Biology 340
Comparative Embryology
Lecture 2
Dr. Stuart Sumida

Phylogenetic Perspective and the Evolution of Development

“Evo-Devo”

So, what is all the fuss about "phylogeny?"

PHYLOGENETIC SYSTEMATICS allows us both define groups and their relationships.

However, those definitions MUST be careful, rigorous, and testable. (If they aren't testable, they aren't science.)

Biologically valid groups must be defined on the basis of SHARED, DERIVED characteristics.

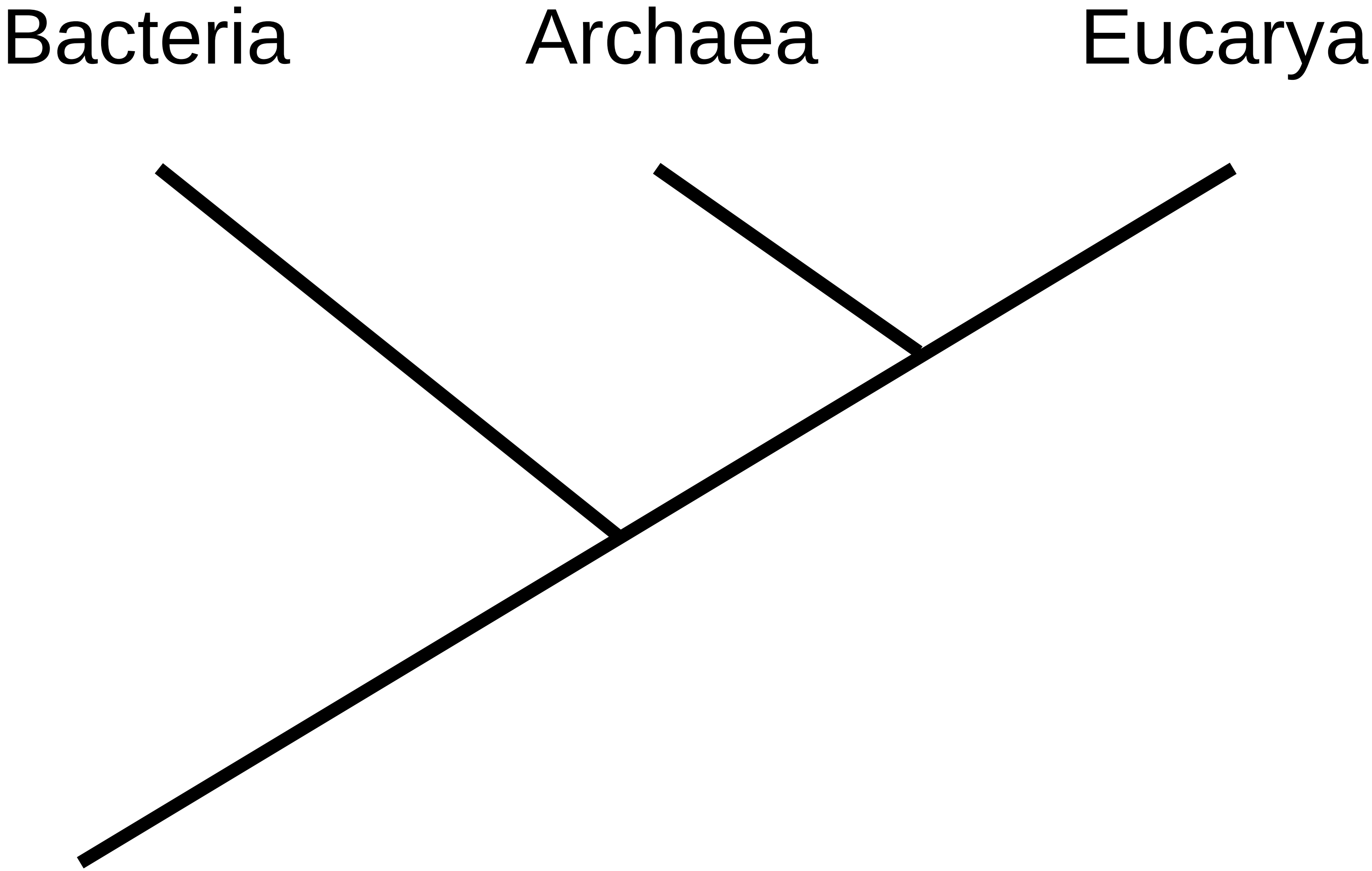
In other words: a biologically valid group is defined on the basis of features that are found in ALL members of the group, and ONLY in members of that group.

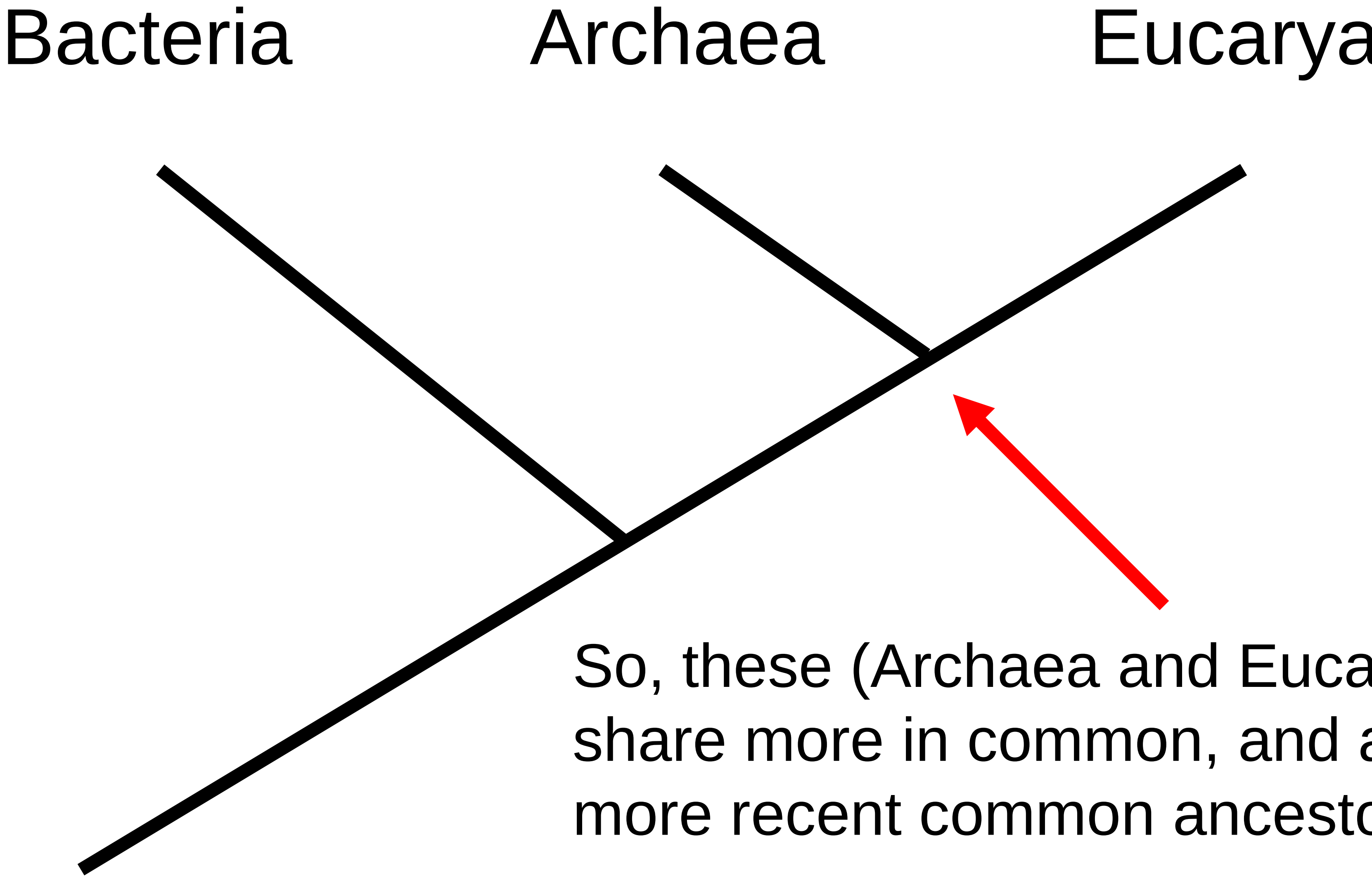
These SHARED, DERIVED characters are known as “SYNAPOMORPHIES.*”

*Singular: Synapomoprhy

The degree of relatedness of groups is dependant on WHAT synapomorphies are shared,and at what level…

What is a shared, derived character at one level, will NOT be a shared derived character at another level.

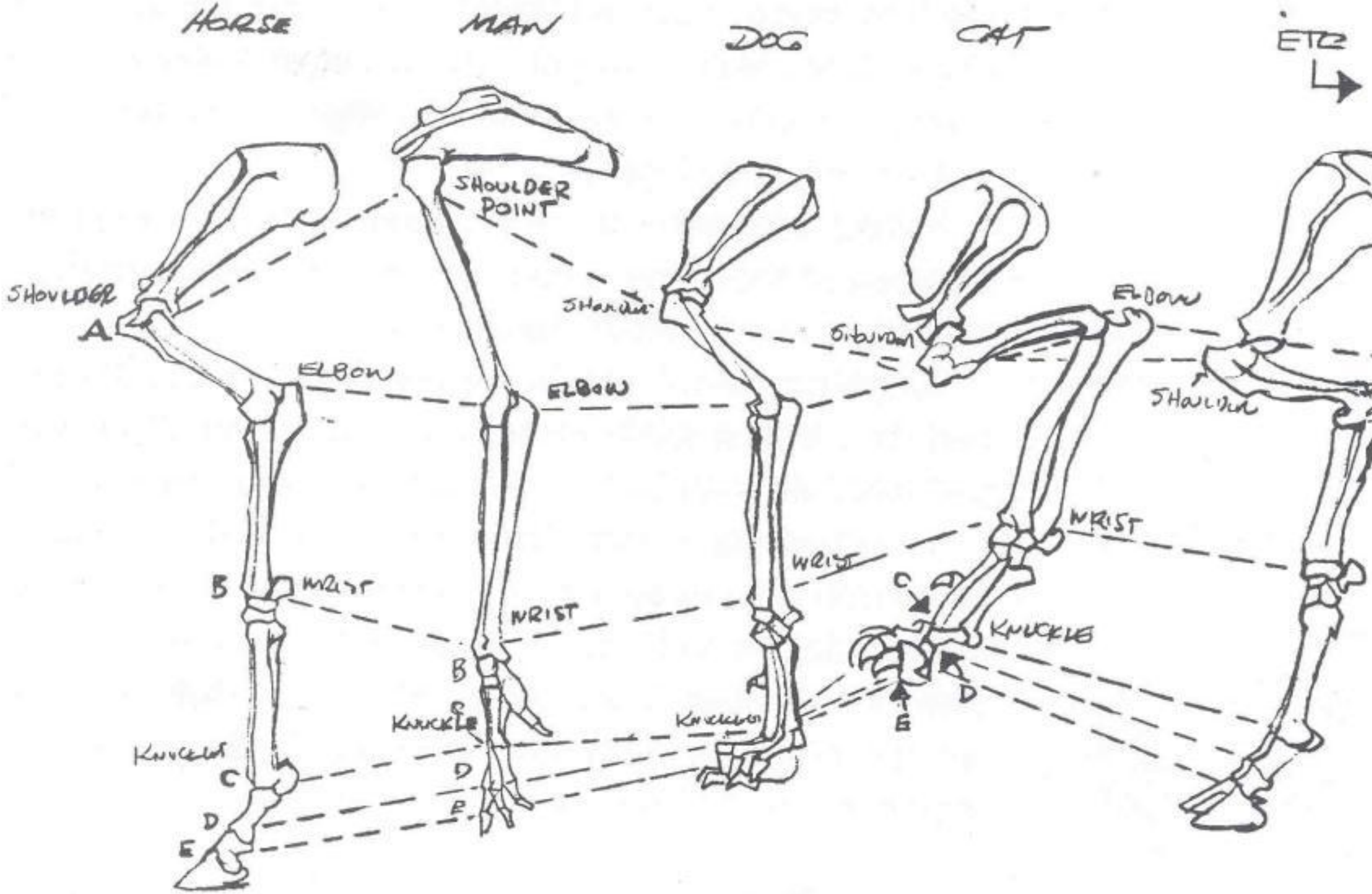

Bacteria
Archaea
Eucarya



So, these (Archaea and Eucarya) share more in common, and a more recent common ancestor.

What kind of features can be used to generate phylogenetic trees?

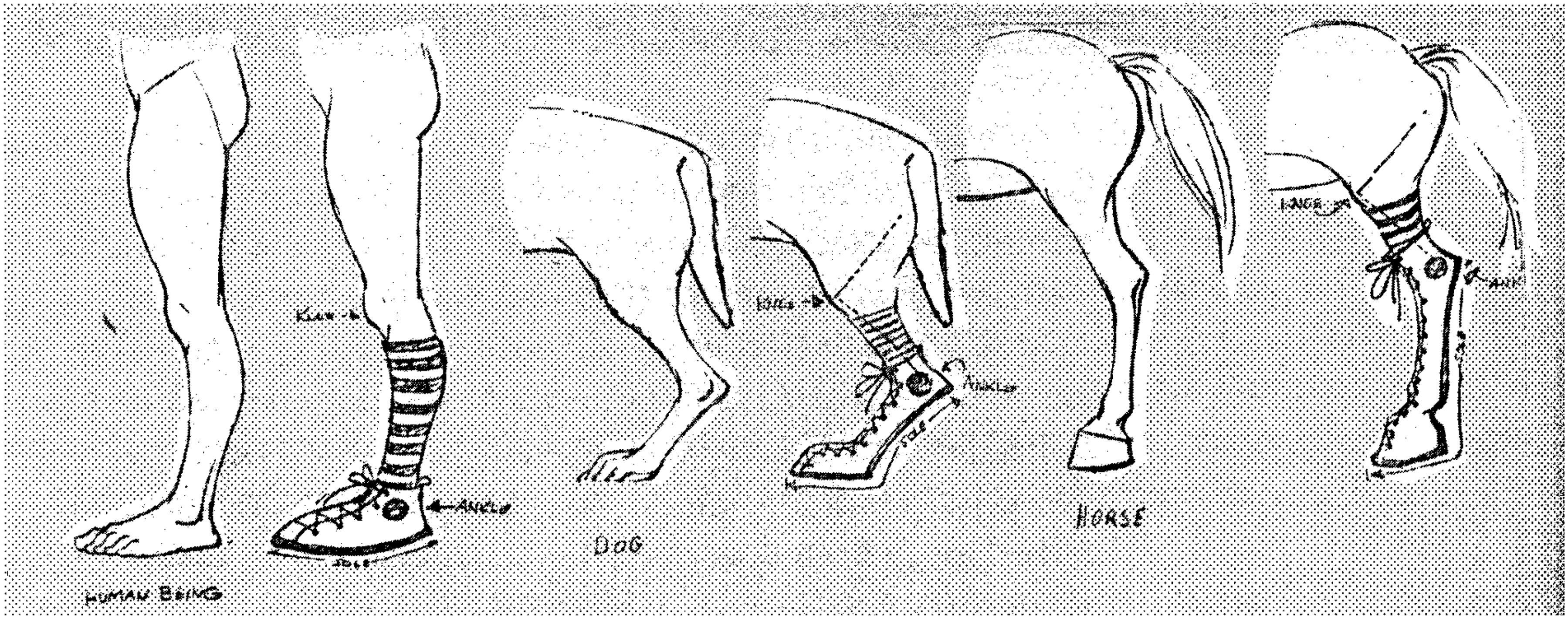
They must be HOMOLOGOUS CHARACTERS. That is, they must be structures or features inherited from a common structure in a common ancestor.


HORSE
MAN
DOG
CAT
ETC
SHOULDER POINT
SHOULDER
A
ELBOW
B
WRIST
KNUCKLE
C
D
E
SHOULDER
ELBOW
WRIST
KNUCKLE
KNUCKLE
SHOULDER
ELBOW
WRIST
SHOULDER
ELBOW
WRIST
KNUCKLE
C
D
E
SHOULDER

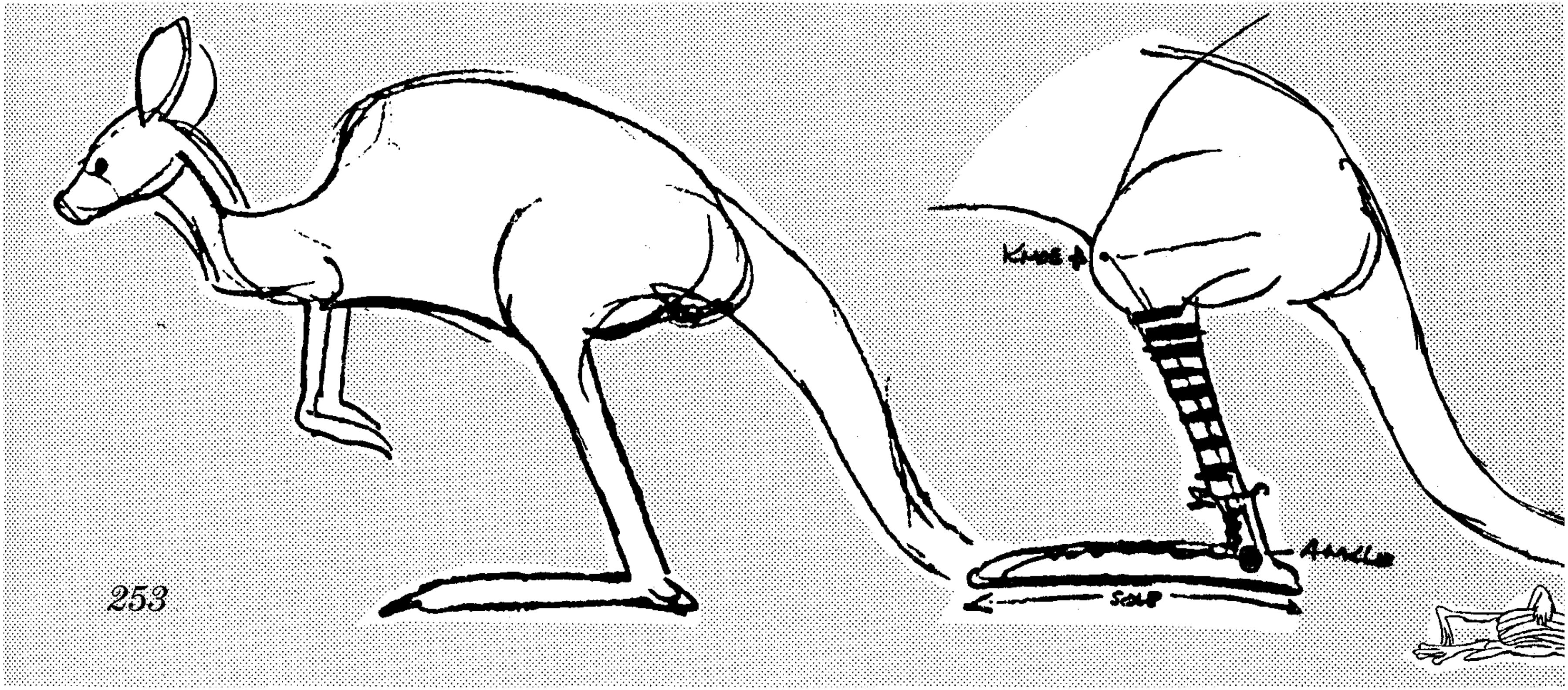
Criteria for Anatomical Homology:

- Same Anatomical Position
- Same Embryological Material
- (In animals) Supplied by Same Nerve

