Body Plans and the Diversity of Life

36-149 The Tree of Life

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The Body Plan Concept

- Body plans form an idealized, overlapping hierarchy of "types" containing groups of organisms.
- Analogy: Watersheds
- These relate strongly to intuitive/folk categories of living things.
- They also relate to features during the gestational development of the organism.
- We will see that the concept has critical limitations, but it is a useful starting point in our thinking about how to organize life's diversity.

Two Inspirations for the “Body Plan” Concept

1. In the 1840s, Richard Owen noticed the similar structures underlying the organs and bones of different species.

   He saw these similarities as the manifestation of an “archetype” – an idealized, standard body plan for a group of animals.

   (Owen was one of the premier comparative anatomists of his day, the namer of Dinosaurs, and a character we’ll meet again.)

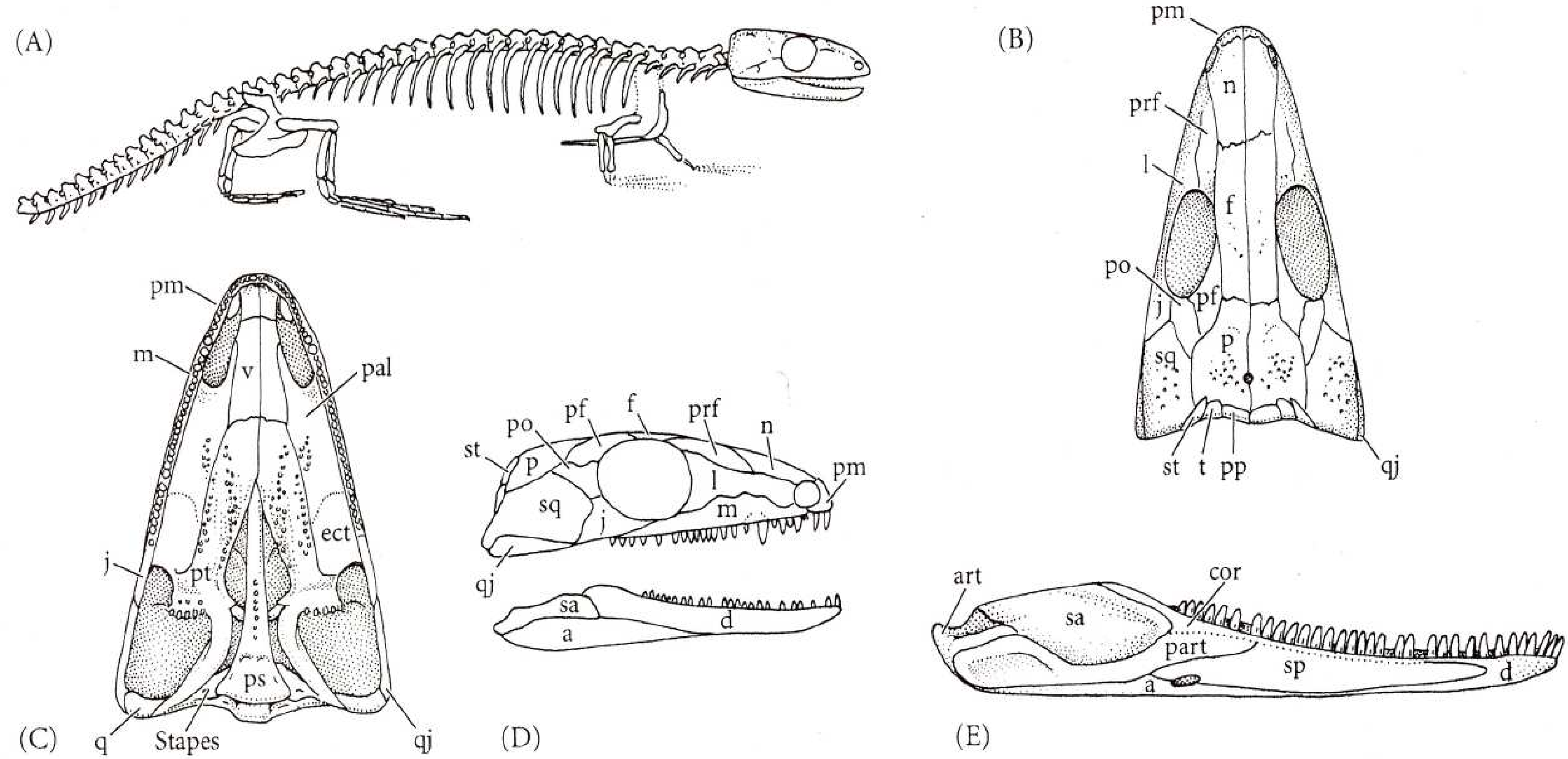
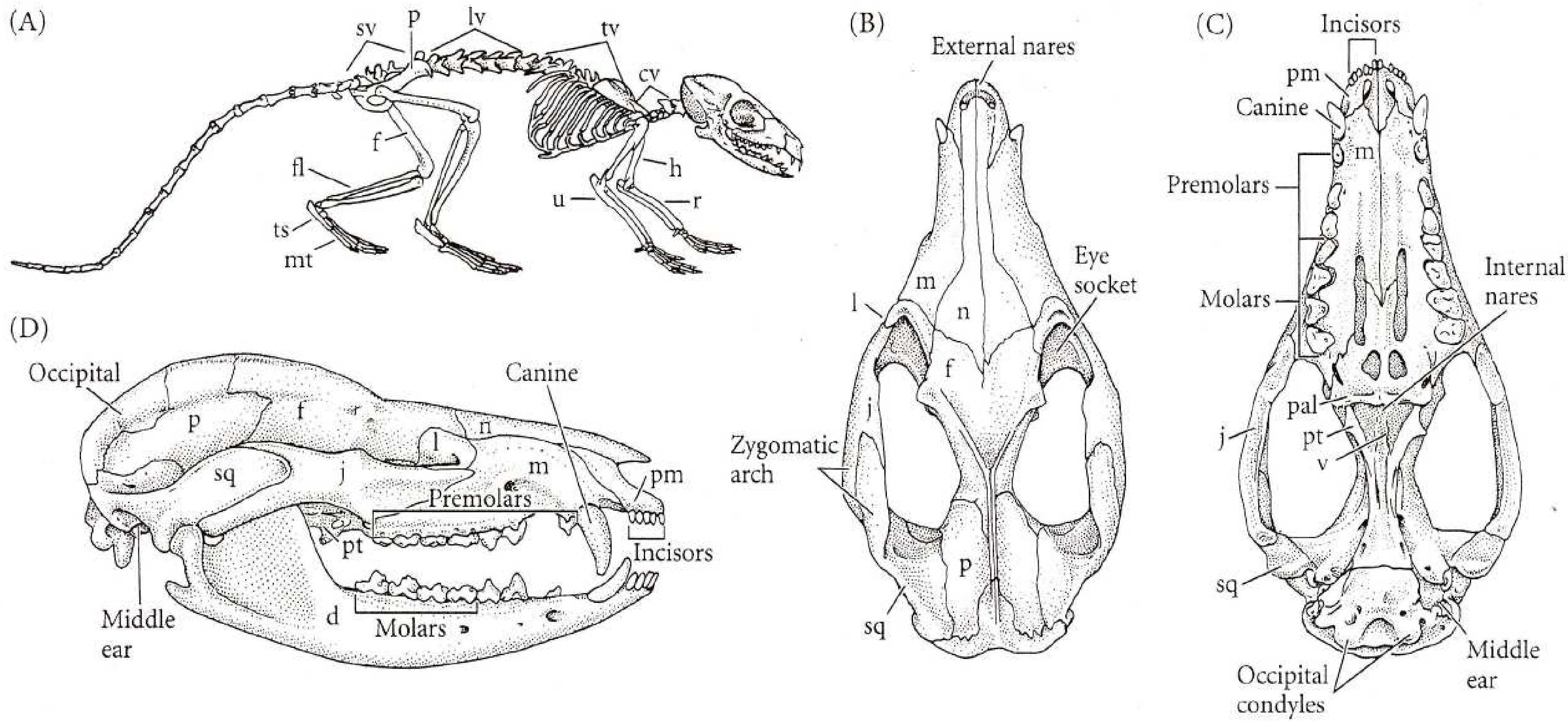


