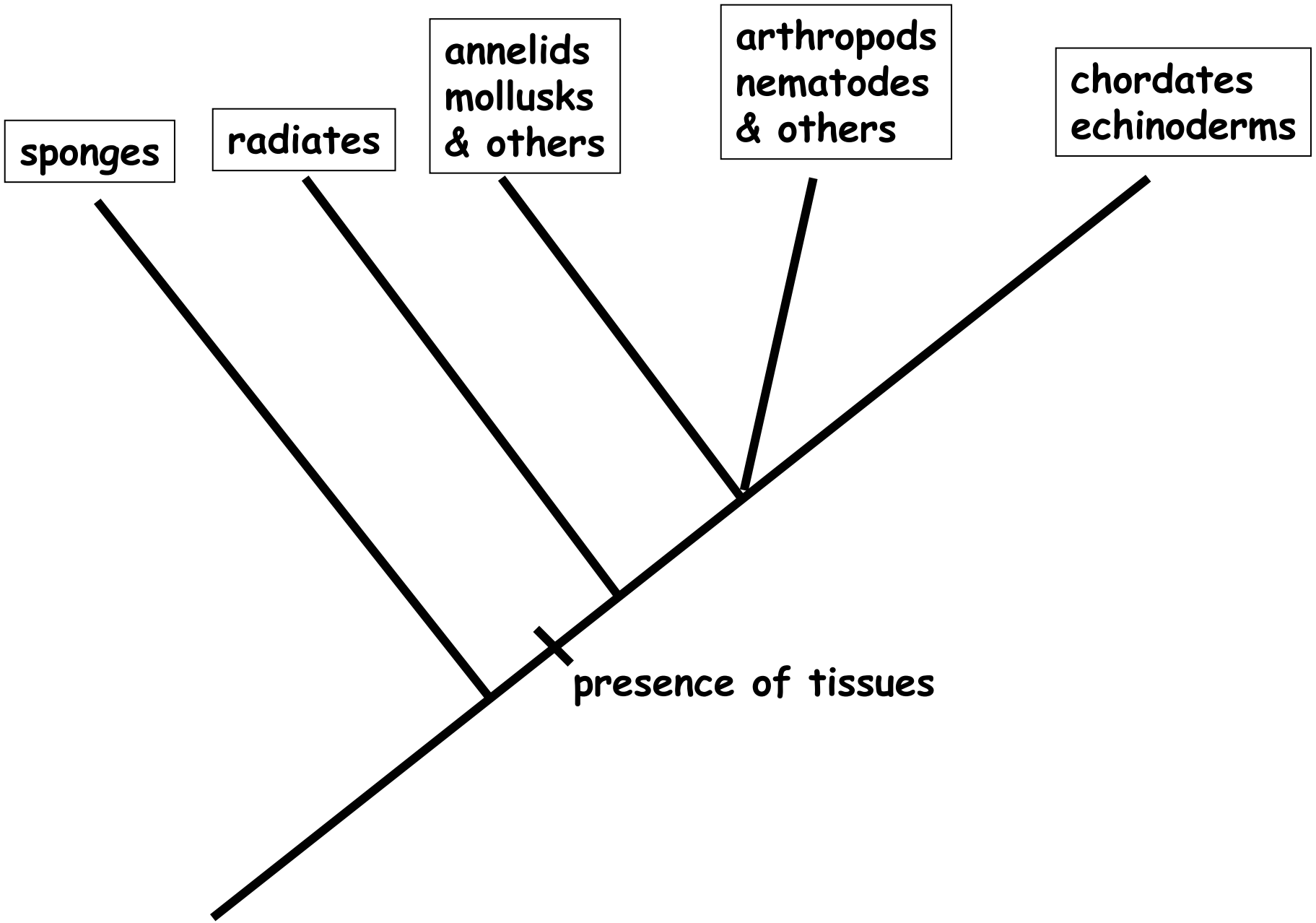
- Of the 35 modern lineages of animals, most remain aquatic (marine)
- About half of the lineages are exclusively marine
- Only 5 lineages have adapted to land (nematodes, annelids, mollusks, arthropods and chordates represented by vertebrates)
- Only the nematodes, arthropods and vertebrates have diversified extensively on land