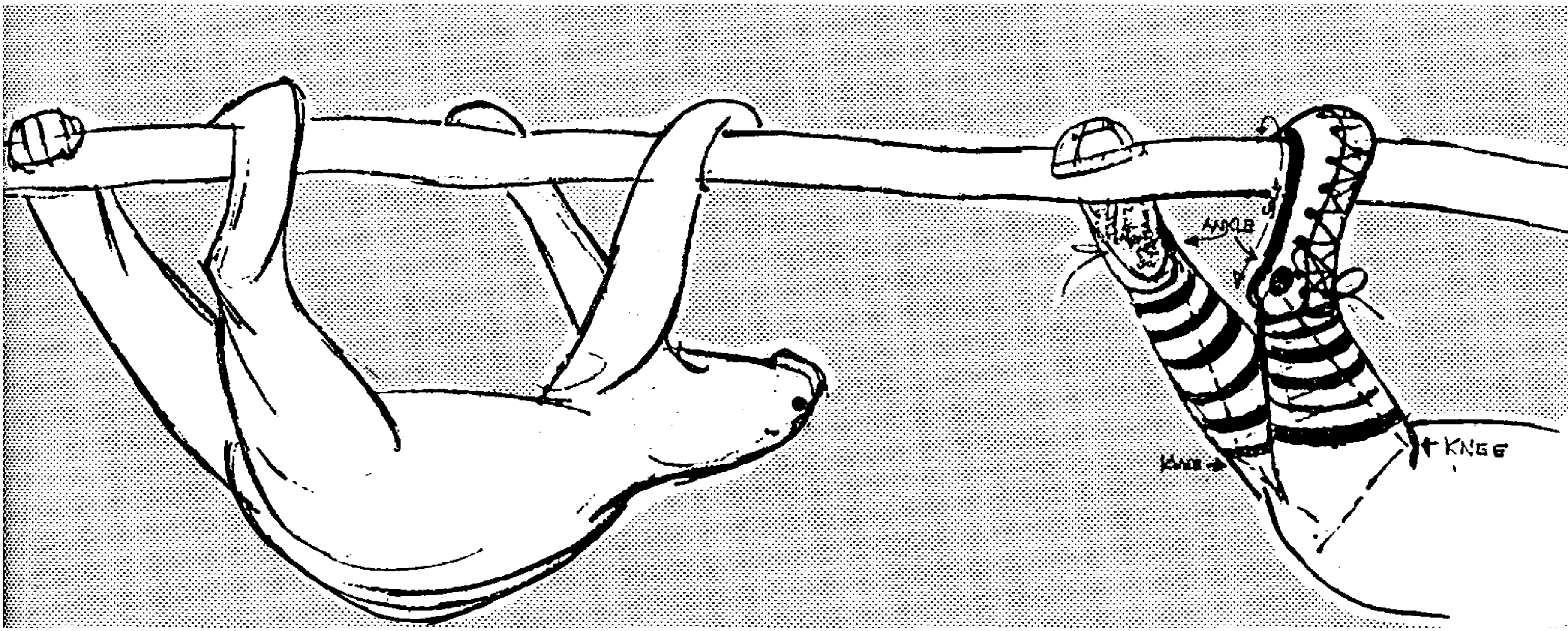
Function is NOT a good criterion (because functions can change over time…)



From: ***Chuck Amuck*** **by Chuck Jones, Farrar Straus Giroux Publishers, New York, 1989.**



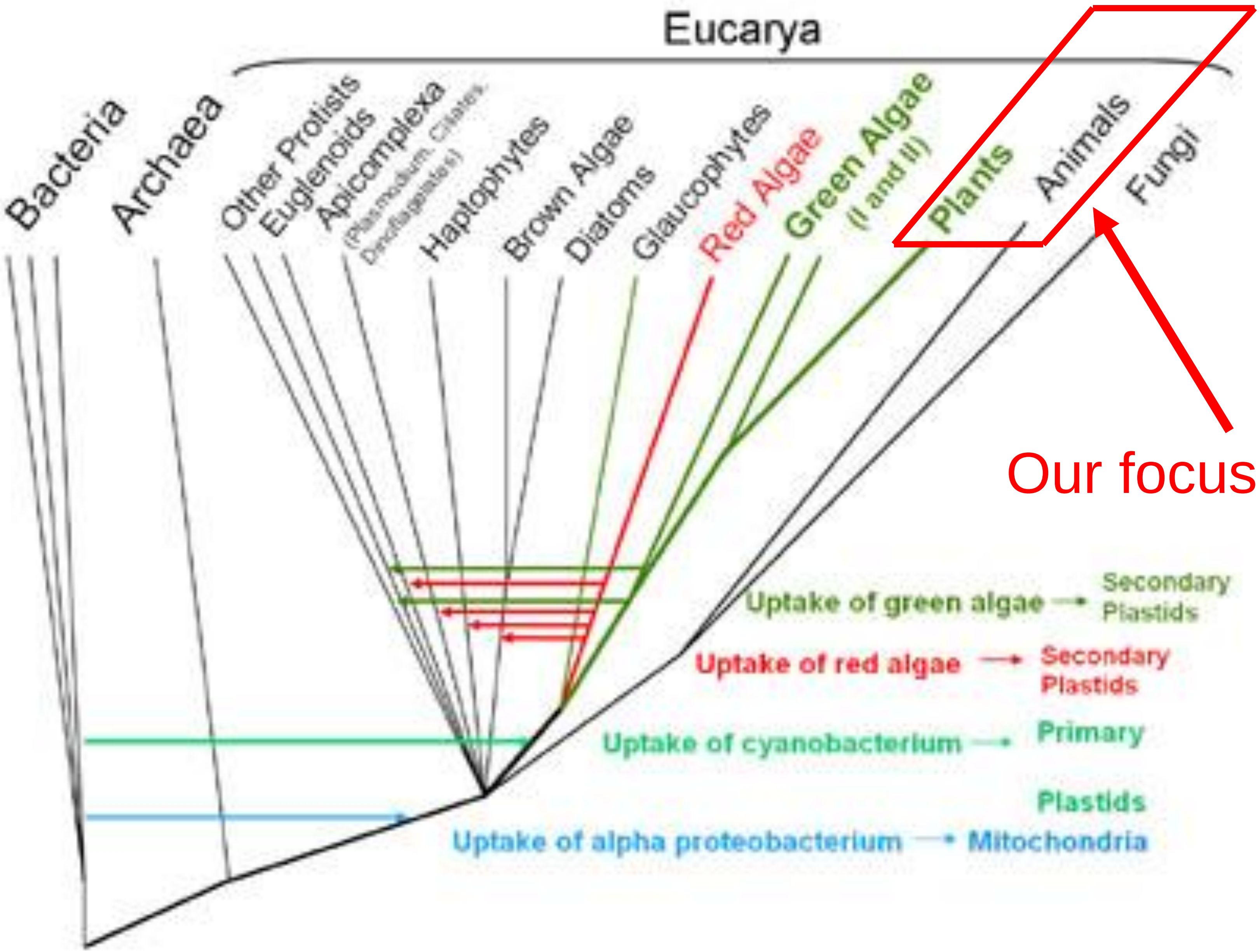
253


ANKLE
KNEE

Knowing the relationships of organisms allows us to consider certain other concepts:

CONVERGENT EVOLUTION – the acquisiton of similar features due to similar environmental pressures.

PARALLEL EVOLUTION – (a special case of convergence) when convergent evolution takes place between very closely related lineages.


Eucarya
Bacteria
Archaea
Other Protists
Euglenoids
Apicomplexa
(Plasmodium, Ciliates, Dinoflagellates)
Haptophytes
Brown Algae
Diatoms
Glaucophytes
Red Algae
Green Algae
(I and II)
Plants
Animals
Fungi
Our focus
Uptake of green algae → Secondary Plastids
Uptake of red algae → Secondary Plastids
Uptake of cyanobacterium → Primary Plastids
Uptake of alpha proteobacterium → Mitochondria

GERM LAYERS

and

SEGMENTATION

Eumetazoa has:

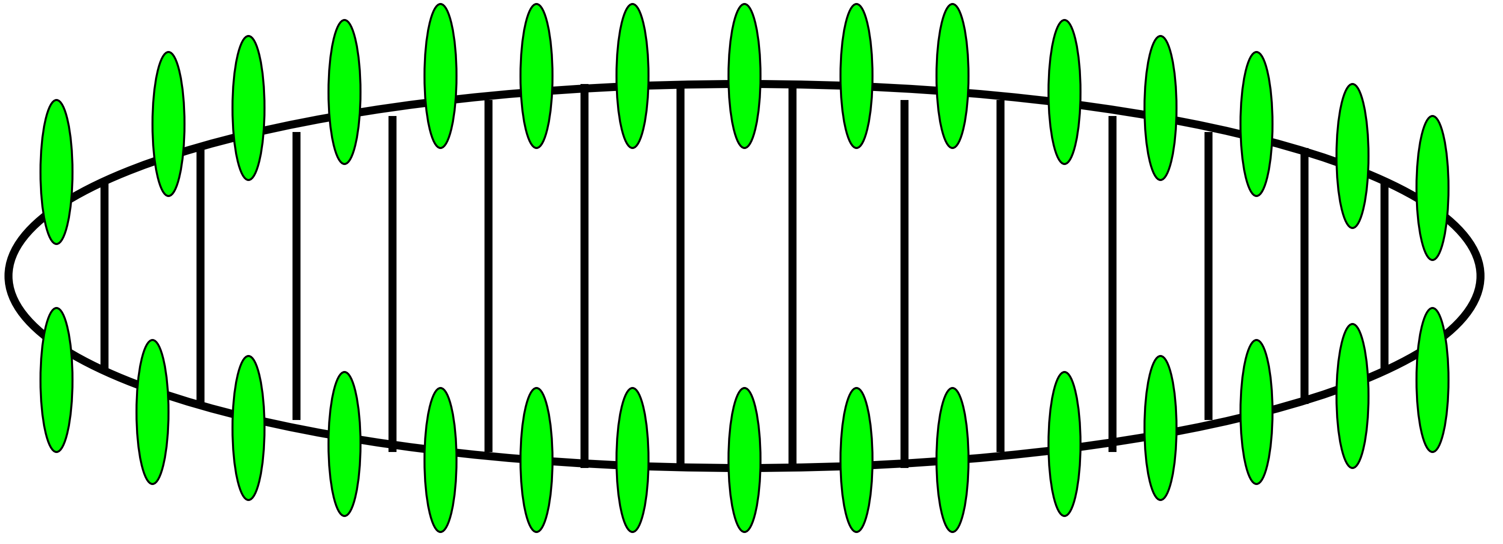
Germ Layers

- Endoderm
- Ectoderm

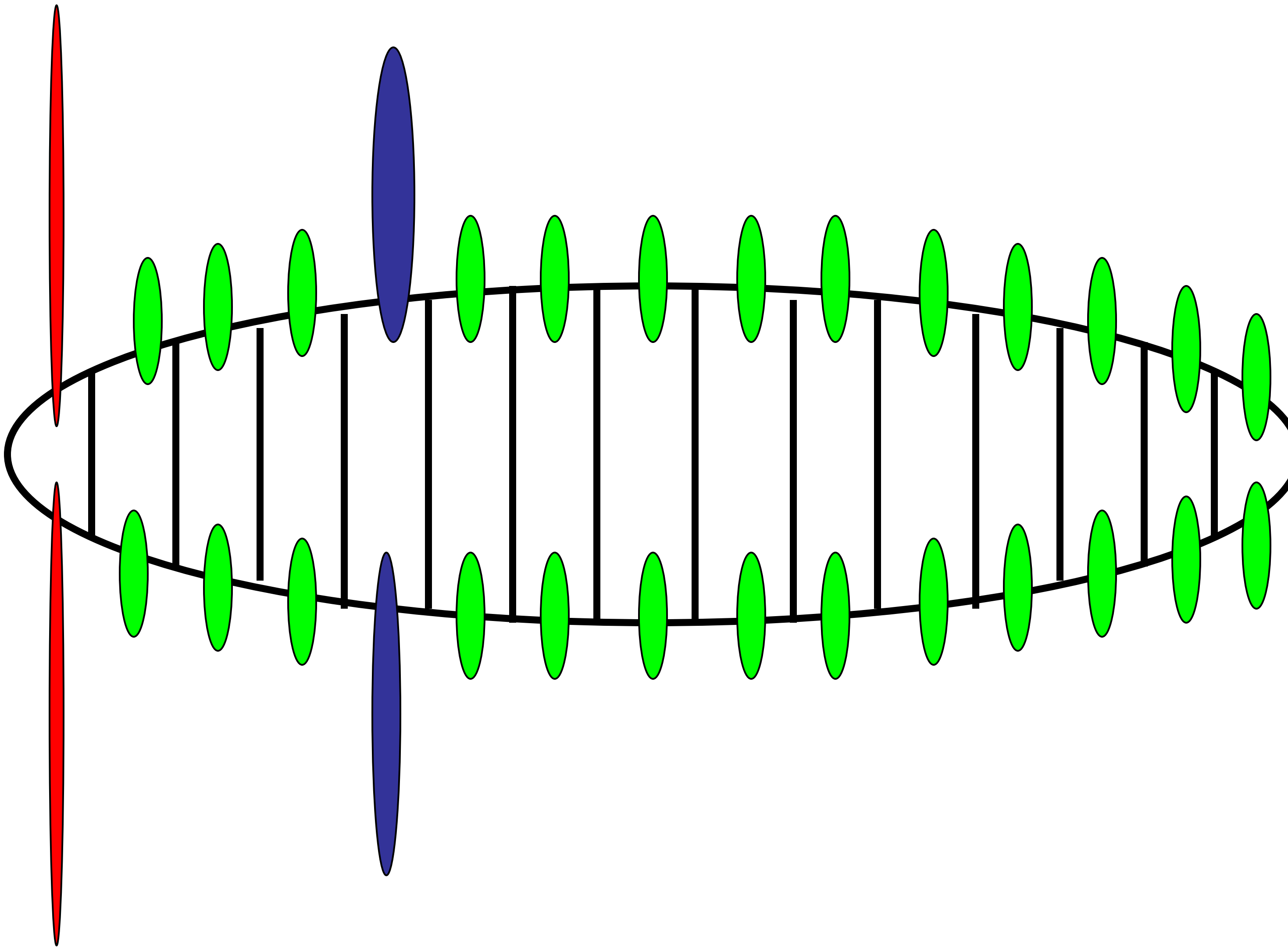
Tissues

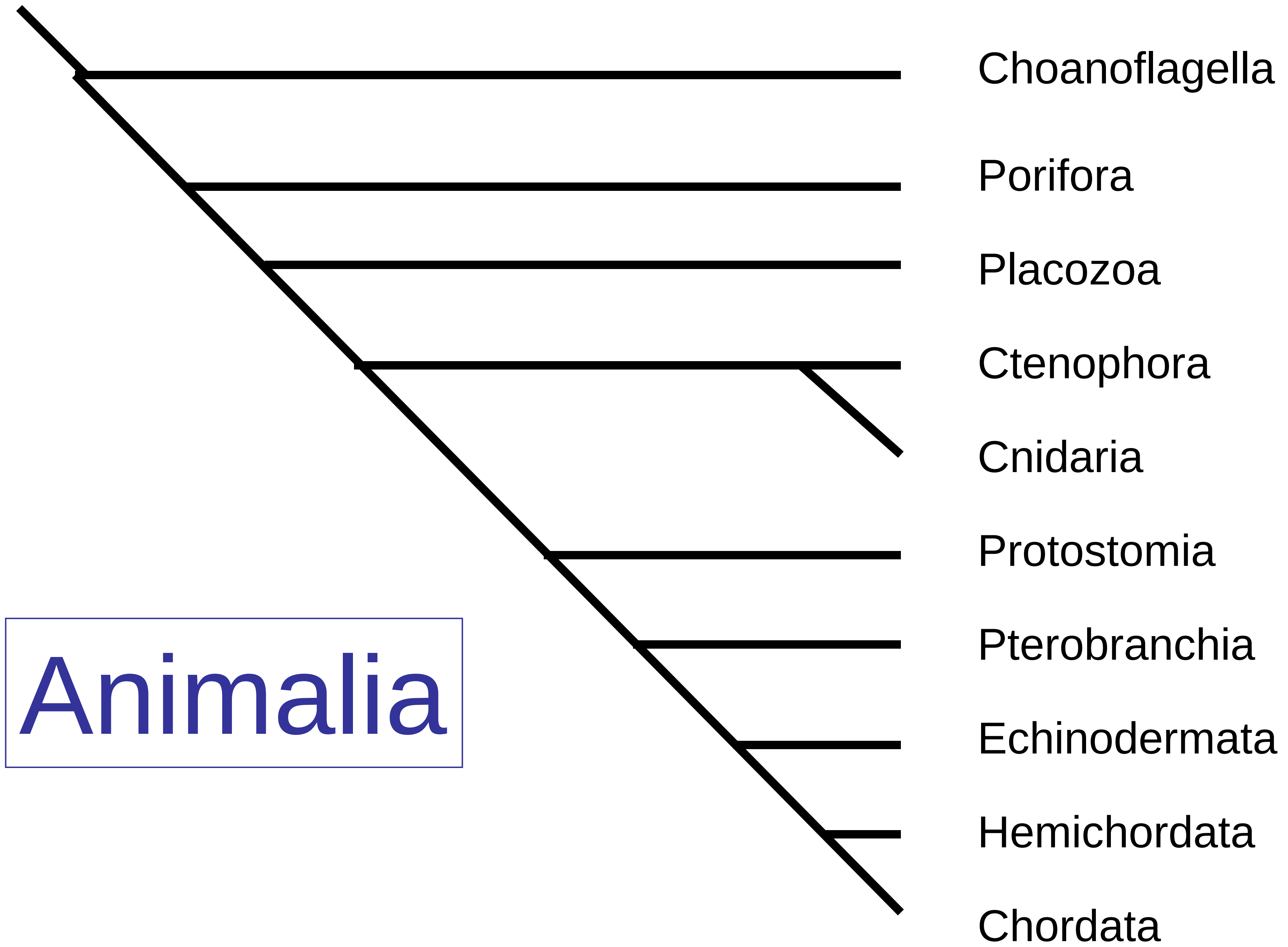
Segmentation: an example:

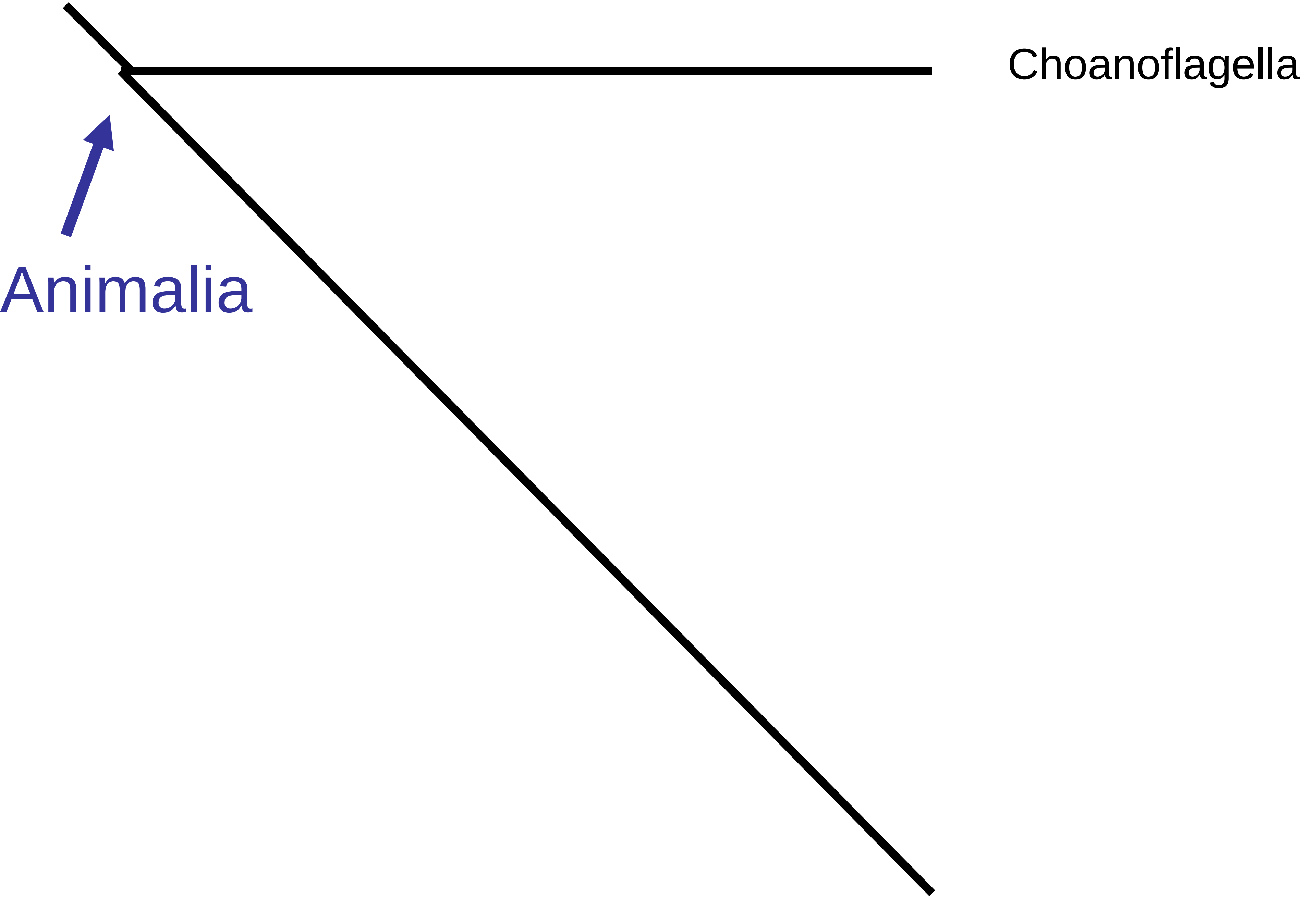
A simplified arthropod larva with multiple segments, each with appendages, or the genetic ability to develop appendages.