FIGURE 6.20 Early amniotes ("reptiles") in the family Protorothyridae. One of the few differences from amphibians is the lack of a notch at the rear of the skull (cf. Figure 6.19). (A) Skeleton of *Hylonomus.* (B–D) Dorsal, ventral, and lateral views of skull of *Paleothyris.* (E) Medial (inner) view of lower jaw of *Protorothyris.* Compare with amphibians (Figure 6.19) and mammal-like "reptiles." (A–C after Carroll and Baird 1972; D after Carroll 1988; E after Clark and Carroll 1973.)

FIGURE 6.21 The "ground plan" of the skeleton of modern mammals. Compare with early amniotes ("reptiles"), as in Figure 6.20, and with mammal-like reptiles (Figures 6.23–26). (A) Skeleton of a tree shrew (*Tupaia*). cv, tv, lv, sv: cervical, thoracic, lumbar, and sacral vertebrae; f, femur; fl, fibula; h, humerus; mt, metatarsals; p, pelvic girdle; r, radius; ts, tarsals; u, ulna. (B,C,D) Dorsal, ventral, and lateral views of the skull of a marsupial, the opossum *Didelphis*. See Figure 6.18 for abbreviations. Note: differentiated teeth, the premolars and molars with multiple cusps; frontals (f) and parietals (p) constitute walls of anterior part of braincase; eye socket confluent with a large fenestra, laterally bounded by zygomatic arch consisting of parts of the jugal (j) and squamosal (sq); two occipital condyles; lower jaw of one bone, the dentary (d). (A after Romer 1966; B–D after Carroll 1988.)