simplified
evolutionary tree
for the animal kingdom

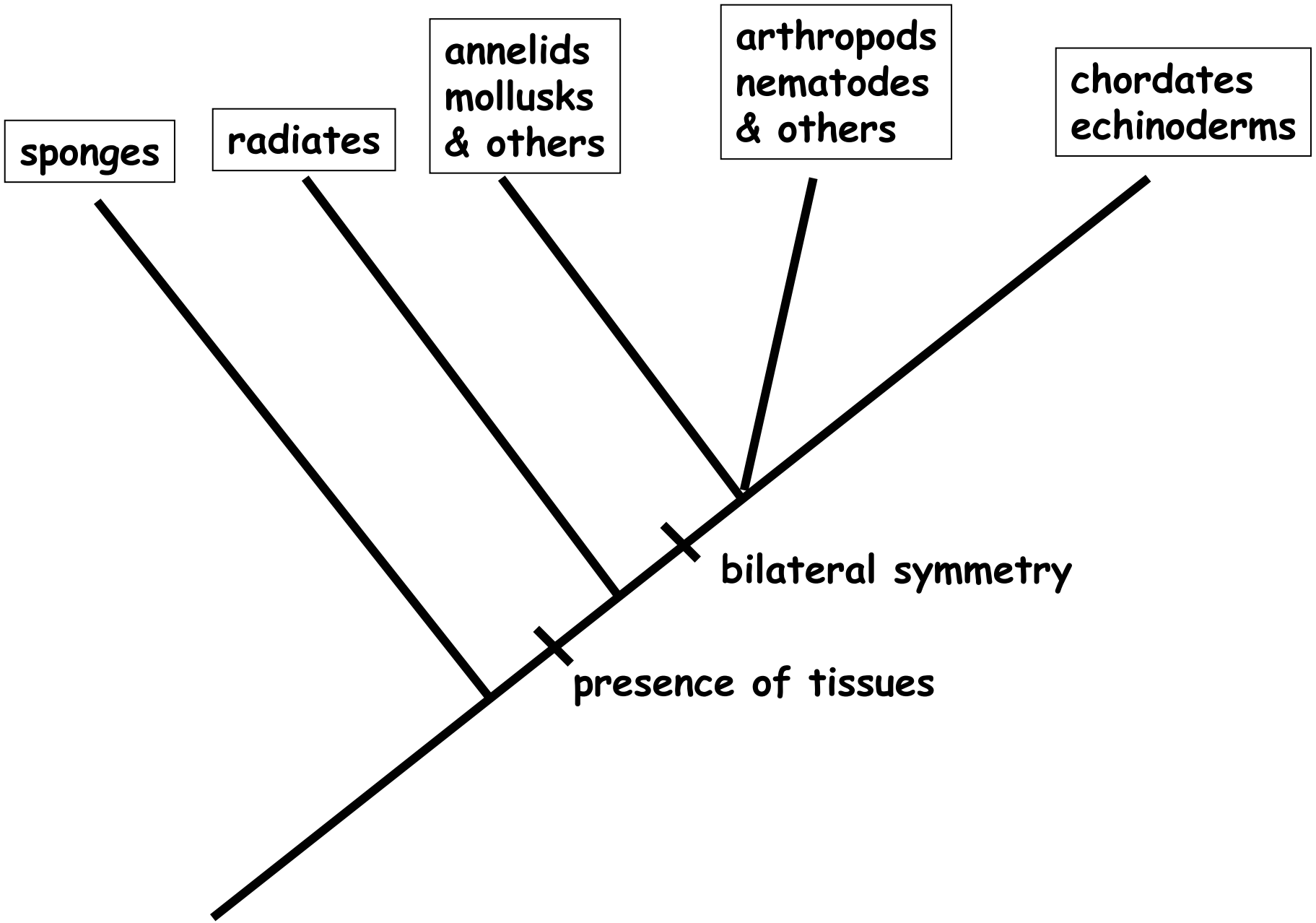
TOL III: Animals (major lineages)

- Earliest lineage of animals is the sponges
- Least specialized of all animals
- Lack any kind of tissues
- Tissue = an integrated group of cells with a common structure and function (e.g., muscles, nerves)


sponges
radiates
annelids
mollusks
& others
arthropods
nematodes
& others
chordates
echinoderms
presence of tissues

TOL III: Animals (major lineages)