Different kinds of arthropods can elaborate upon different segments and appendages. This provides an enormous versatility.

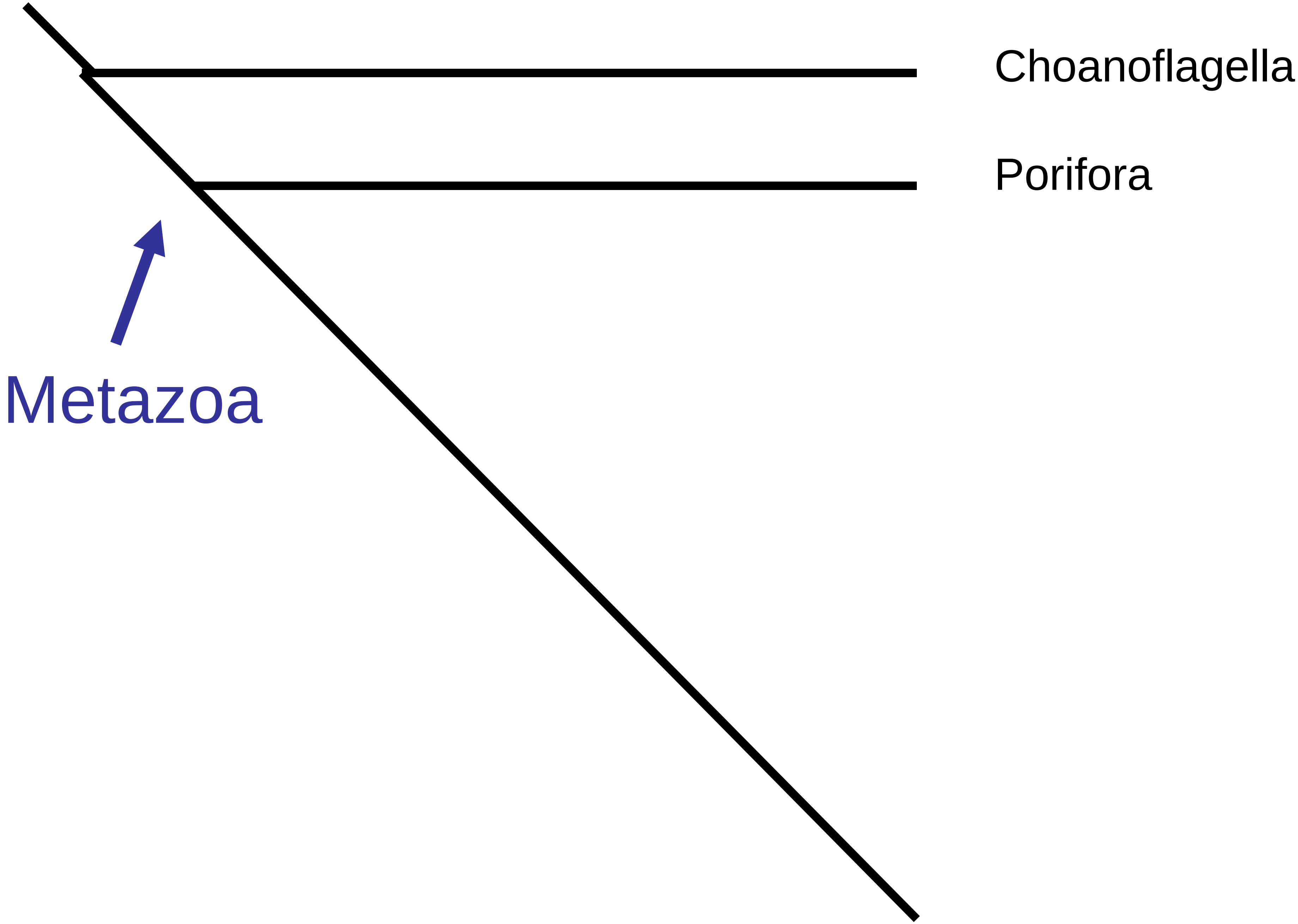



Choanoflagella
Porifora
Placozoa
Ctenophora
Cnidaria
Protostomia
Pterobranchia
Echinodermata
Hemichordata
Chordata
Animalia


Choanoflagella
Animalia

Animalia

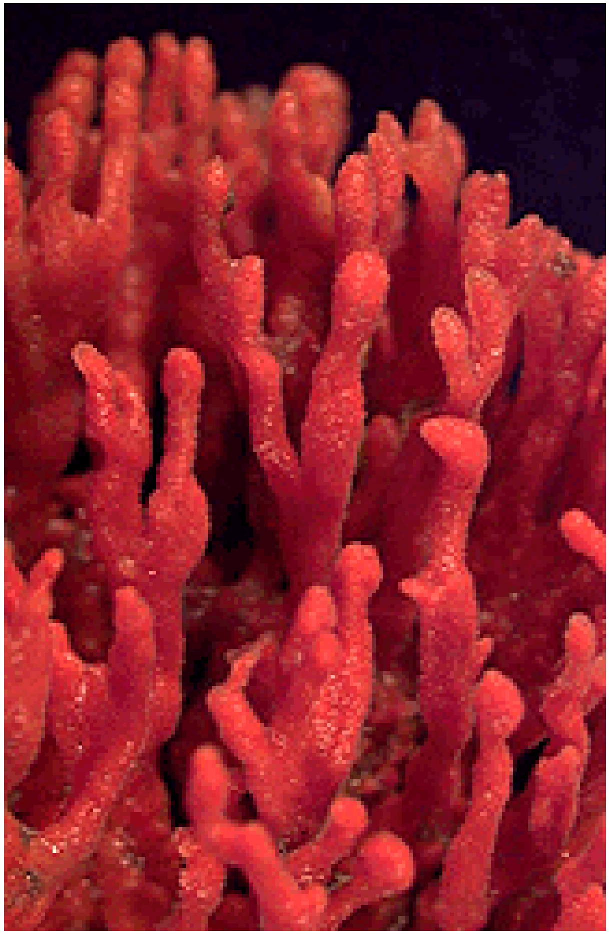
Multicellular heterotrophs

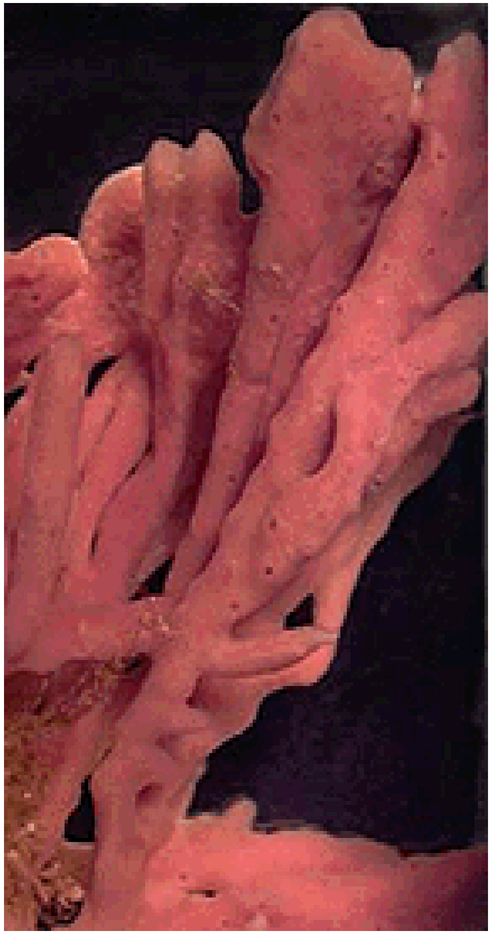

Choanoflagella
Porifora
Metazoa

Porifera (Sponges):

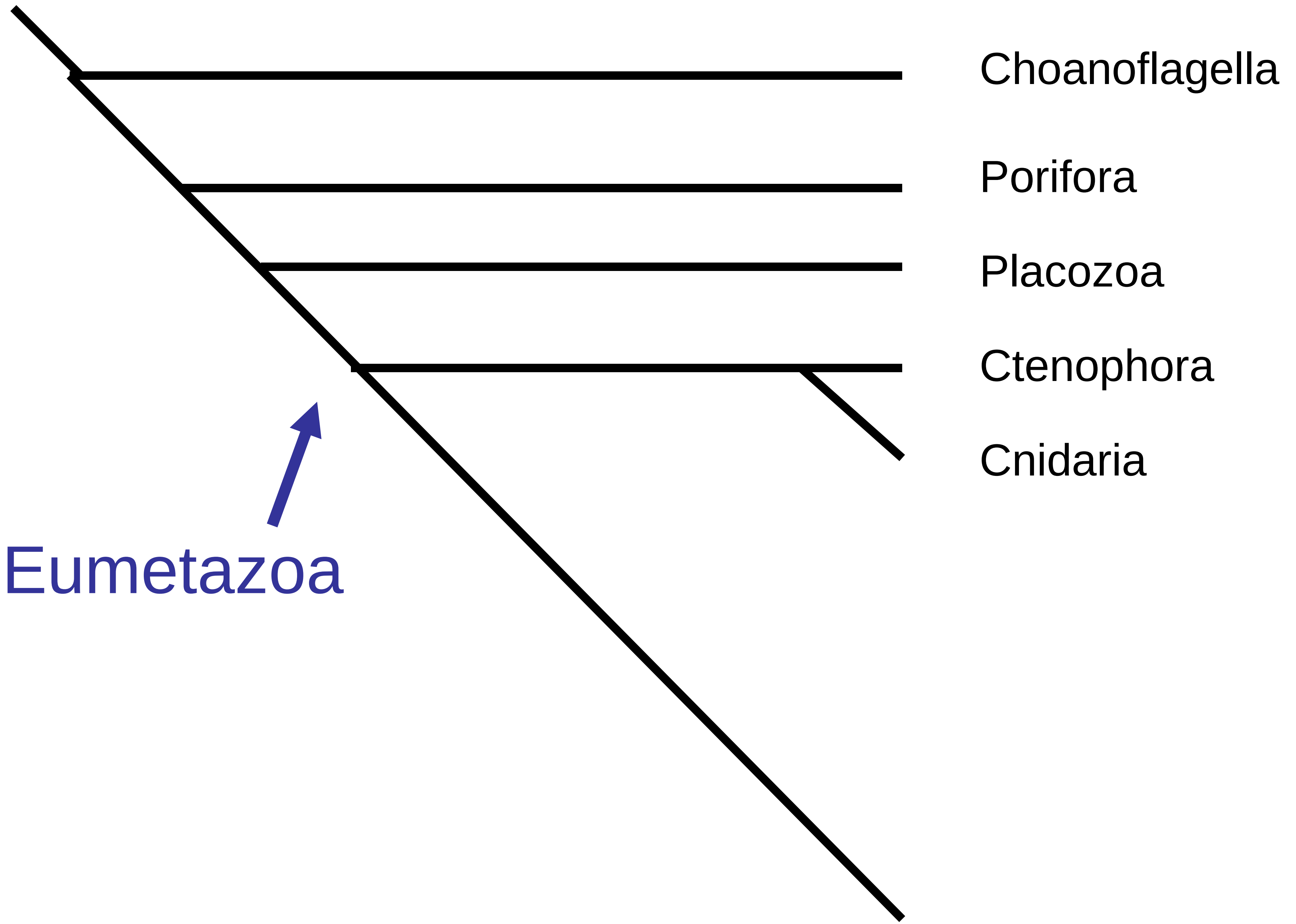
Known as far back as PreCambrian

600 million years ago.





Example: Porifora (Sponges): No true germ layers or tissues


Choanoflagella
Porifora
Placozoa
Ctenophora
Cnidaria
Eumetazoa

Eumetazoa

Germ Layers

- Endoderm
- Ectoderm

Tissues

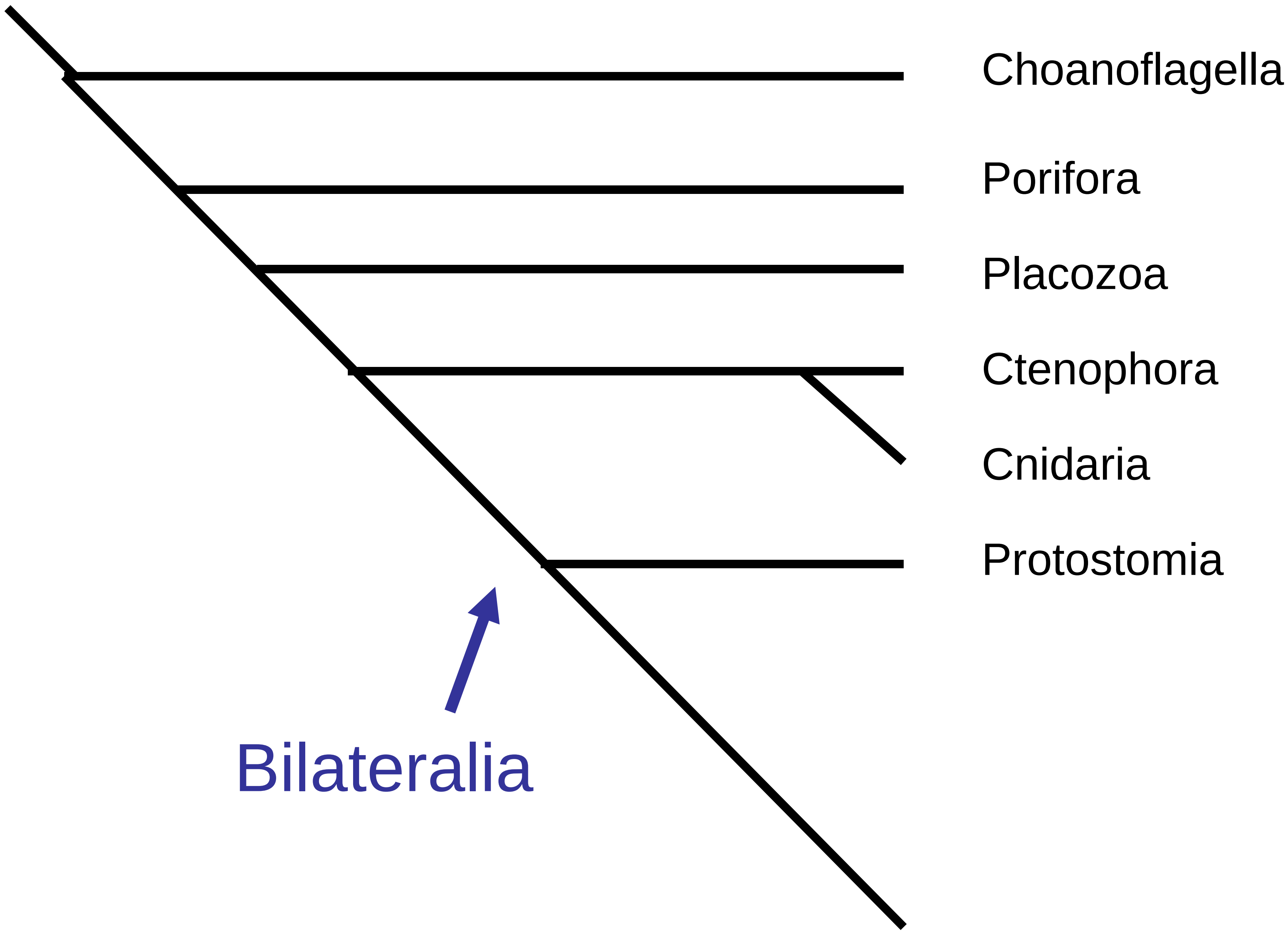
Ctenophores and Cnidarians

Known as far back as PreCambrian "Ediacarian Faunas".

- Two germ layers – ectoderm and endoderm
- Only one opening into gut.

Ctenophores and Cnidarians

Known as far back as PreCambrian “Ediacarian Faunas”.


Choanoflagella
Porifora
Placozoa
Ctenophora
Cnidaria
Protostomia
Bilateralia

Bilateralia

Bilaterally symmetrical at some point during ontogeny

Three germ layers: ectoderm, endoderm, mesoderm.