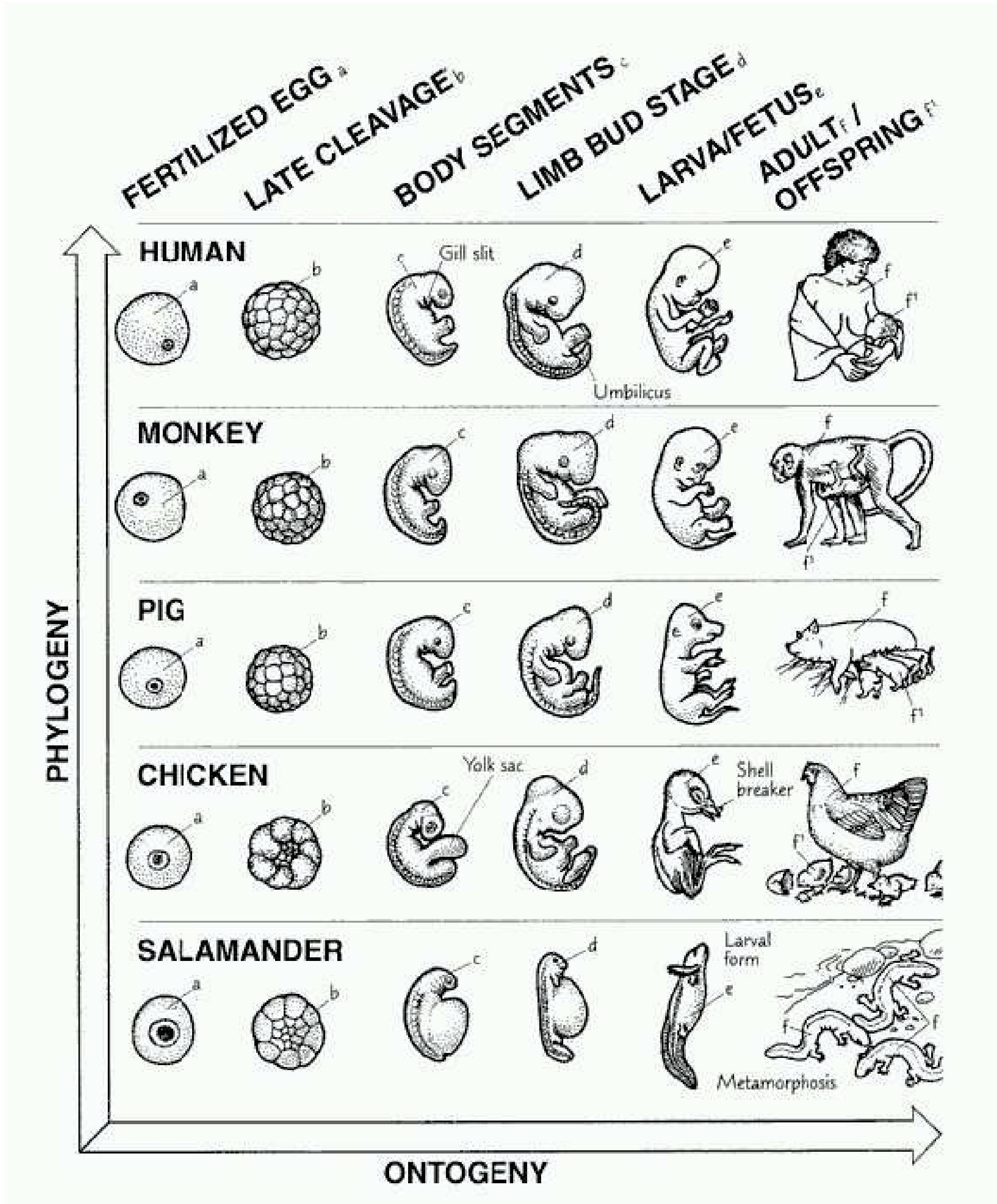


Two Inspirations for “Body Plan” (cont’d)

2. In the late 1820s, Karl Ernst von Baer studied the development of animal embryos and concluded that “[t]he general features of a large group of animals appear earlier in the embryo than the special features.”

   That is, in the early states of embryonic development, related animals are highly similar, but they diverge as development proceeds and distinguishing features are added.

   The basic architecture of the body thus emerges quite early.


FERTILIZED EGG a
LATE CLEAVAGE b
BODY SEGMENTS c
LIMB BUD STAGE d
LARVA/FETUS e
ADULT f /
OFFSPRING f¹
HUMAN
Gill slit
Umbilicus
MONKEY
PIG
CHICKEN
Yolk sac
Shell
breaker
SALAMANDER
Larval
form
Metamorphosis
PHYLOGENY
ONTOGENY