- The next major adaptation, after the evolution of tissues, was the split between radial vs. bilateral body symmetry
- Radial = parts radiate from the center, any plane through the animal creates two equal halves
- Bilateral = has two sides, left and right, such that a plane through the animal can be placed only one way to get two equal halves

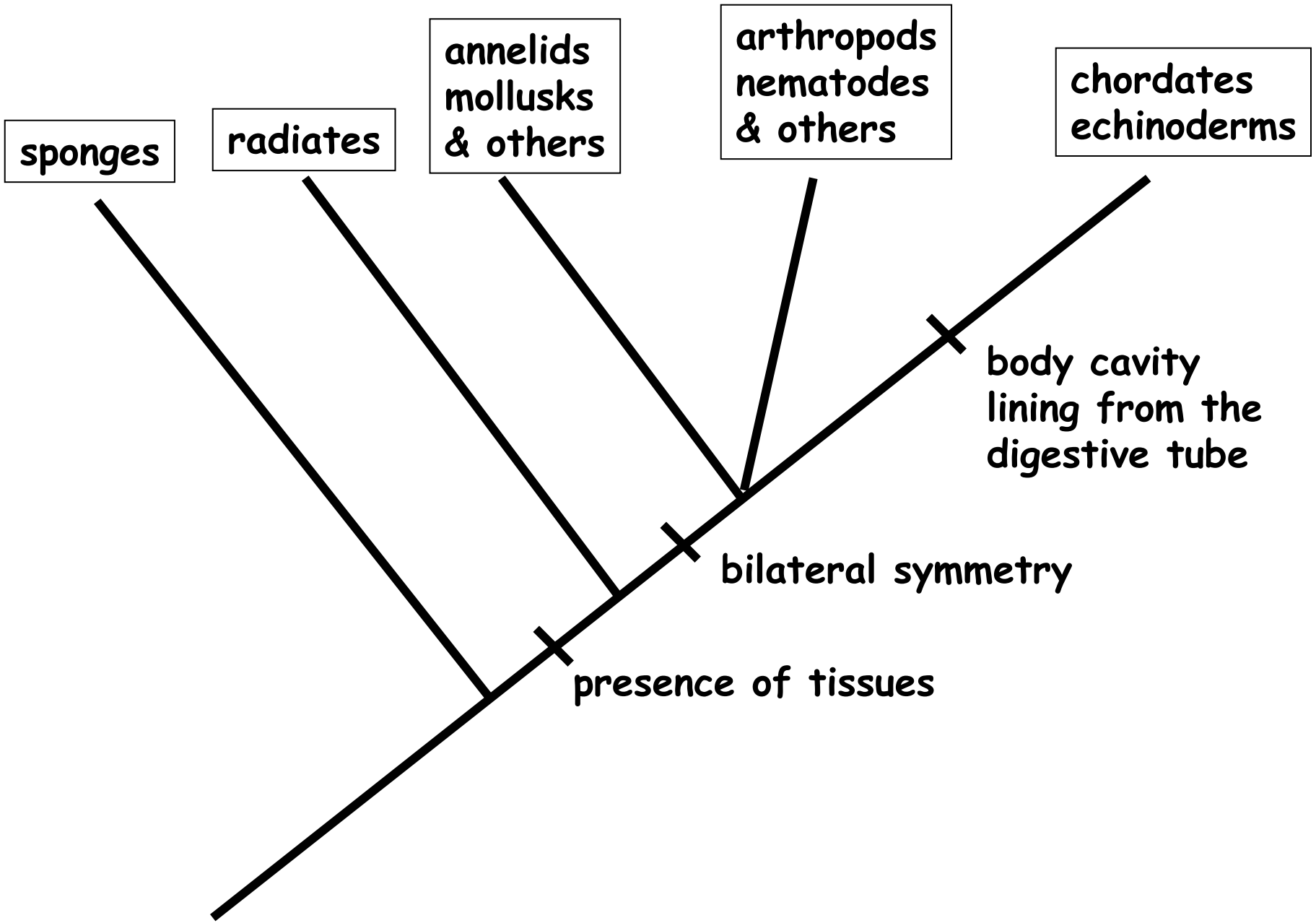

sponges
radiates
annelids
mollusks
& others
arthropods
nematodes
& others
chordates
echinoderms
bilateral symmetry
presence of tissues

TOL III: Animals (radiates)