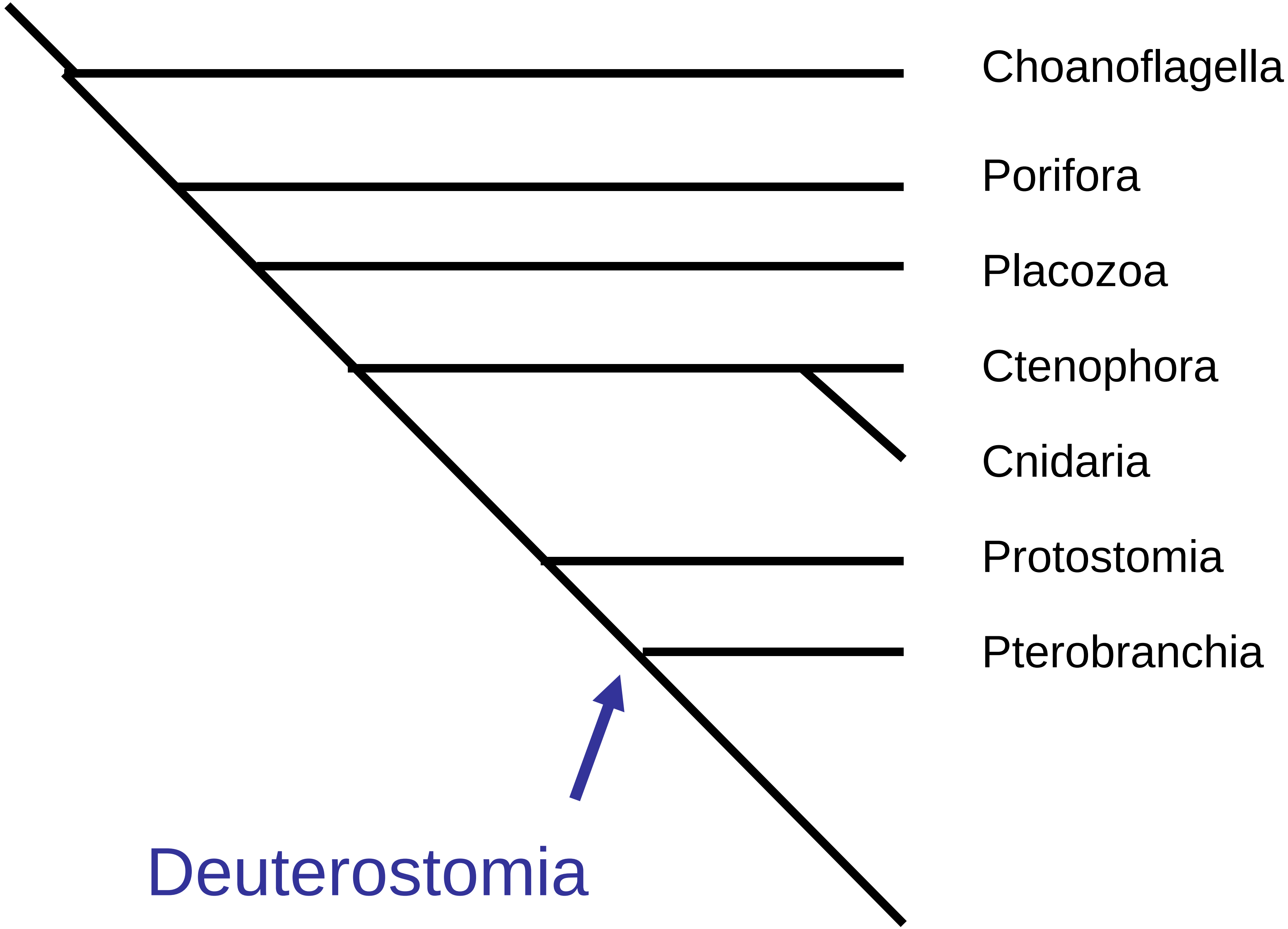
Bilateralia

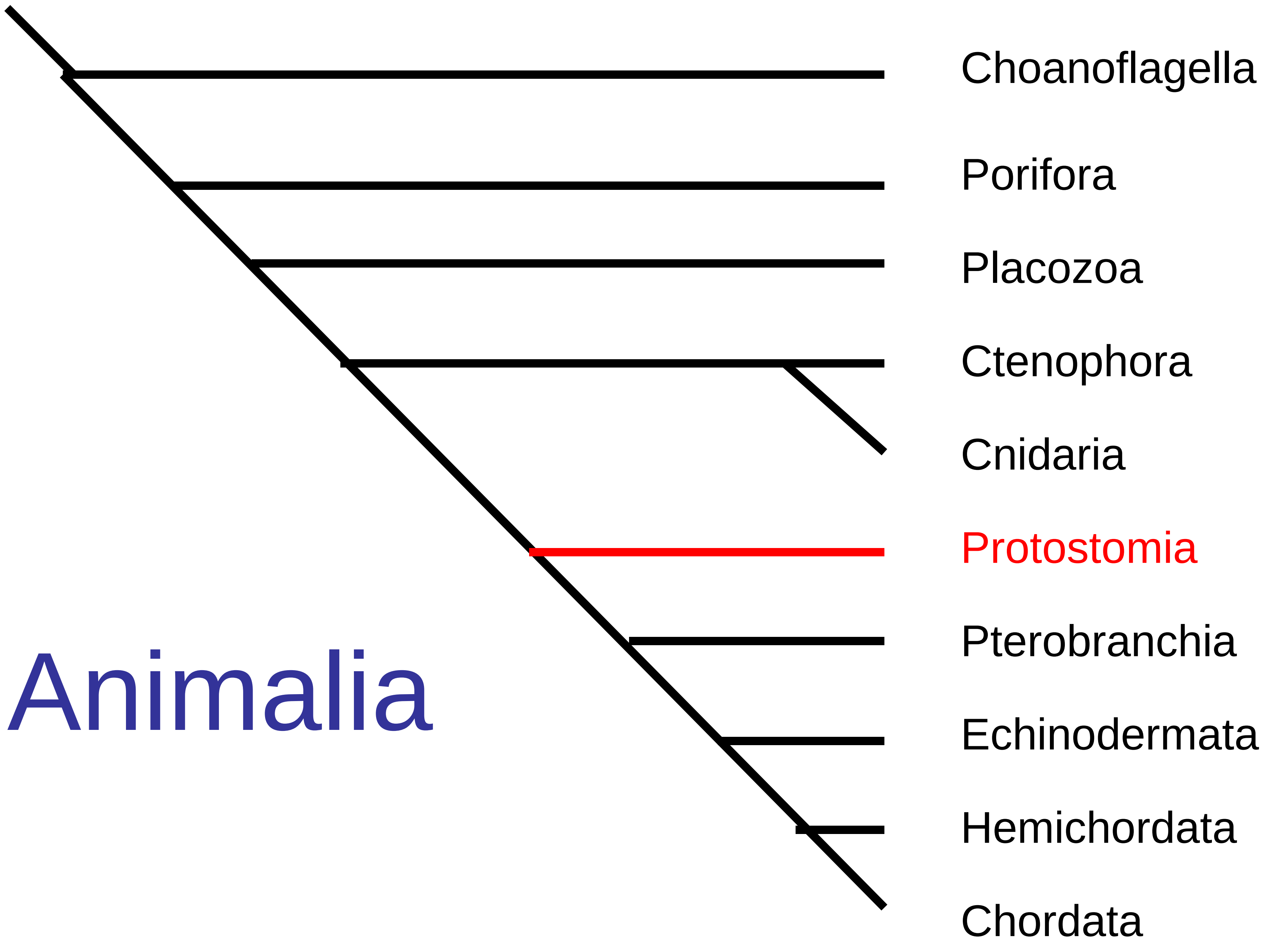
Includes two great groups of animals:

Protostomia (means 1st mouth)
Deuterostomia (means 2nd mouth)

Protostomia includes many phyla, including:

- Arthropoda
- Mollusca
- Annelida (segmented worms)
- Many others


Choanoflagella
Porifora
Placozoa
Ctenophora
Cnidaria
Protostomia
Pterobranchia
Deuterostomia


Choanoflagella
Porifora
Placozoa
Ctenophora
Cnidaria
Protostomia
Pterobranchia
Echinodermata
Hemichordata
Chordata
Animalia

Protostomia includes many phyla, including:

- Arthropoda
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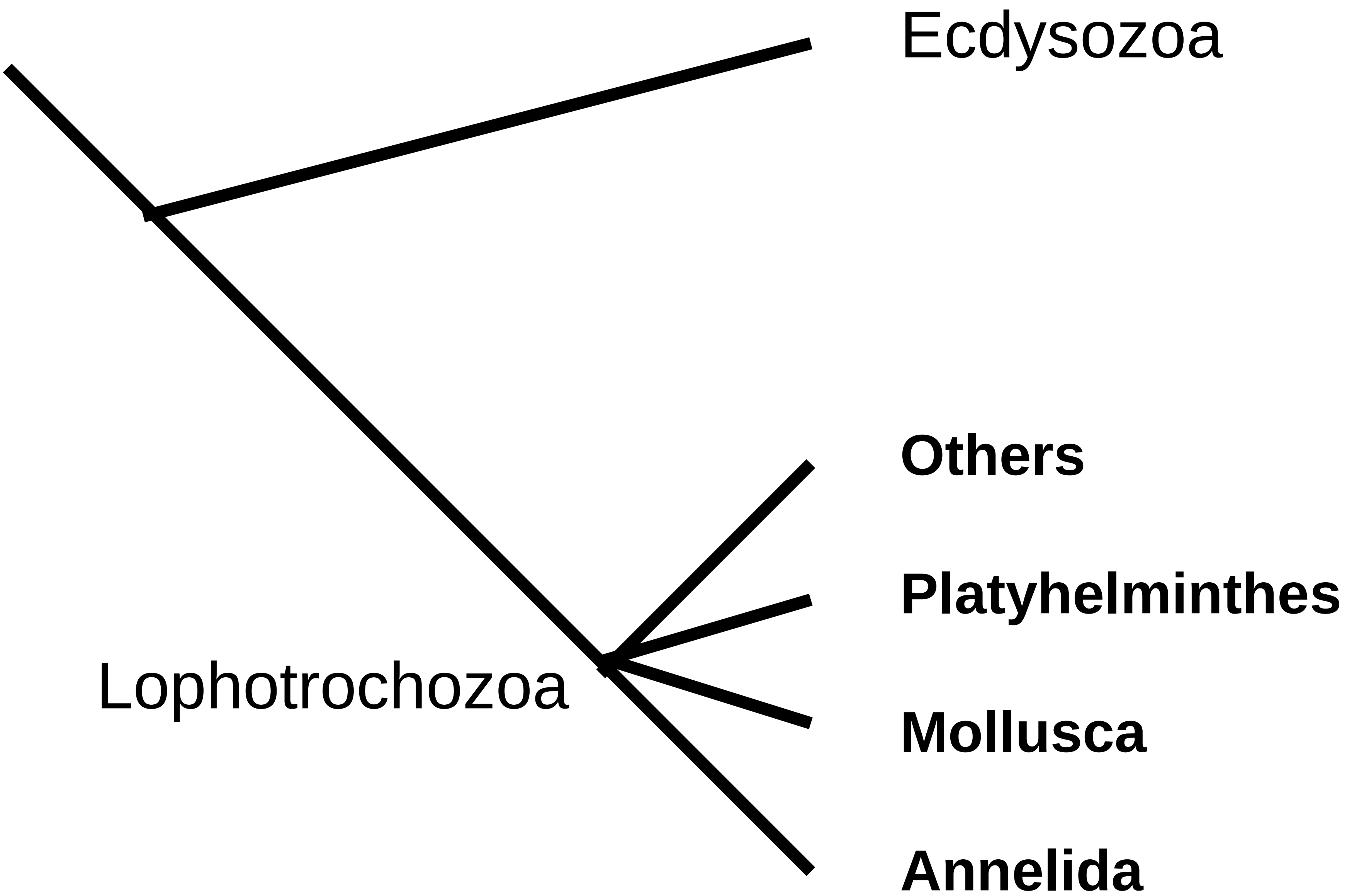
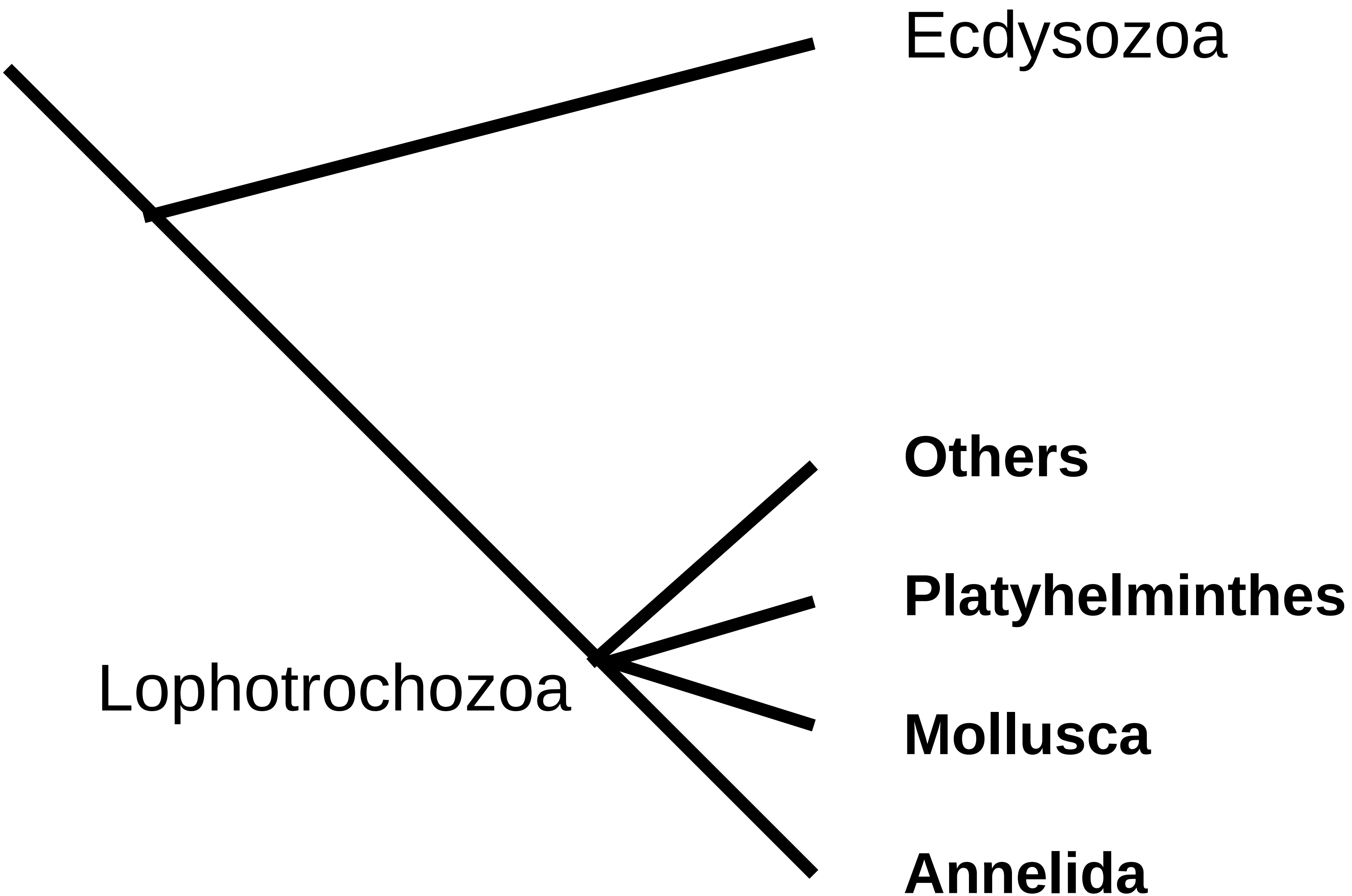
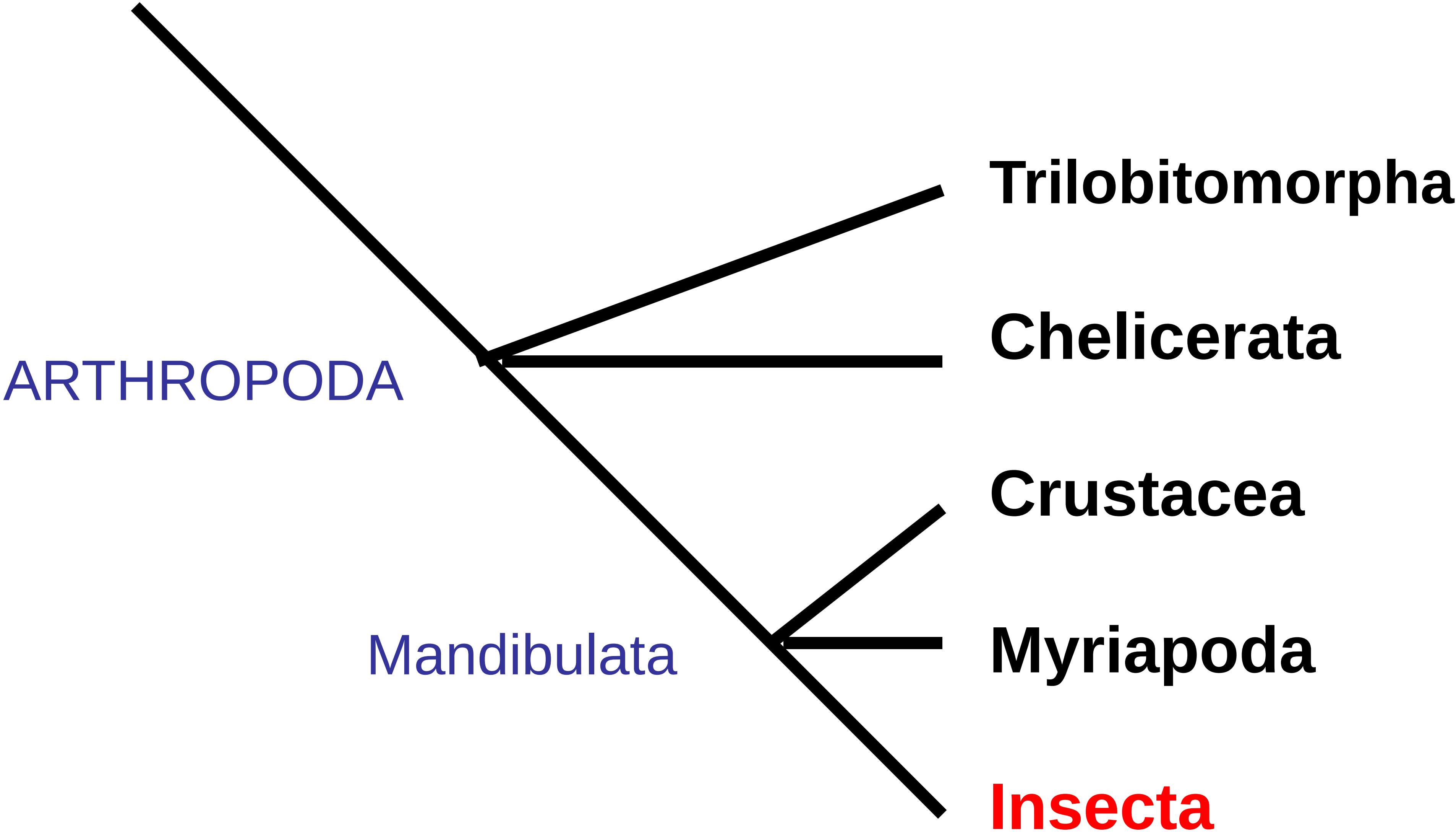
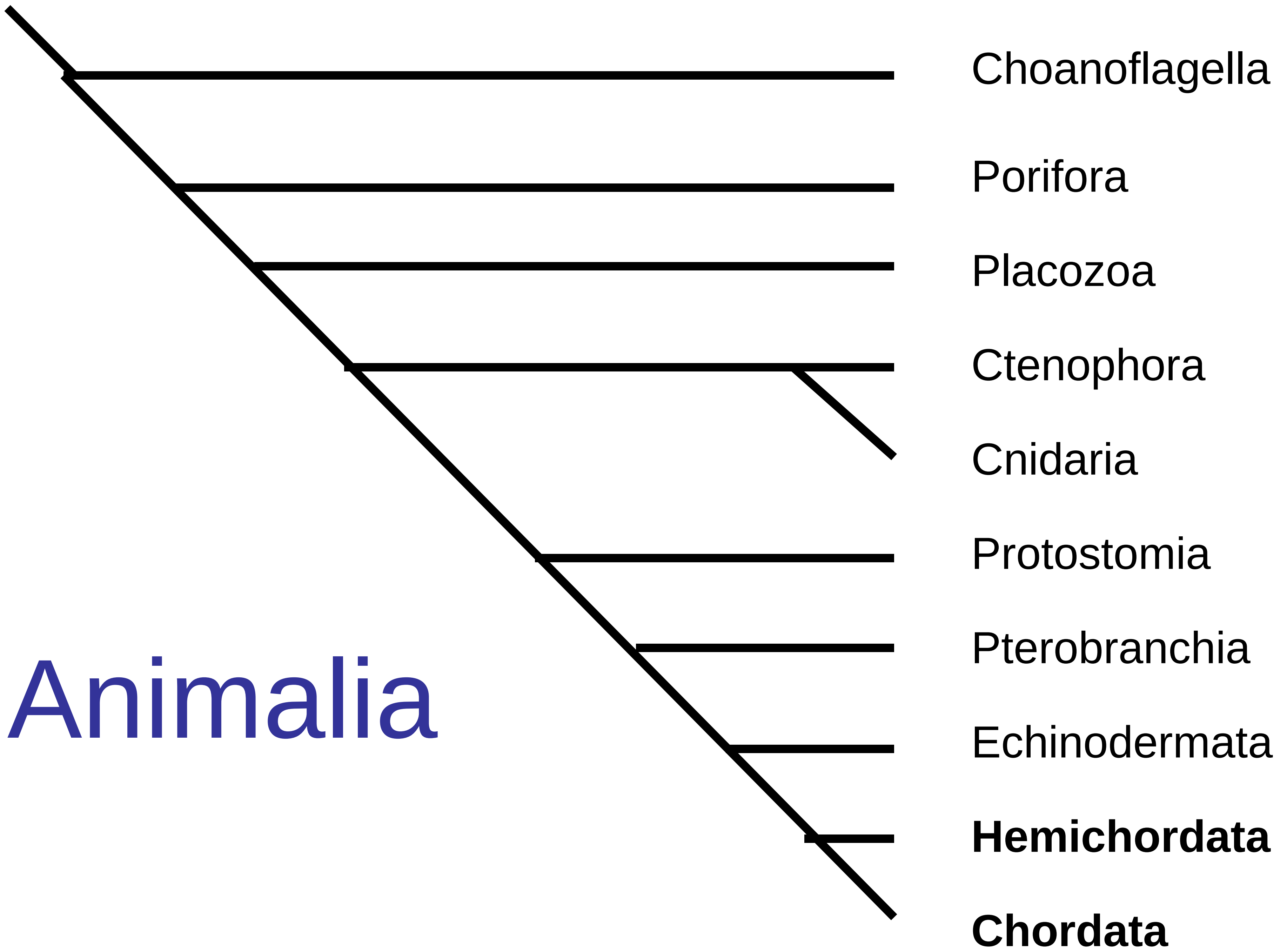