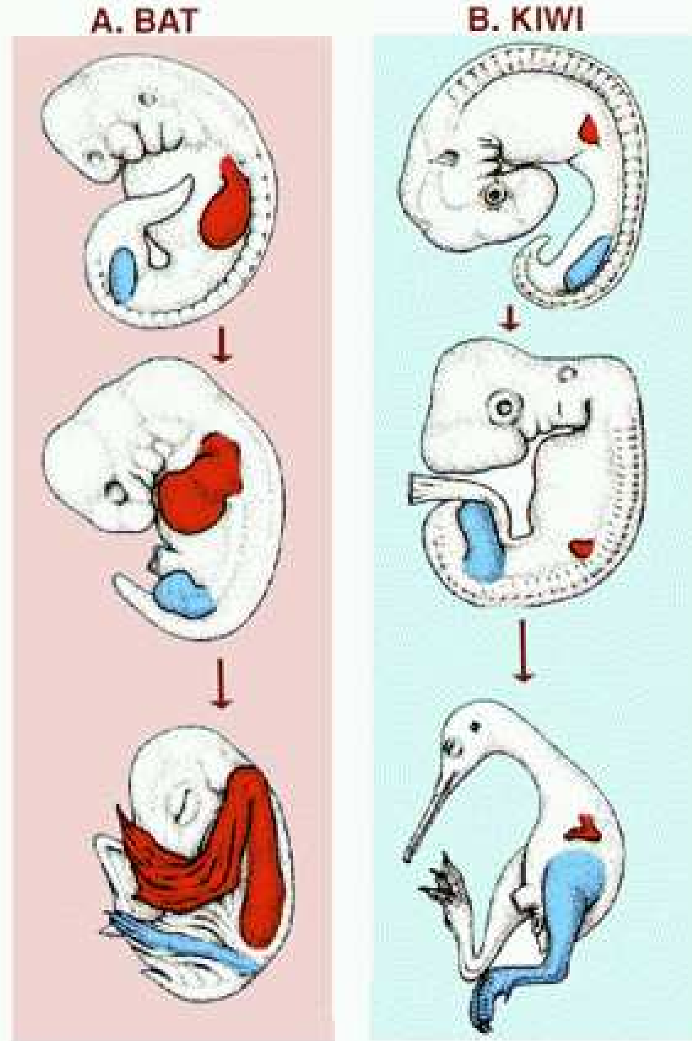


Figure 1 Development of (A) the bat (*Rousettus amplexicaudatus*) which has a large forelimb bud and wing, and (B) the kiwi (*Apteryx australis*), a flightless bird with relatively small forelimbs. (After Richardson 1999.)

Important Terminology

- morphology — form, shape, external structure or arrangment of a living organism and its parts.
- character — a (heritable) trait possessed by an organism (e.g., number of appendages, has feathers, has a wishbone, number of teeth)
- character state: a value that a character may have (e.g., 4, yes, yes, 0)

  Many characters are *binary* meaning that they can have one of two states, usually presence or absence of some anatomical feature.
- homology – a specific notion of structural similarity between parts of two organisms; we'll come back later to this important idea in more detail.

What is a Body Plan?

- A body plan is a collection of major structural features and developmental processes that correspond by homology within a large group of animals.
- Traditionally, body plans are identified as unique combinations of character states, including the following:

Character	Main States
Skeleton	internal, external, hydrostatic
Symmetry	bilateral, radial, asymetric
Appendages	0, 4, 6, 8, . . .
Segmentation	yes, no
Body Cavity	yes (coelom), no (aceol), sort of (pseudocoel)
Germ Layers	2 (diploblasts), 3 (triploblasts)
Cleavage Pattern	spiral, radial, superficial, . . .

Body Plan Examples

Character	Group		
	Tetrapod	Insects	Jellyfish (Cnidarians)
Skeleton			
Symmetry			
Appendages			
Segmentation			
Body Cavity			
Germ Layers			
Cleavage Pattern			

Body Plan Examples (cont'd)

Character	Group		
	Tetrapod	Insects	Jellyfish (Cnidarians)
Skeleton	Internal		
Symmetry	Bilateral		
Appendages	4		
Segmentation	Yes		
Body Cavity	Yes		
Germ Layers	3		
Cleavage Pattern	radial		

Body Plan Examples (cont'd)

Character	Group		
	Tetrapod	Insects	Jellyfish (Cnidarians)
Skeleton	Internal	External	
Symmetry	Bilateral	Bilateral	
Appendages	4	6	
Segmentation	Yes	Yes	
Body Cavity	Yes	Yes	
Germ Layers	3	3	
Cleavage Pattern	radial	superficial	

Body Plan Examples (cont'd)

Character	Group		
	Tetrapod	Insects	Jellyfish (Cnidarians)
Skeleton	Internal	External	Hydrostatic
Symmetry	Bilateral	Bilateral	Radial
Appendages	4	6	many
Segmentation	Yes	Yes	No
Body Cavity	Yes	Yes	No
Germ Layers	3	3	2
Cleavage Pattern	radial	superficial	spiral

So Similar, Yet So Different

- How do we tell when two structures in different organisms are similar or different?
- We must be careful. Structures can look similar but be different, or look different but be similar.
- Owen defined a term – homology – which he described as "the same organ [structure] in different animals under every variety of form and function."

  But how do we tell it's the same if its form and function will be different? In the coming weeks, we will refine this idea of homology very carefully.
- But for now, some examples. Which of the following are the same, which are different?