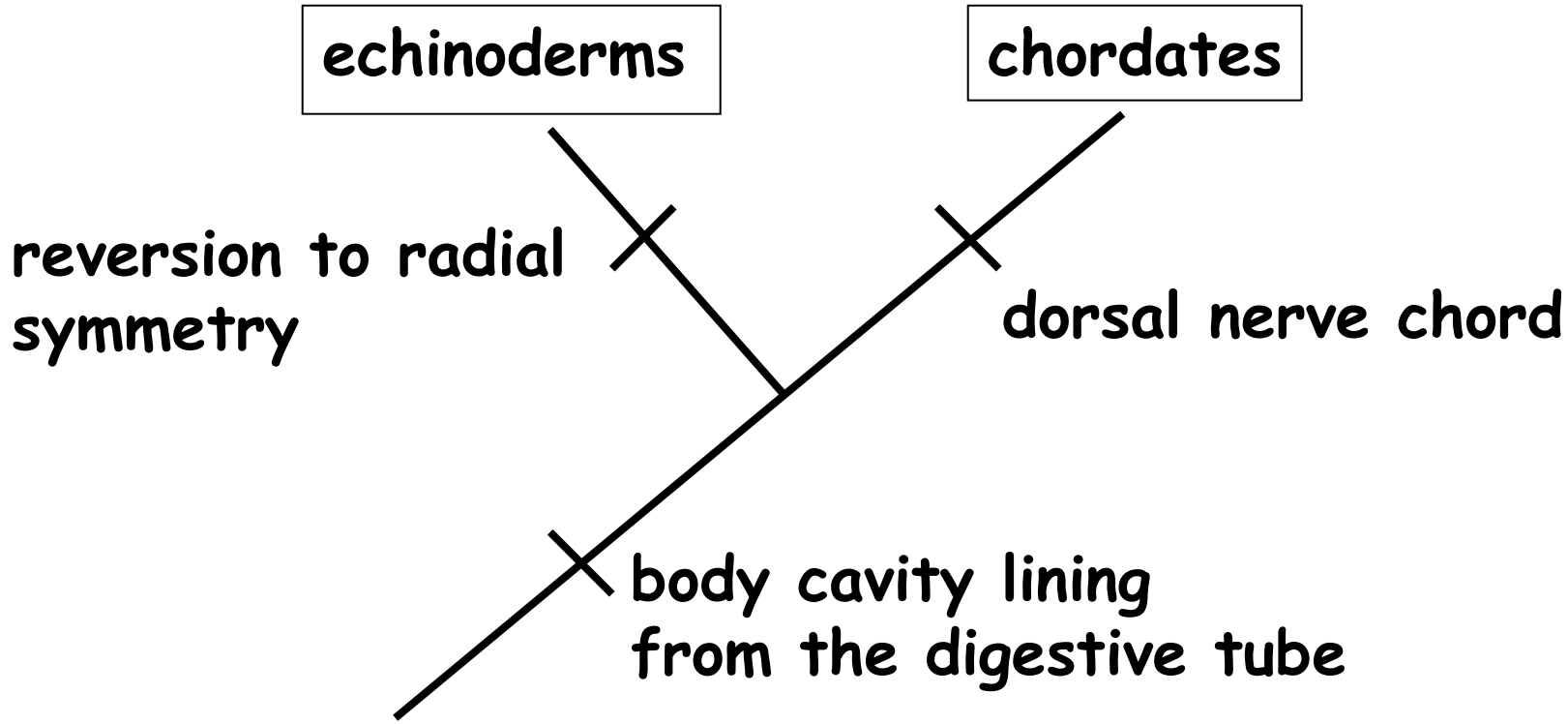
- Radial symmetry an adaptation to a more sedentary lifestyle in which the organism stays in one place and meets the environment equally from all sides
- Radiates (or cnidarians) have stinging tentacles
- Include the jellyfish, sea anemones, and corals

TOL III: Animals (major lineages)

- Bilateral symmetry is an adaptation to a more active lifestyle in which the organism moves around to obtain food and must detect and respond to stimuli
- Associated with the concentration of sensory function into the head
- The three major groups of bilateral animals exhibit various specializations in the formation of the body cavity


sponges
radiates
annelids
mollusks
& others
arthropods
nematodes
& others
chordates
echinoderms
body cavity
lining from the
digestive tube
bilateral symmetry
presence of tissues