Ecdysozoa
Others
Platyhelminthes
Lophotrochozoa
Mollusca
Annelida


Ecdysozoa
Others
Platyhelminthes
Lophotrochozoa
Mollusca
Annelida

Ecdysozoa

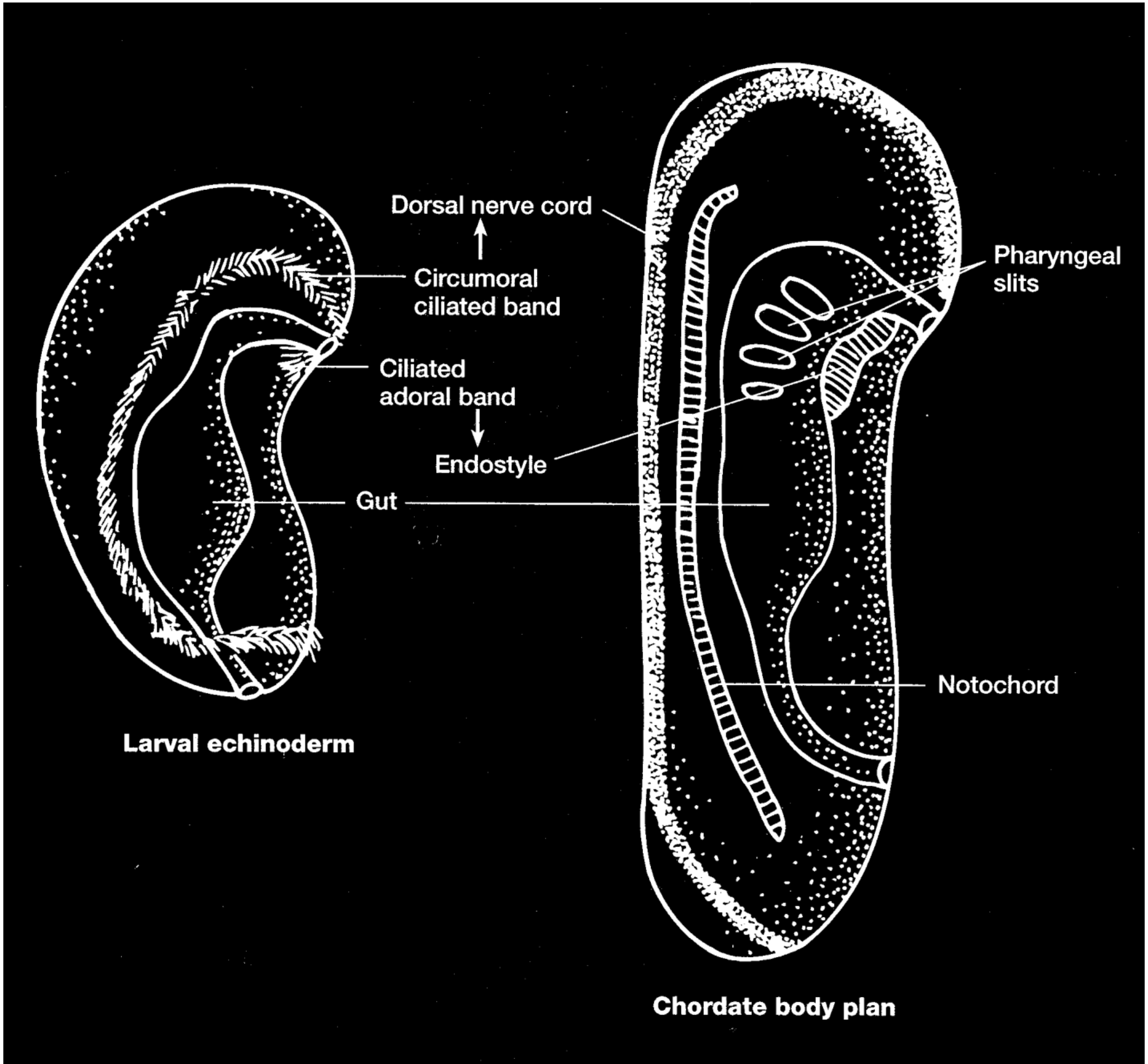

Trilobitomorpha
Chelicerata
ARTHROPODA
Crustacea
Mandibulata
Myriapoda
Insecta


Choanoflagella
Porifora
Placozoa
Ctenophora
Cnidaria
Protostomia
Pterobranchia
Echinodermata
Hemichordata
Chordata
Animalia

Recall Bilateralia

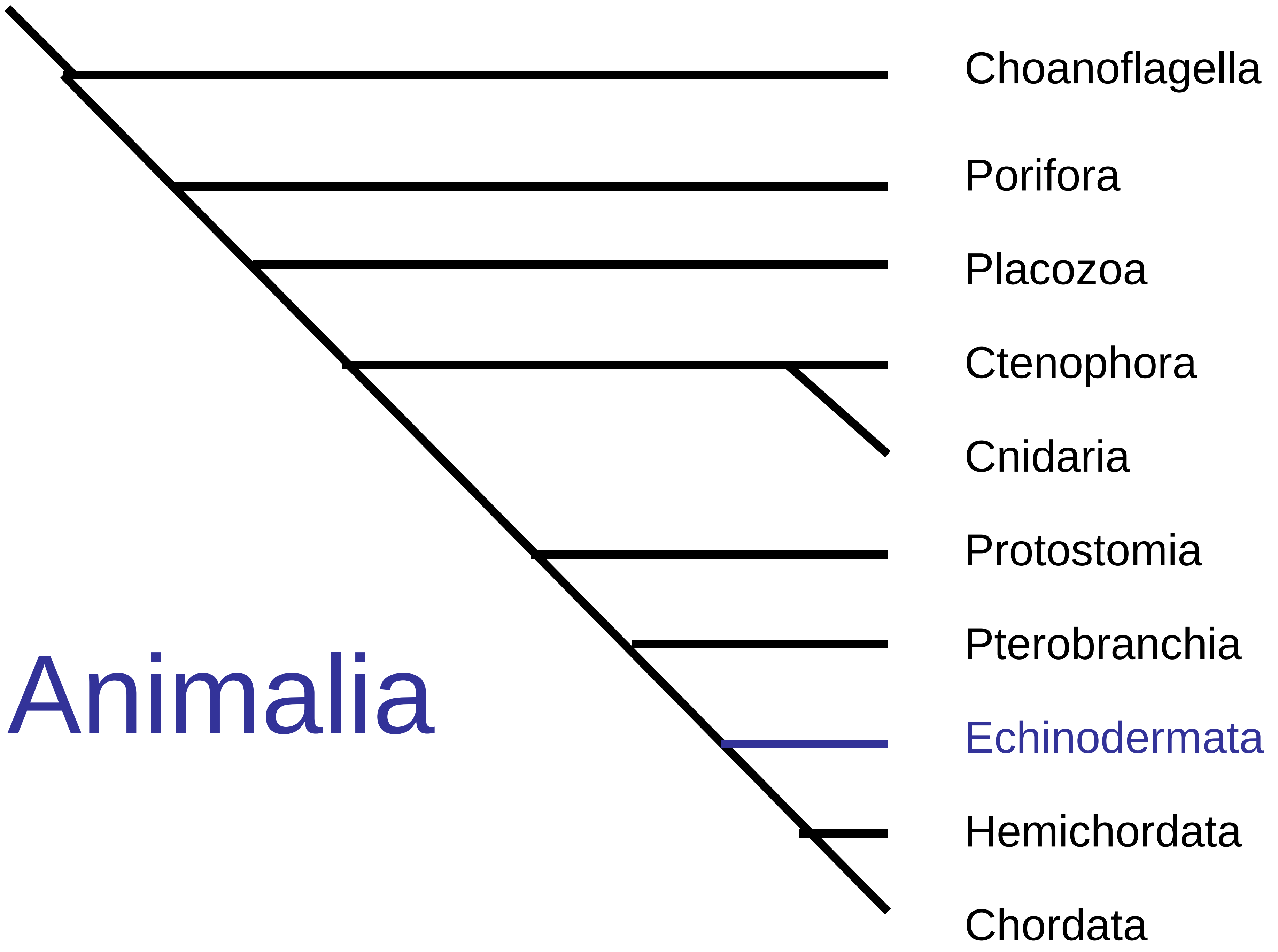
Protostomia (means 1st mouth)

Deuterostomia (means 2nd mouth)


Dorsal nerve cord
Circumoral
ciliated band
Ciliated
adoral band
Endostyle
Gut
Pharyngeal
slits
Notochord
Larval echinoderm
Chordate body plan

The best known of the Deuterostomia:

- Pterobranchia
- Echinodermata
- Hemichordata
- Chordata


Choanoflagella
Porifora
Placozoa
Ctenophora
Cnidaria
Protostomia
Pterobranchia
Echinodermata
Hemichordata
Chordata
Animalia

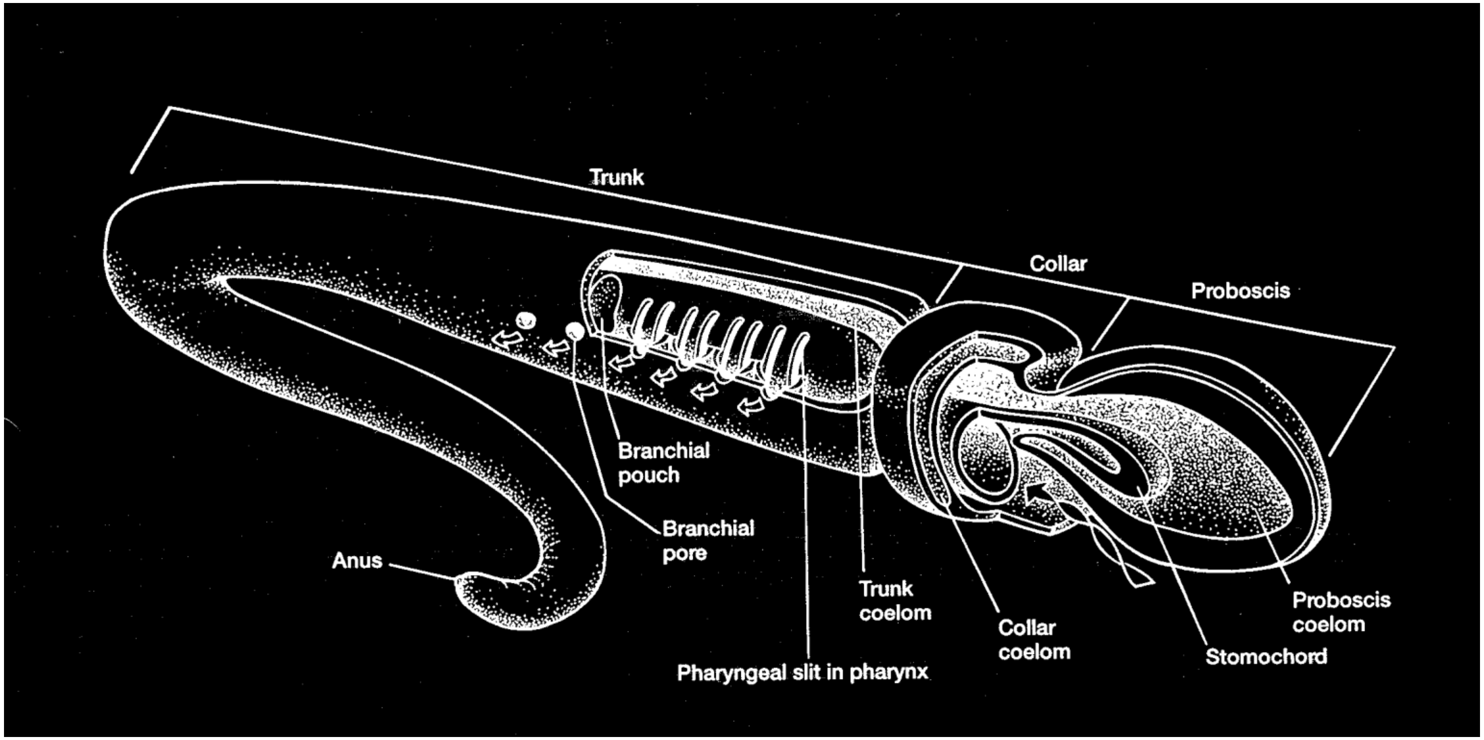
ECHINODERMATA:

Characterized by:

- Radial symmetry as adults (bilateral as larvae)
- Water-vascular system

PHYLUM HEMICHORDATA:

Deuterostomes with GILL SLITS (Original function of gill slits NOT for breathing; for FILTER FEEDING.)



PHYLUM CHORDATA

Deuterostomes with the following synapomorphies:

- Pharyngeal gill slits
- Dorsal hollow nerve cord
- Notochord
- Post-anal tail

PHYLUM CHORDATA

Includes the following subphyla:

- Urochordata
- Cephalochordata
- Vertebrata

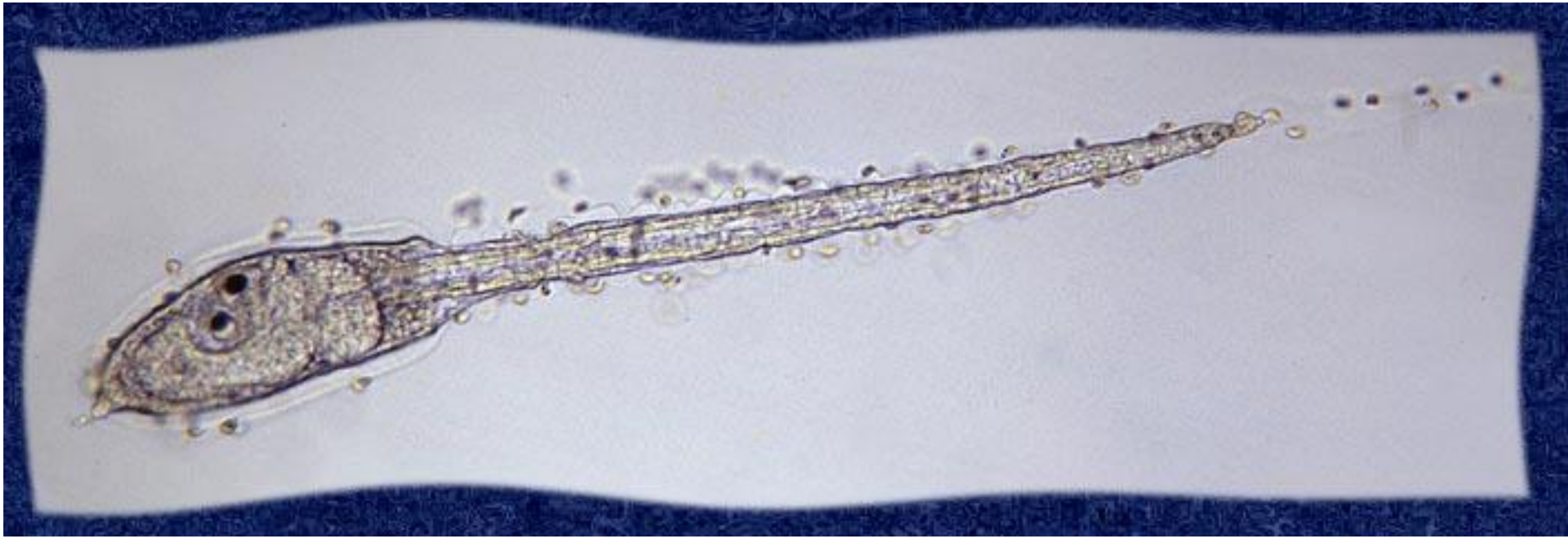
- (People used to think Hemichordata were included, but they turn out to be the sistergroup.)

SUBPHYLUM UROCHORDATA

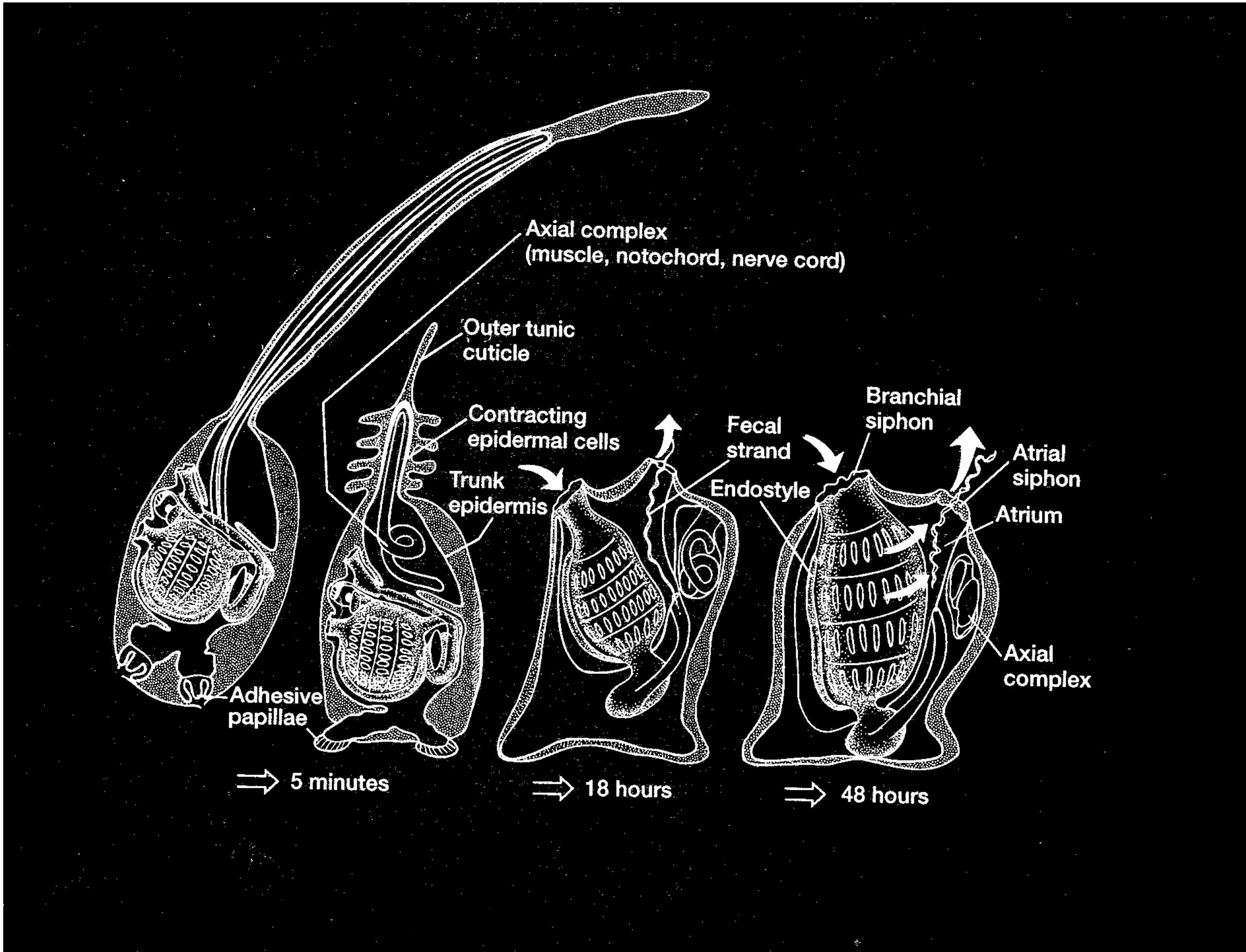
How can something like this be related to chordates like us?

Addition of a new life stage: a mobile larval stage.

CAENOGENESIS: Interpolation of a new life stage into the lifecycle.