TOL III: Animals (chordates and echinoderms)



TOL III: Animals (chordates)

- Chordates include all animals with a dorsal nerve cord
- About 50,000 species total
  - Tunicates
  - Hagfishes
  - Amphioxus
  - Vertebrates:

    fishes, amphibians, reptiles, birds and dinosaurs, mammals

TOL: Summary

1) Close to 2 million species of organisms have been described.
2) Estimates of total diversity range from 5 to 50 (in one case, up to 100) million species
3) Species diversity in several groups, primarily micoorganisms, is grossly understudied and underestimated; among multicellular eukaryotes, fungi and nematodes are also relatively unknown

TOL: Summary

4) Prokaryotes ruled the world long before eukaryotes evolved; prokaryotes exhibit a wide array of metabolic diversity and so control key steps in many nutrient cycles.

5) Evolutionary trees of major groups provide frameworks for understanding the evolutionary history and major adaptive changes in those groups.

TOL: Summary

6) The ecological function of diversity can be subdivided by roles:

   a) primary producers: some bacteria (e.g., cyanobacteria; aquatic), some archaens (aquatic), algae (aquatic), plants (aquatic and terrestrial)

   b) consumers: some bacteria and archeans, protozoans, fungi, animals; includes pathogens and predators

TOL: Summary

6) cont'd.

c) decomposers: primarily bacteria and fungi, also some fungus-like protists, as well as some animals such as nematodes; a few vertebrate carrion-eaters could also be considered as decomposers

d) nutrient cyclers: many bacteria

TOL: Summary

6) cont'd.

e) symbionts: diverse, many kinds of organisms are involved; includes mycorrhizae (plant root + fungus), endosymbionts (e.g., corals, dinoflagellates), lichens (cyanobacteria or green alga + fungus)

TOL: Arthropods (current diversity)

- regardless of how one measures diversity, the arthropods are among the most successful taxa
- nearly a million described, w/ estimates of undescribed species reaching 40 million
- have colonized all major habitats on earth: nearly all marine, freshwater, and terrestrial habitats

TOL: Arthropods

Platnick (1992): "Speaking of biodiversity is essentially equivalent to speaking about arthropods. In terms of numbers of species, other animal and plant groups are just a gloss on the arthropod scheme."

Wilson (1999): "Entomologists often are asked whether insects will take over if the human race extinguishes itself. This is an example of a wrong question inviting and irrelevant answer: insects have already taken over… Today about a billion billion insects are alive at any given time… Their species, most of which lack a scientific name, number in to the millions… The human race is a newcomer dwelling among the masses… with a tenuous grip on the planet. Insects can thrive without us, but we and most other land organisms would perish without them."

TOL: Arthropods (major groups)

- 1) Chelicerates – includes spiders, mites, scorpions
- 2) Crustaceans – includes crabs, shrimp, copepods, barnacles, etc.
- 3) Uniramia – includes millipedes, centipedes, insects
- 4) Trilobites – extinct, known only from fossils

TOL: Arthropods (major features)

- 1) Body segmented internally and externally
- 2) Tagmosis (regional body specialization of groups of segments: e.g., head, thorax, abdomen)
- 3) Chitinous exoskeleton (with thin areas between segments)
- 4) Segmented (jointed) appendages
- 5) Cephalization well developed

Arthropods

Reasons for success

1) **Small size**

   <u>Advantages</u>:

   a) assists escape, movement in confined spaces

   b) need smaller bits of resources

   <u>Disadvantages</u>:

   a) small surface : volume ratio, which leads to increased heat and water loss

Arthropods

Reasons for success

2) Exoskeleton

Advantages:

a) protection - much stronger than internal skeleton

b) greater surface area for muscle attachment

c) helps prevent desiccation

Disadvantages:

a) constrained movement

b) problems re. growth… needs to be shed

c) respiratory, sensory, & excretory issues (impervious layer)

Arthropods

Reasons for success

3) Arthropodization (presence of jointed appendages)
   Includes legs, antennae, mouthparts, etc.
   Permits fine-tuned movements, manipulation of food & other objects, locomotion, etc.
   Regional specialization of body (tagmosis); e.g., insect w/
   - (a) head: feeding, nerve & sensory center
   - (b) thorax: locomotory center… legs, sometimes wing
   - (c) abdomen: specialized for reproduction & contains much of digestive system

Arthropods

Reasons for success

4) Short life cycles - allows use of food resources that may be available for only short period of time

5) High fecundity - typically several hundred to several thousand eggs (but is high mortality)

Arthropods: Insects

Reasons for success

6) Wings (re. most insects)

Advantages:

a) allow dispersal to food resources

b) increased potential for finding mates

c) assist escape from predators

d) miscellaneous: sexual displays, signaling

Disadvantages:

a) require lots of energy to produce

b) can be awkward / bulky

c) windy, exposed habitats?