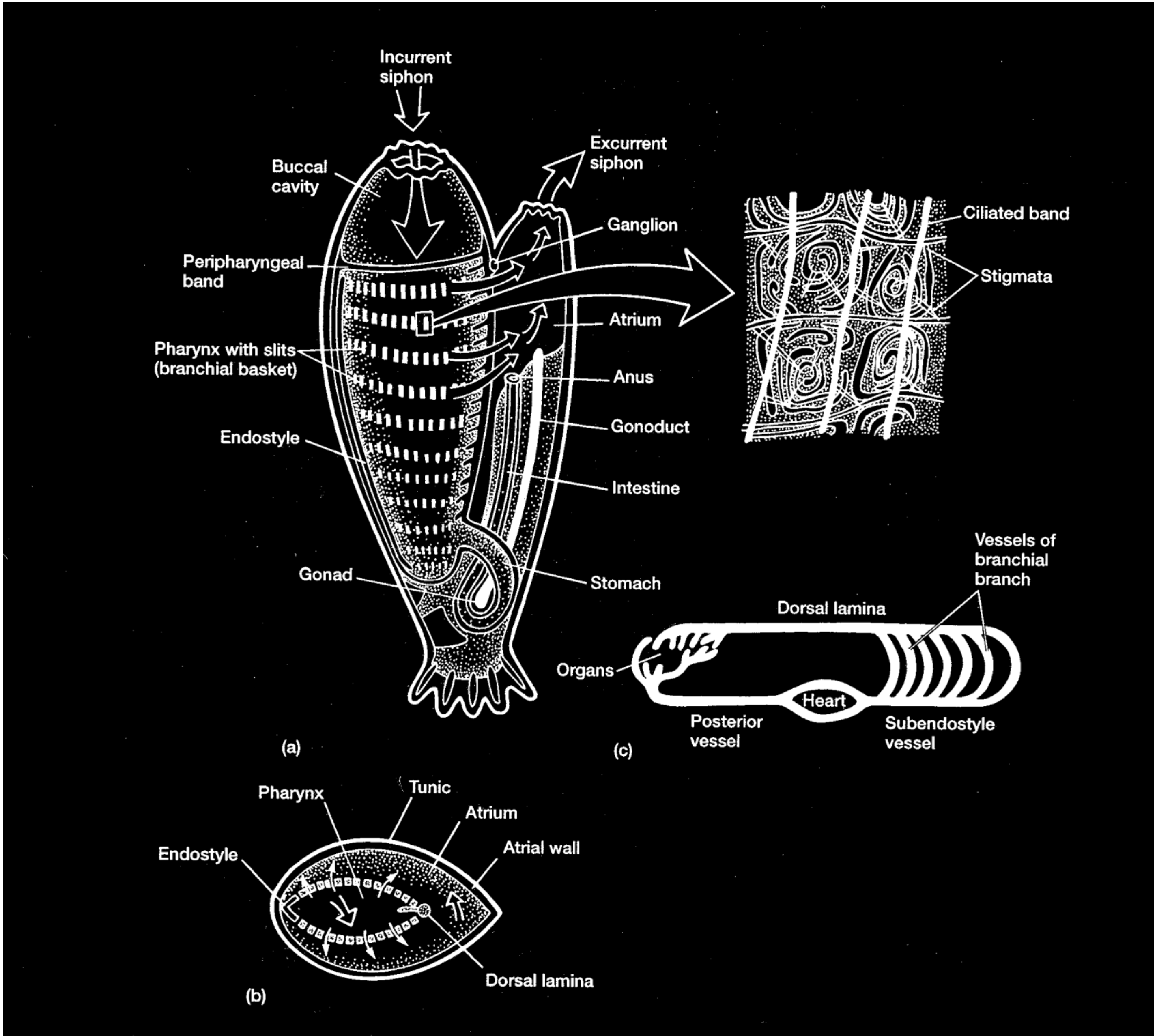


The new larval stage of a urochordate



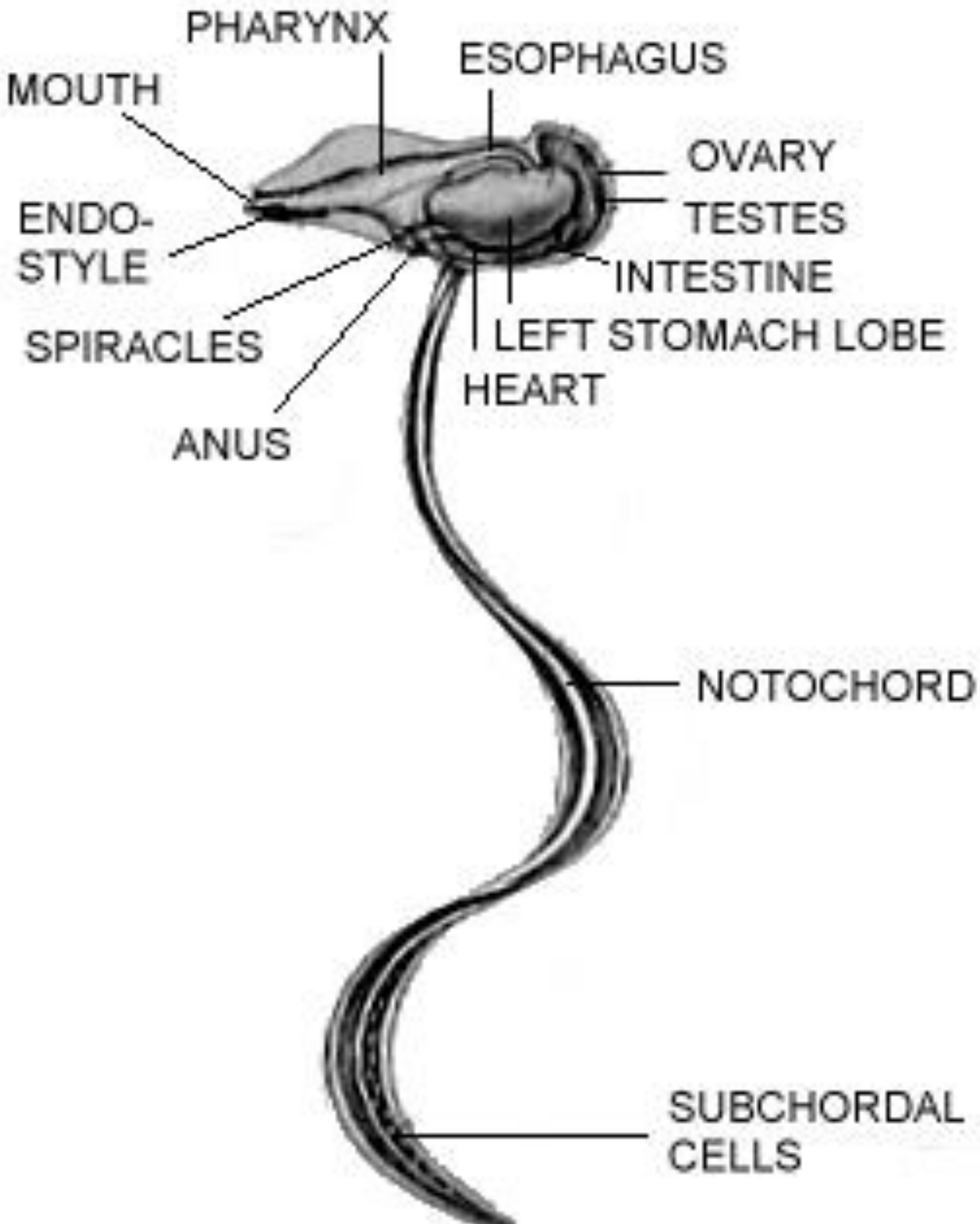
rom
larva to adult

Adult
urochordate

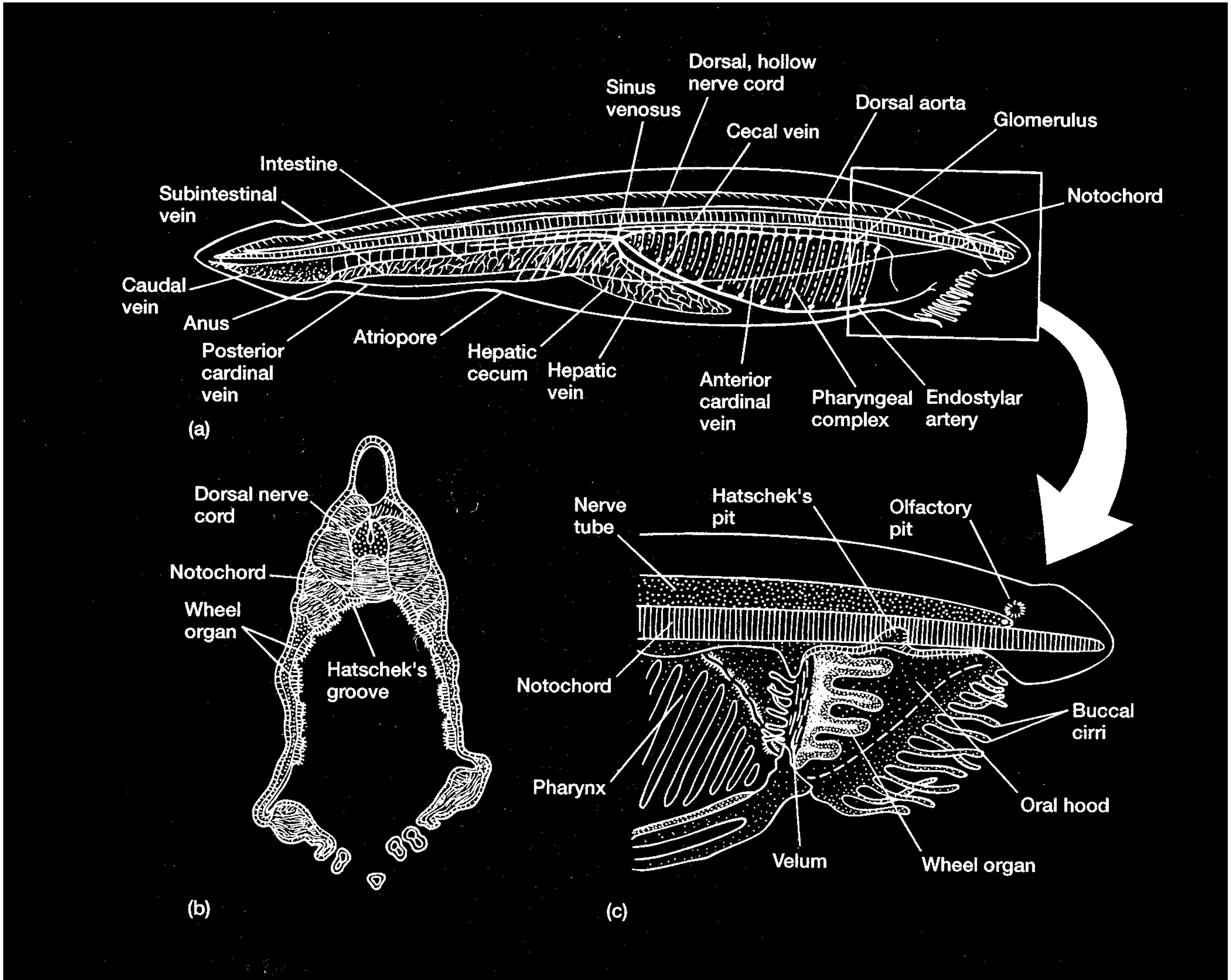


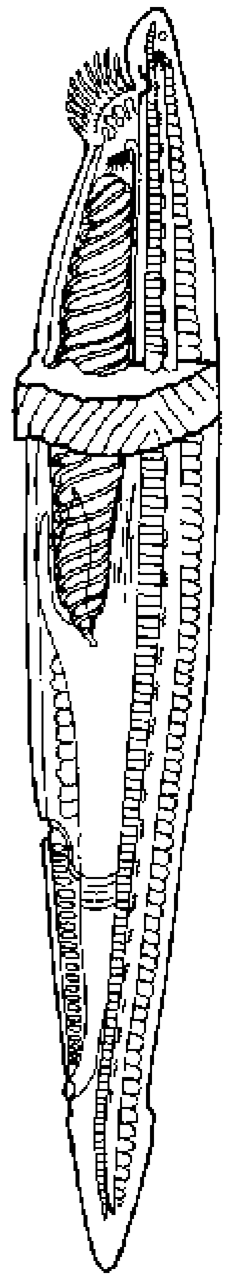
Incurrent siphon
Excurrent siphon
Buccal cavity
Ganglion
Peripharyngeal band
Atrium
Pharynx with slits (branchial basket)
Anus
Gonoduct
Endostyle
Intestine
Gonad
Stomach
(a)
Ciliated band
Stigmata
Vessels of branchial branch
Dorsal lamina
Organs
Heart
Posterior vessel
Subendostyle vessel
(c)
Pharynx
Tunic
Atrium
Atrial wall
Endostyle
Dorsal lamina
(b)

Some urochordates stay larval all life long, but they become sexually mature – an example of NEOTONY.

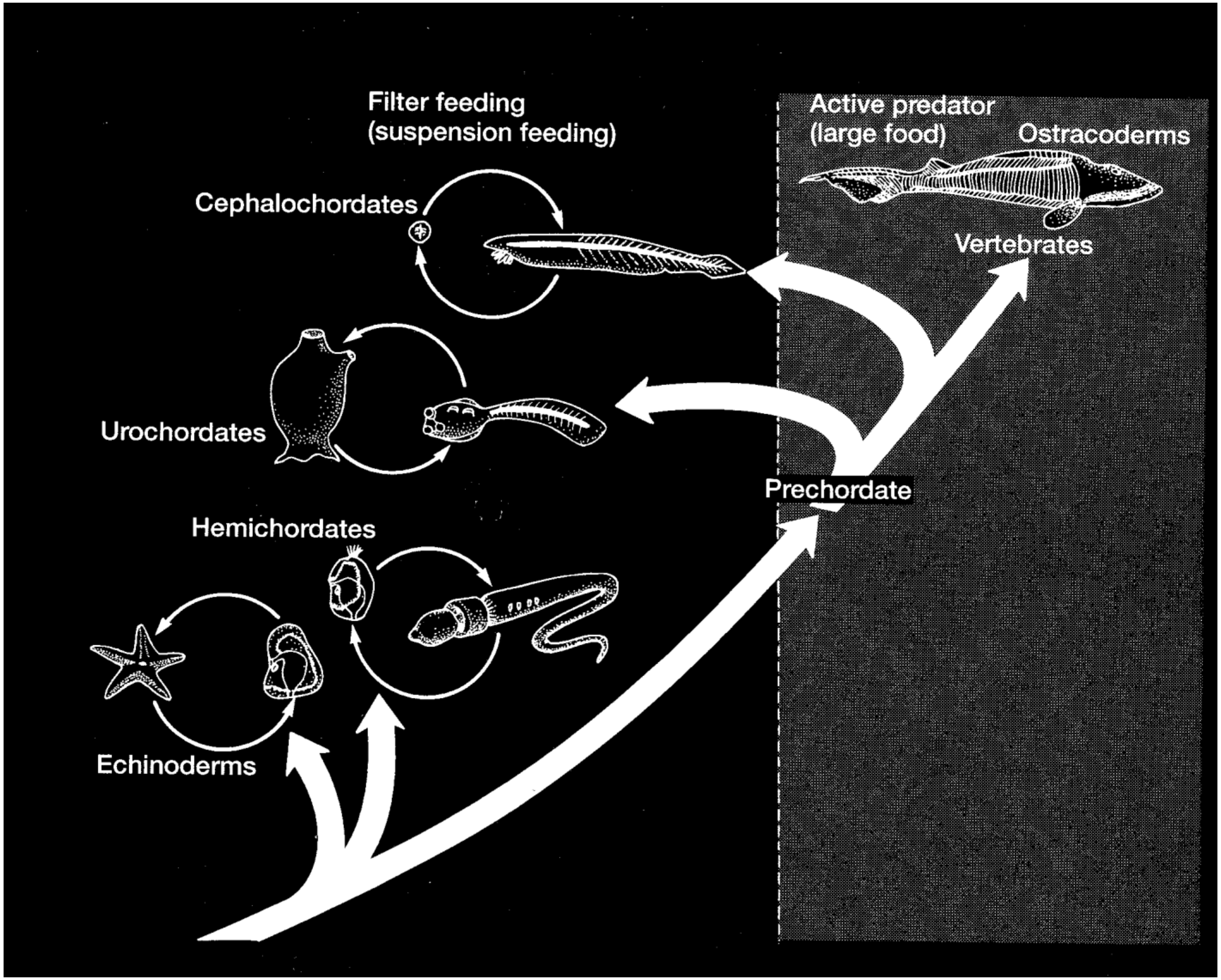

PHARYNX
ESOPHAGUS
MOUTH
OVARY
ENDO-
STYLE
TESTES
INTESTINE
SPIRACLES
LEFT STOMACH LOBE
HEART
ANUS
NOTOCHORD
SUBCHORDAL
CELLS

More “fish-like” PHYLUM CEPHALOCHORDATA

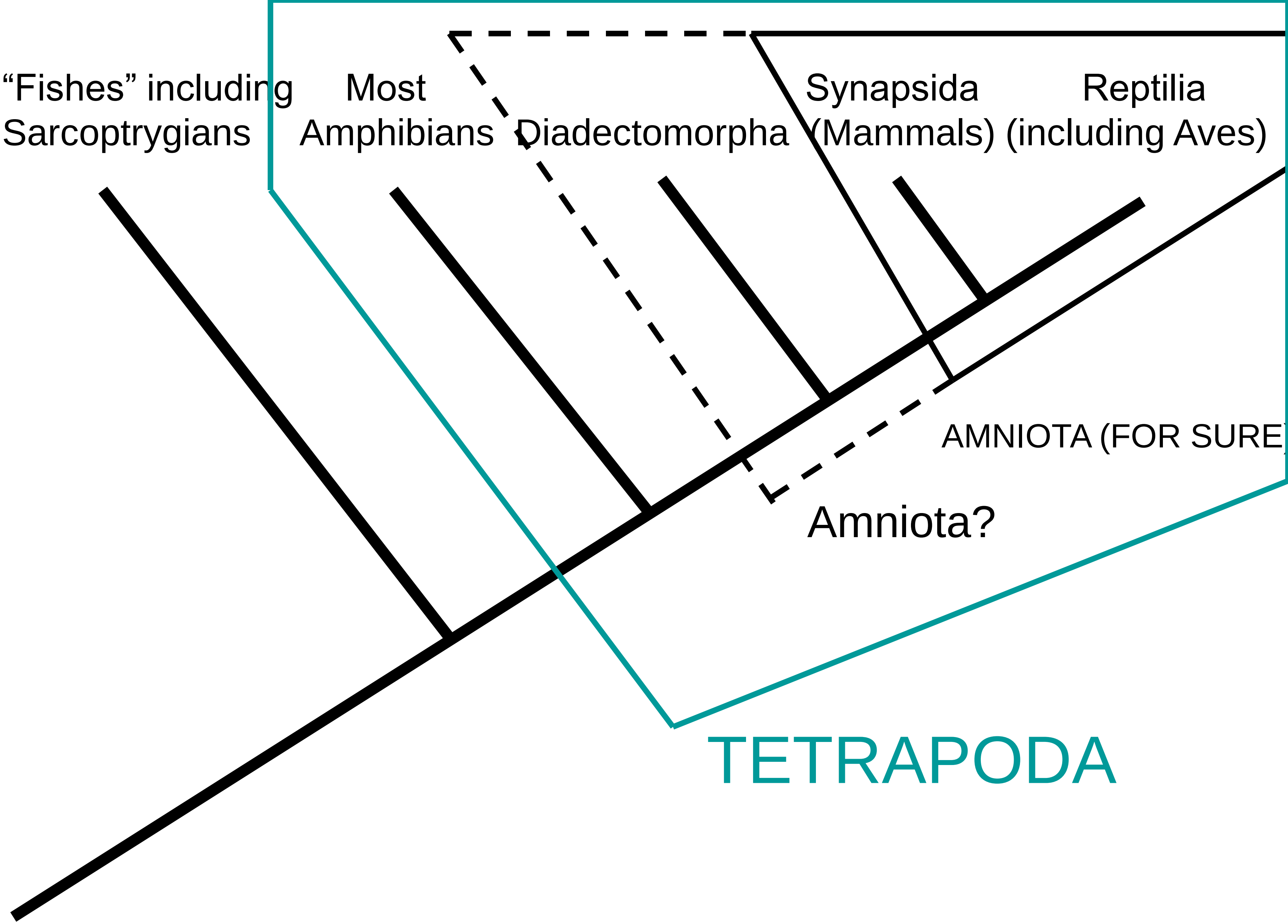

Dorsal, hollow nerve cord
Sinus venosus
Dorsal aorta
Glomerulus
Cecal vein
Intestine
Subintestinal vein
Notochord
Caudal vein
Anus
Posterior cardinal vein
Atriopore
Hepatic cecum
Hepatic vein
Anterior cardinal vein
Pharyngeal complex
Endostylar artery
(a)
Dorsal nerve cord
Notochord
Wheel organ
Hatschek's groove
(b)
Nerve tube
Hatschek's pit
Olfactory pit
Notochord
Buccal cirri
Pharynx
Oral hood
Velum
Wheel organ
(c)



So, then what’s a vertebrate…?