Arthropods: Insects

Reasons for success

7) Metamorphosis

Advantages:

a) different life stages adapted for different habitats & food

… immature stages adapted for feeding & growth

… adults adapted for reproduction & dispersal

b) minimizes competition between various life stages

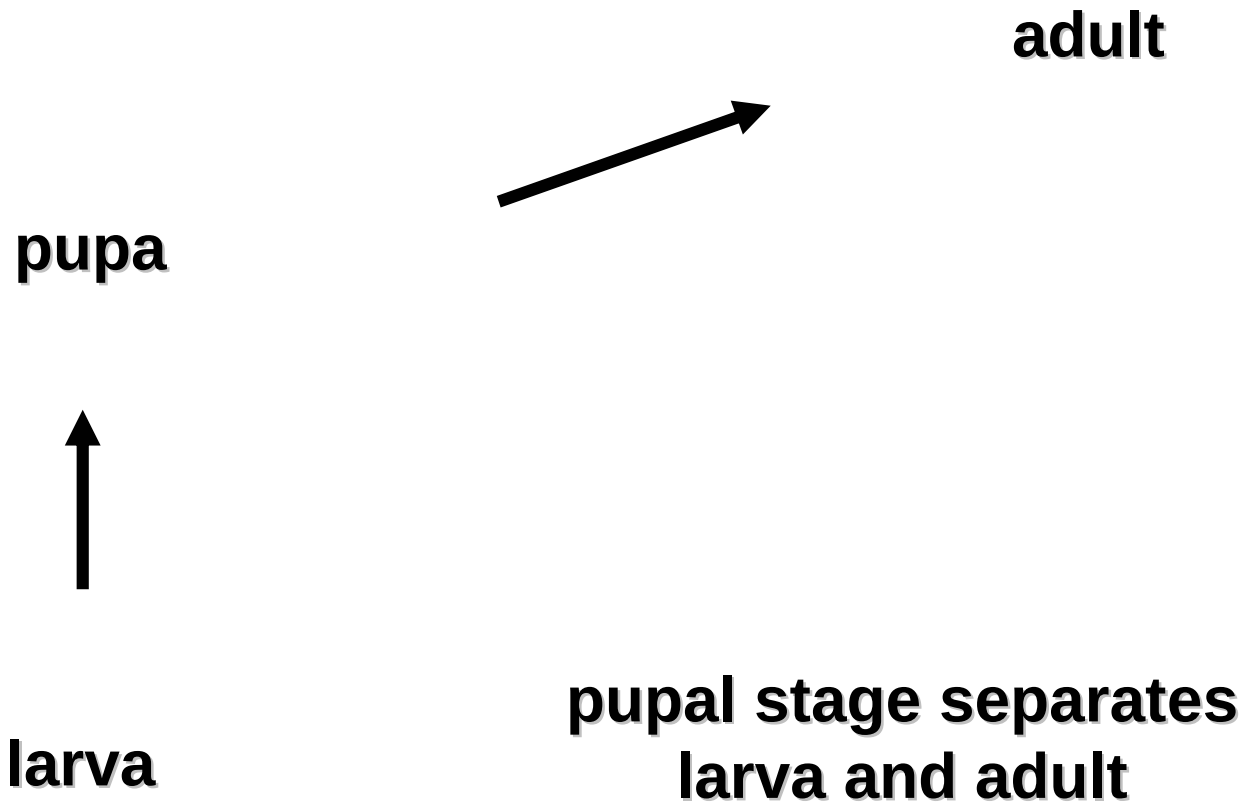
Disadvantages:

a) require lots of energy for drastic changes

b) molting difficult, potentially damaging / dangerous

Arthropods: Insects

“Complete” metamorphosis



pupal stage separates larva and adult