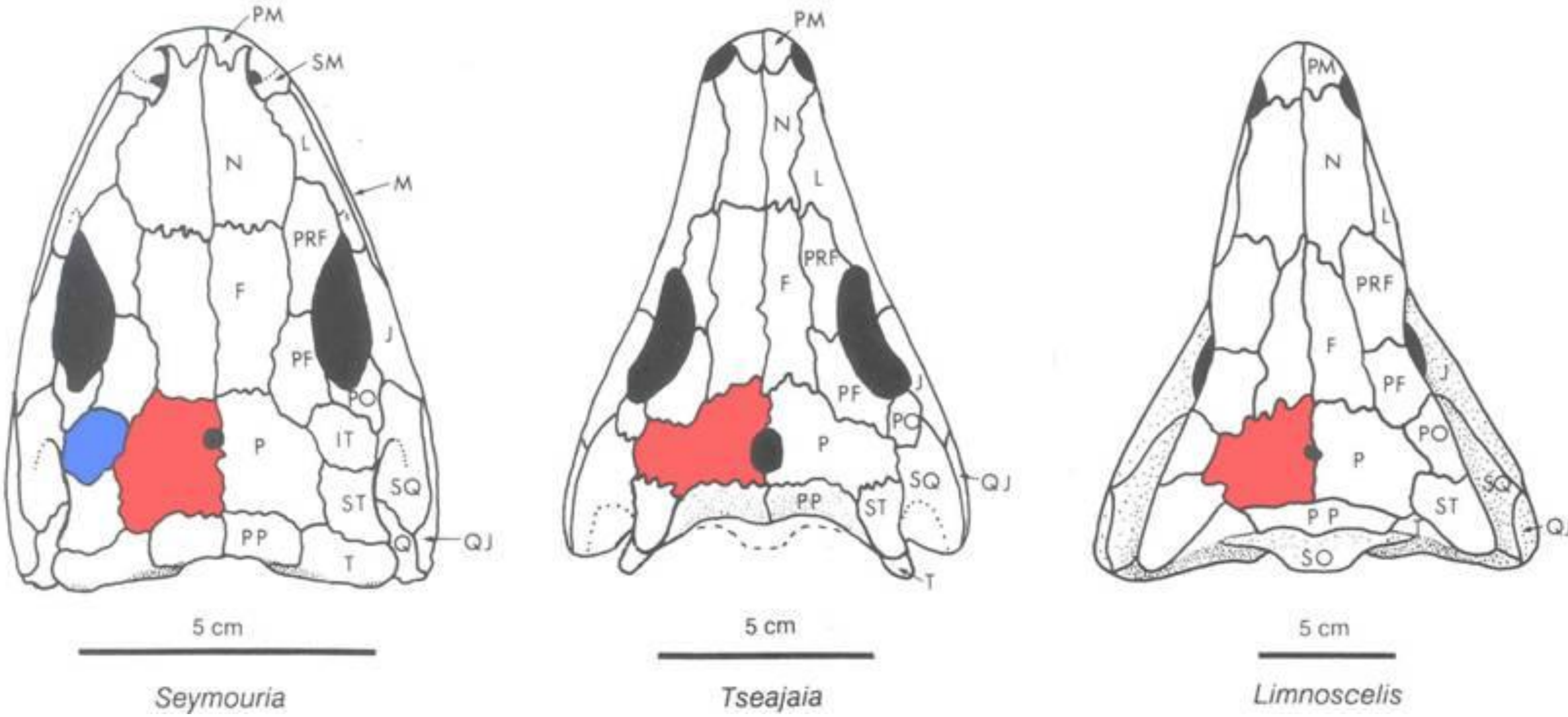
Filter feeding
(suspension feeding)
Active predator
(large food)
Ostracoderms
Cephalochordates
Vertebrates
Urochordates
Prechordate
Hemichordates
Echinoderms



“Fishes” including Sarcoptrygians
Most Amphibians
Diadectomorpha
Synapsida (Mammals)
Reptilia (including Aves)
AMNIOTA (FOR SURE)
Amniota?
TETRAPODA

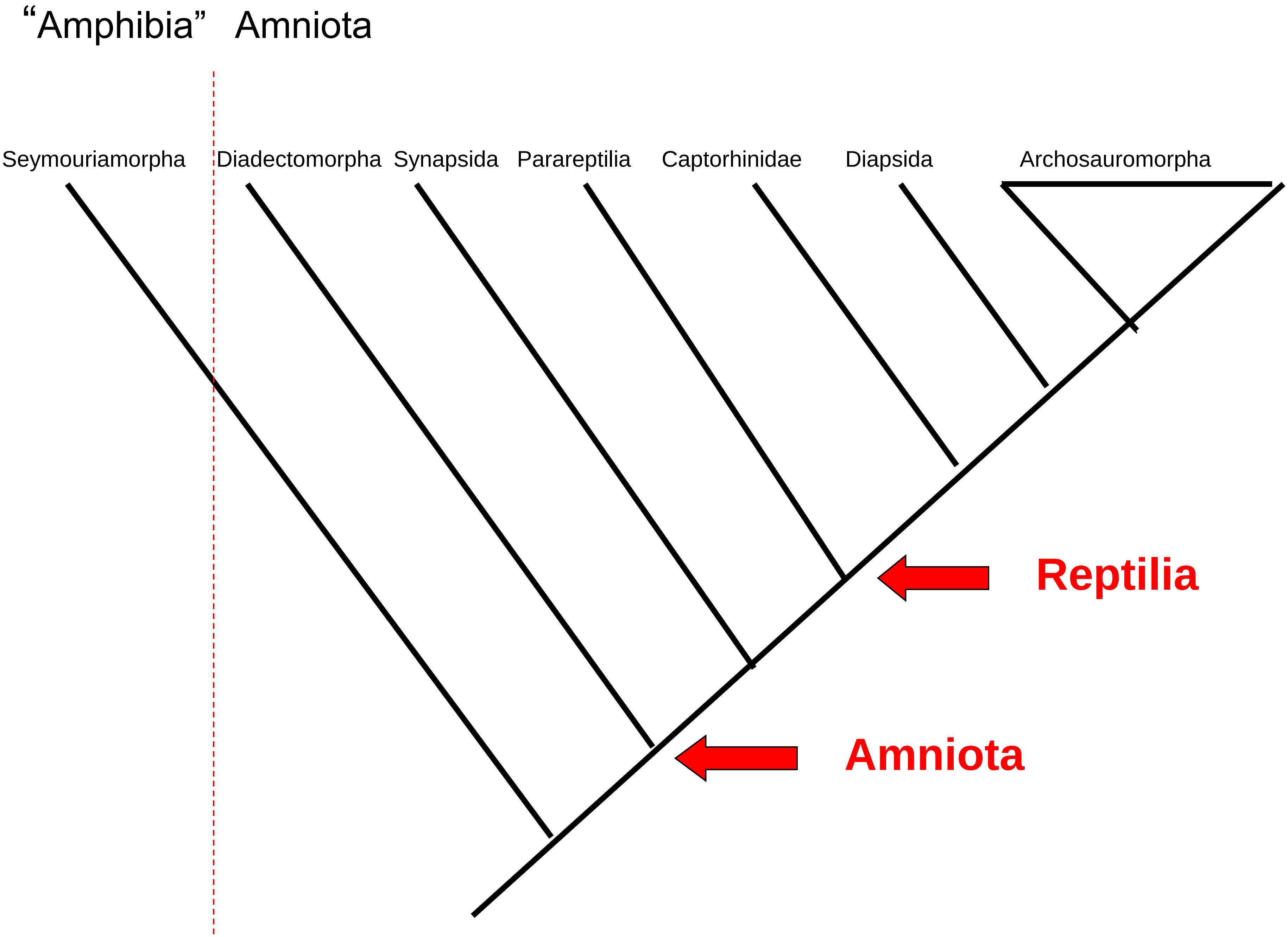
Amniotes: have four embryonic structures that reside outside the embryo to help it survive:

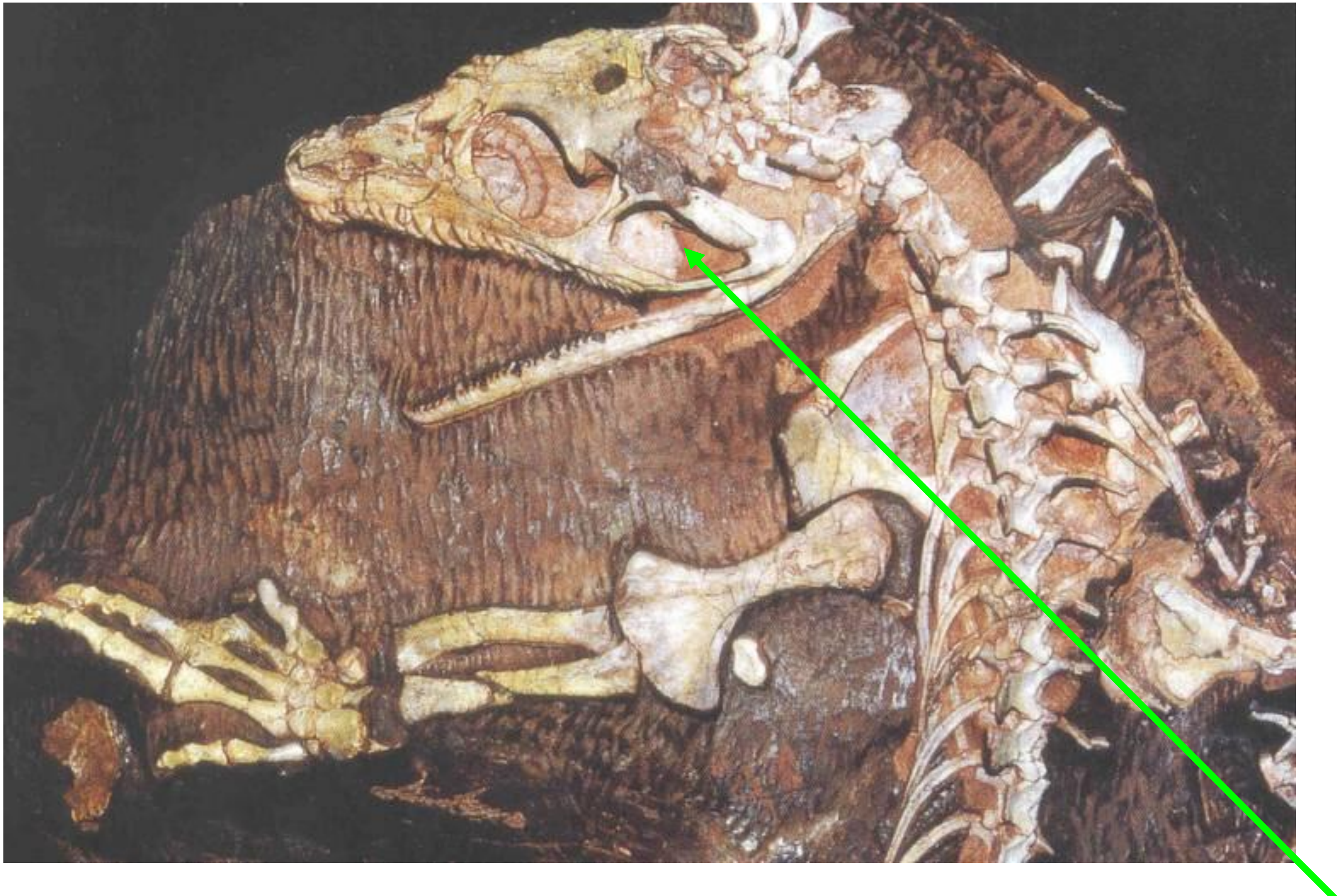
- Amnion
- Yolk sac
- Chorion
- Allantois



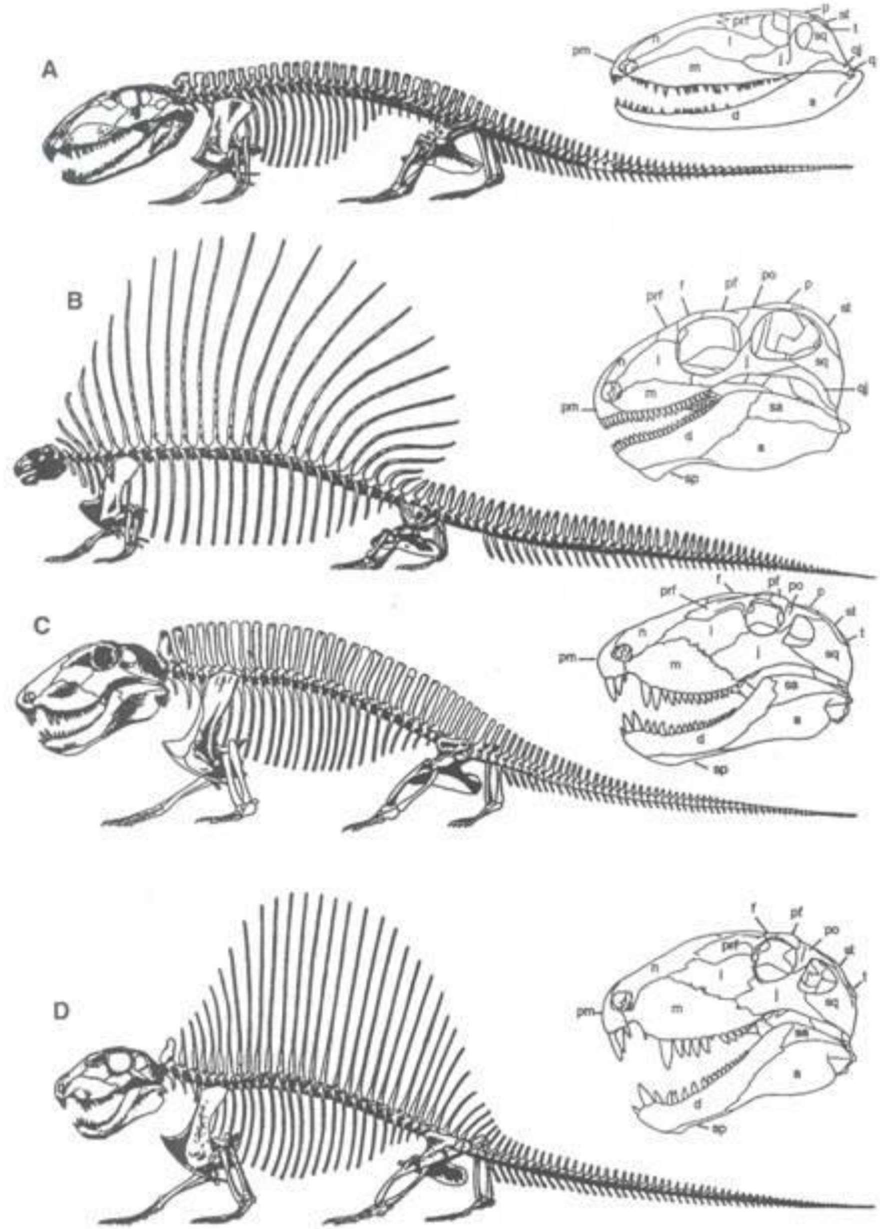
Diadectomorpha:

- No intertemporal bone like other amniotes
- Very terrestrially adapted


“Amphibia”
Amniota
Seymouriamorpha
Diadectomorpha
Synapsida
Parareptilia
Captorhinidae
Diapsida
Archosauromorpha
Reptilia
Amniota

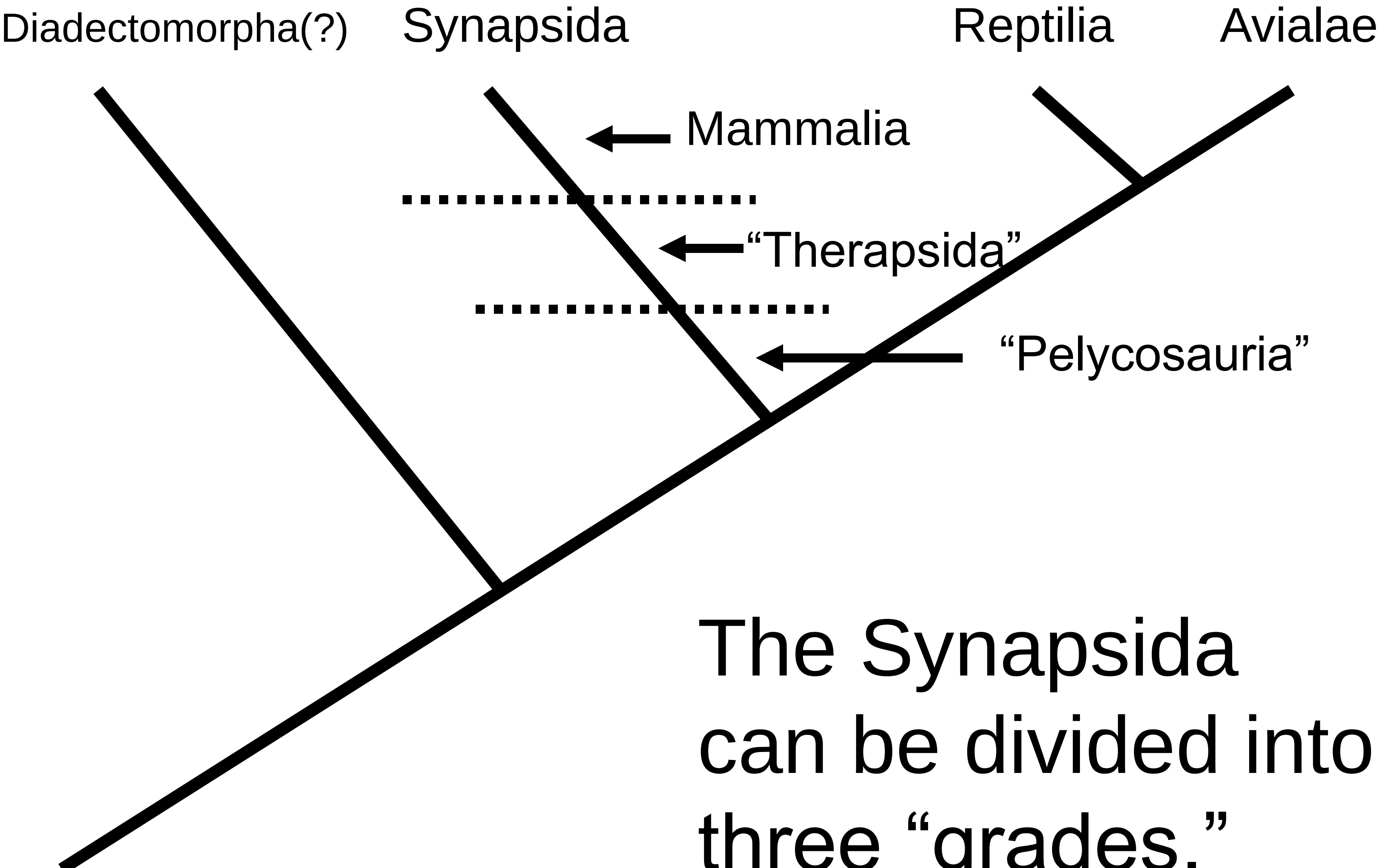


Basal Synapsida ("Pelycosauria"): A single opening on side of skull


A
B
C
D

Synapsida: Including Modern Mammals

AMNIOTA



The Synapsida can be divided into three “grades.”

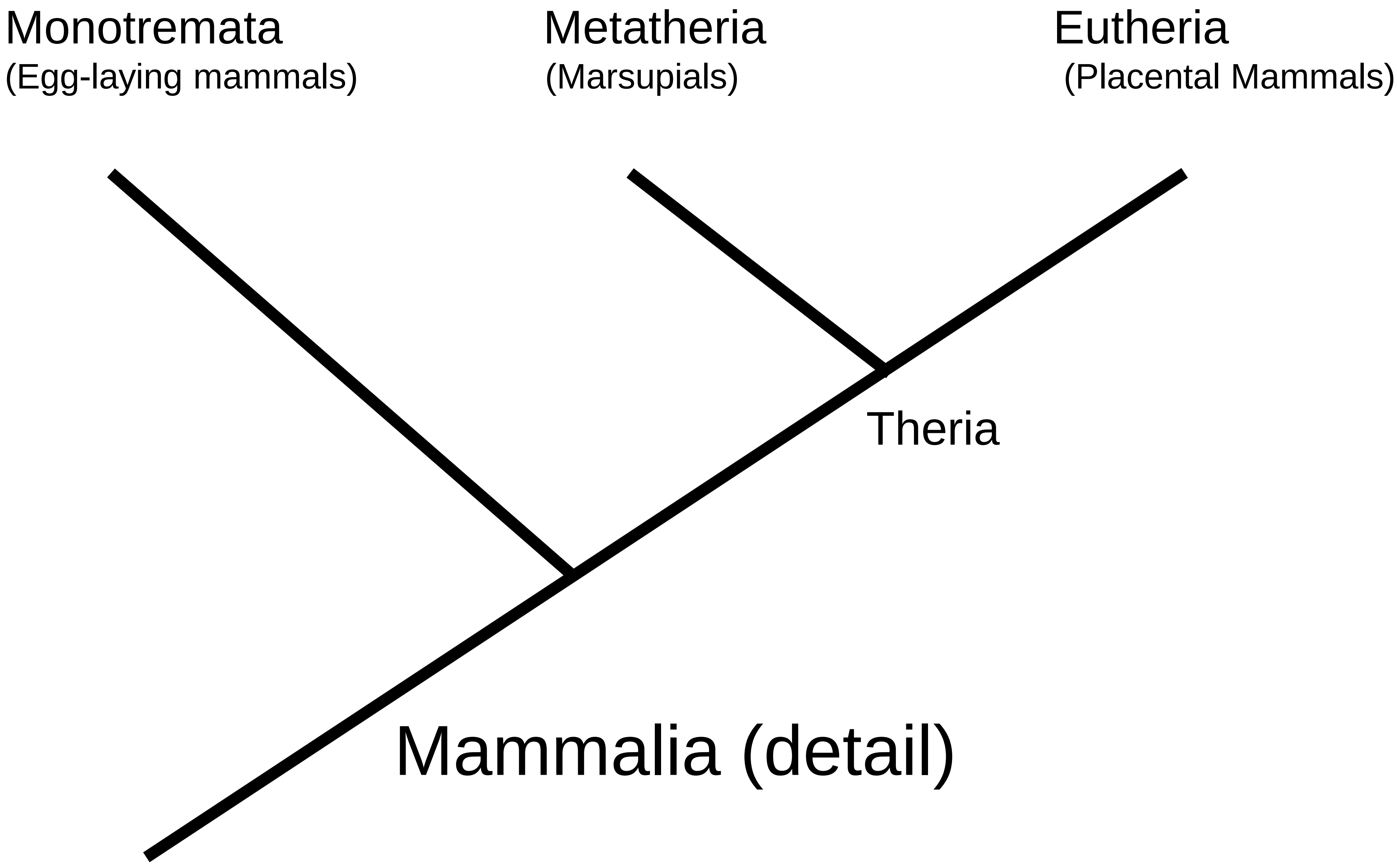
Mammals:

- Mammary glands
- Hair
- Facial muscles – muscles of facial expression
- A specialized jaw joint (between a single bone of the lower jaw (dentary) and the squamosal region of the skull)
- Three bones in the middle ear to help in hearing

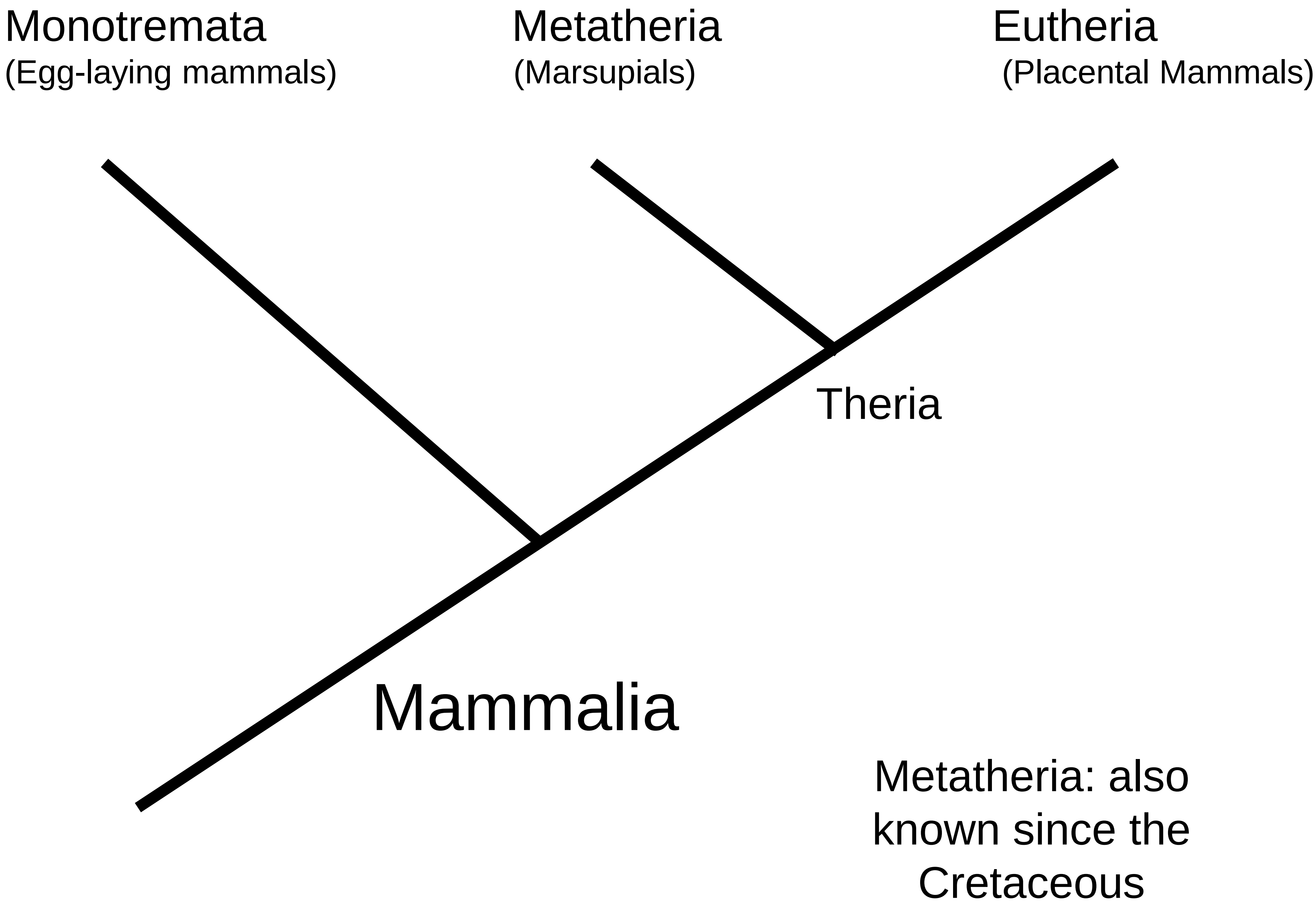
Mammals have mammary glands for NOURISHING THE YOUNG

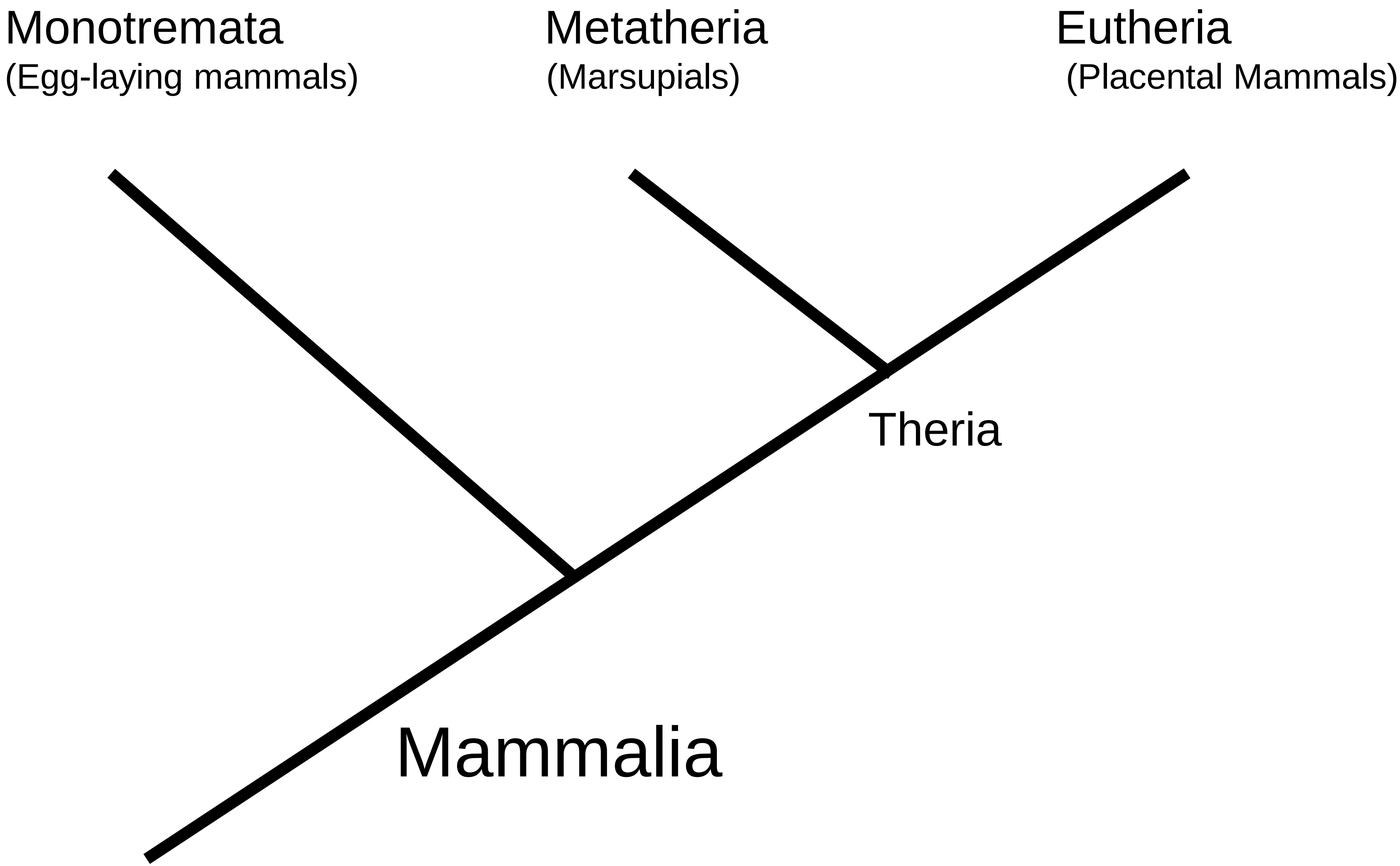
Mammals have HAIR.

Mammals have muscles of facial expression


Monotremata
(Egg-laying mammals)
Metatheria
(Marsupials)
Eutheria
(Placental Mammals)
Theria
Mammalia (detail)

The duck-billed platypus and spiney anteater (*Echidna*) are members of Monotremata (egg-laying mammals).


Monotremata
(Egg-laying mammals)
Metatheria
(Marsupials)
Eutheria
(Placental Mammals)
Theria
Mammalia
Metatheria: also known since the Cretaceous


Monotremata
(Egg-laying mammals)
Metatheria
(Marsupials)
Eutheria
(Placental Mammals)
Theria
Mammalia

The METATHERIA, also known as MARSUPIALS are often called the “pouch mammals” because although initial development is internal, much takes place in the mother’s pouch – which is technically outside the body.

A Placenta:

- Combination of the amniote Chorion and Allantois

- Helps the developing embryo to communicate with mother.

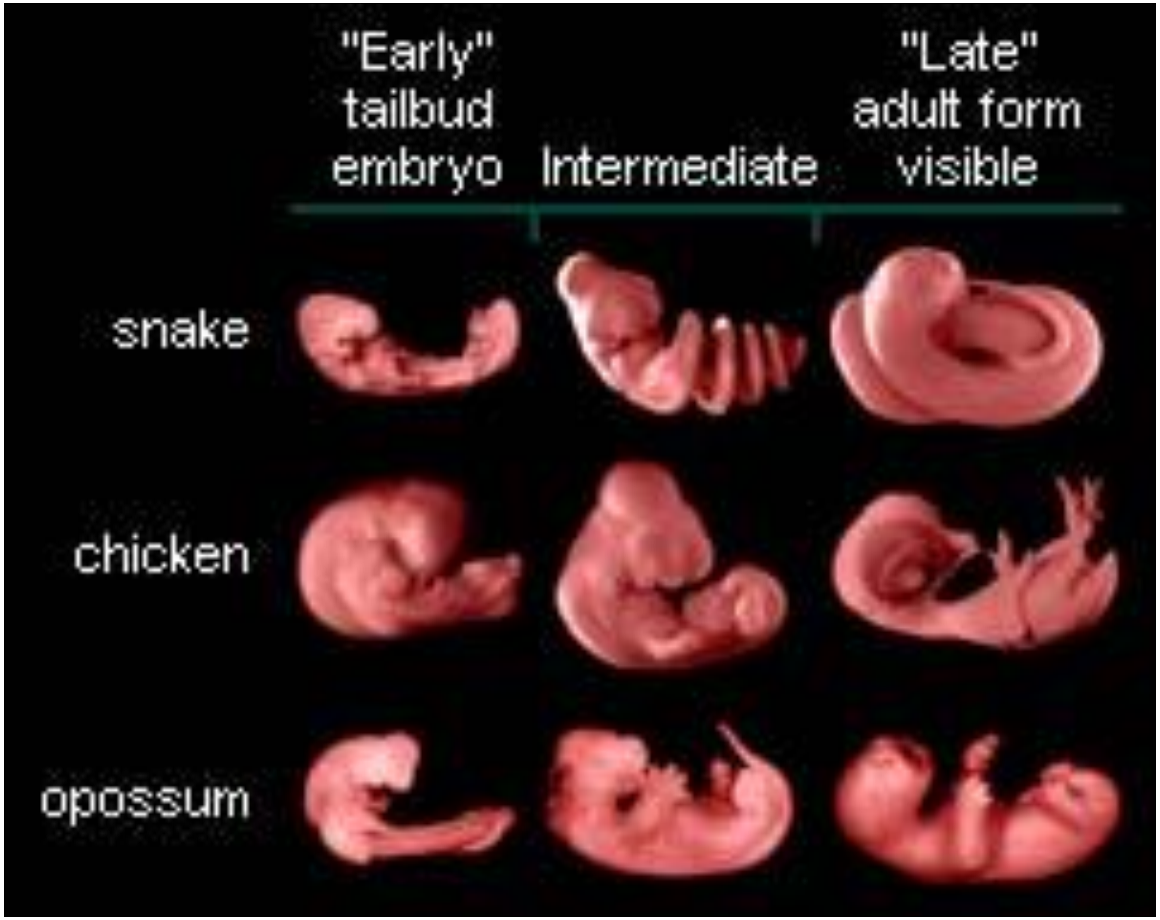
“Evo-Devo”
The Union of Evolutionary and Developmental Biology

Natural for evolutionary biologists and developmental biologists to find common ground. Evolutionary biologists seek to understand how organisms evolve and change their shape and form. The roots of these changes are found in the developmental mechanisms that control body shape and form.

Darwin's perception was given a theoretical basis and evo-devo its first theory when Ernst Haeckel proposed that because ontogeny (development) recapitulates phylogeny (evolutionary history), evolution could be studied in embryos.

Technological advances in histological sectioning and staining made simultaneously in the 1860s and 1870s enabled biologists to compare the embryos of different organisms.

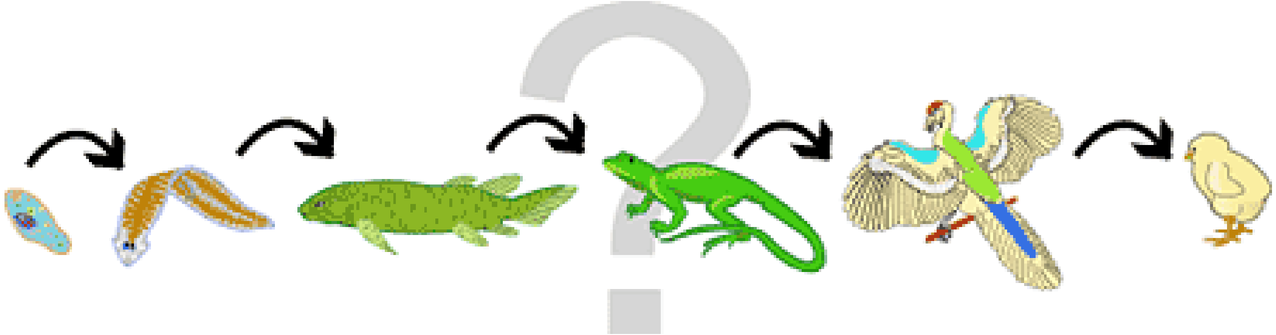
Though false in its strictest form, Haeckel's theory lured most morphologists into abandoning the study of adult organisms in favor of embryos--literally to seek evolution in embryos.



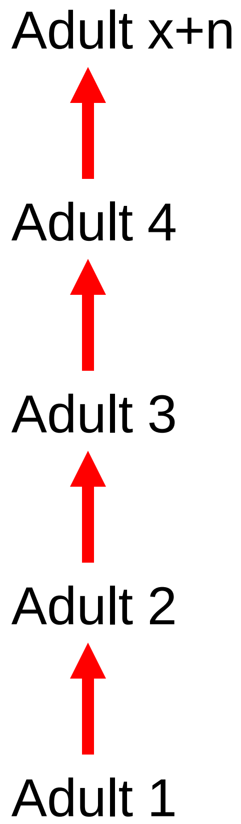
Notice how ontogenetically early forms appear more similar.

The idea that ontogeny recapitulates phylogeny suggests that an organism's development will take it through each of the adult stages of its evolutionary history, or its phylogeny. Thus its development would reiterate its evolutionary history — ontogeny recapitulating phylogeny.

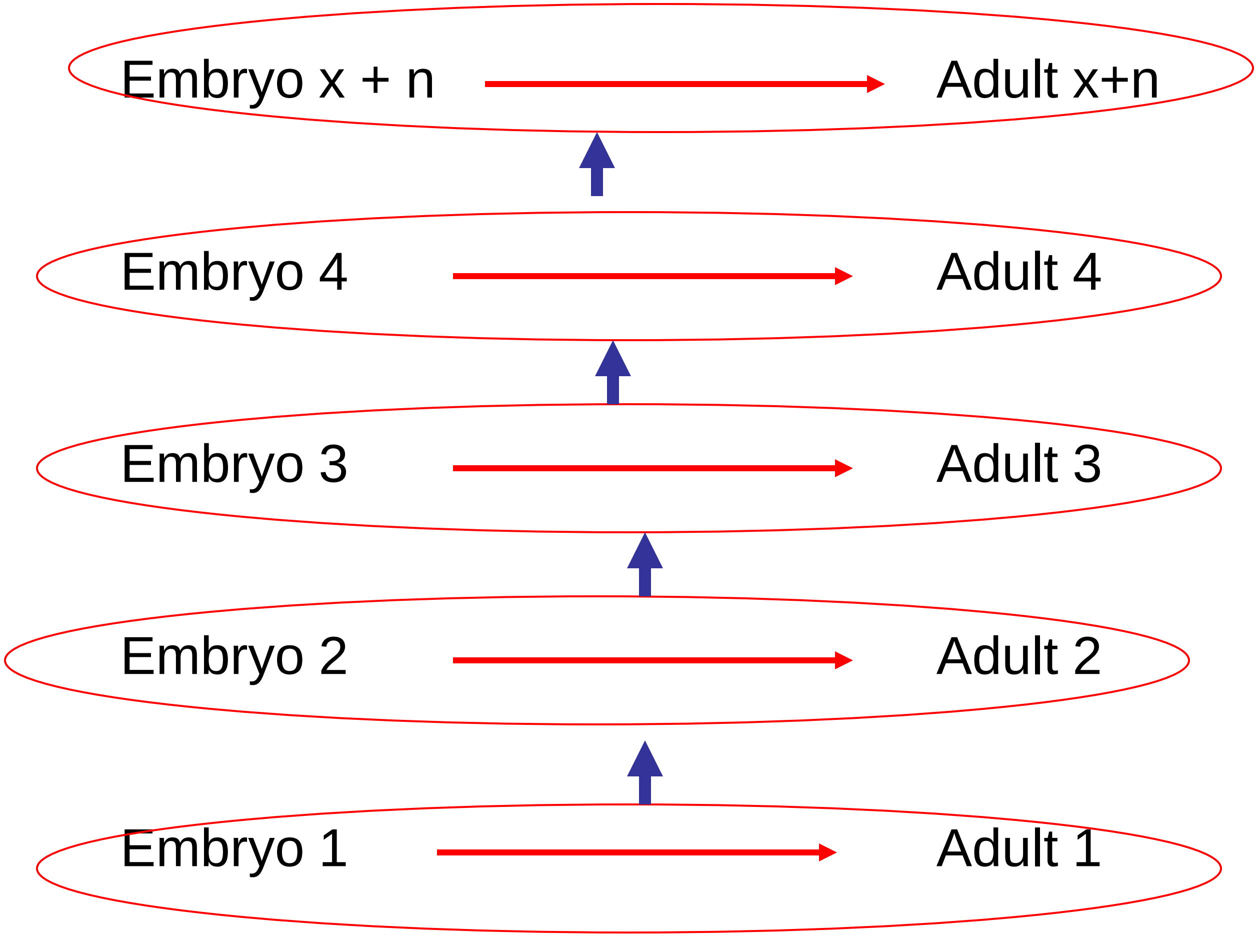
This idea is an extreme one. If it were strictly true, it would predict, for example, that in the course of a chick's development, it would go through the following stages: a single celled organism, a multi-celled invertebrate ancestor, a fish, a lizard-like reptile, an ancestral bird, and then finally, a baby chick.



What is clear is that we cannot only study evolution by looking at a progression of adult structures.



We must study the evolution of ontogenies.



Useful characters for understanding the evolution of organisms/groups can come from any ontogenetic stage.