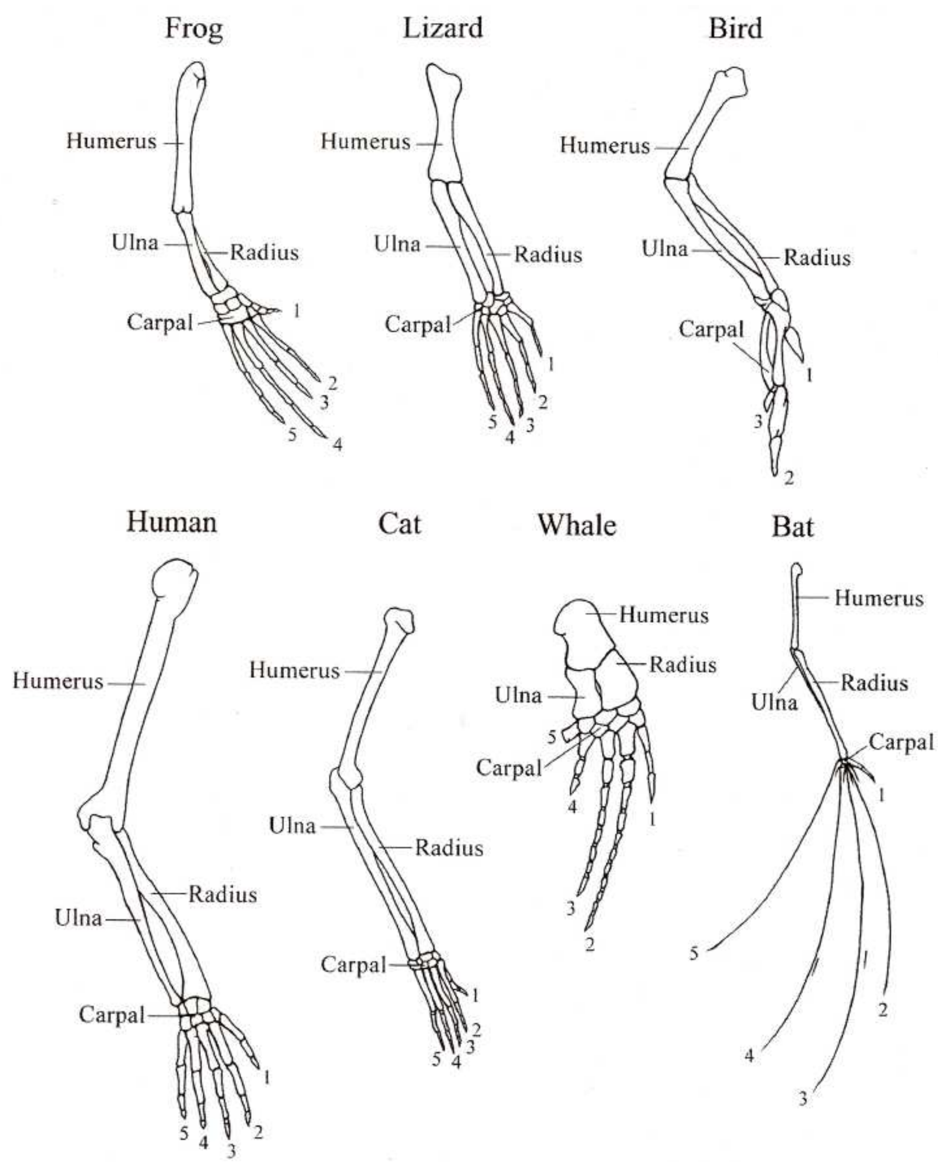
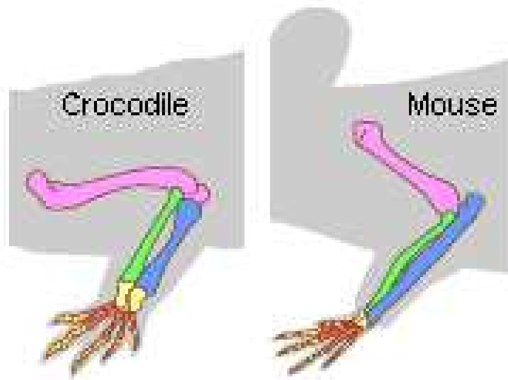
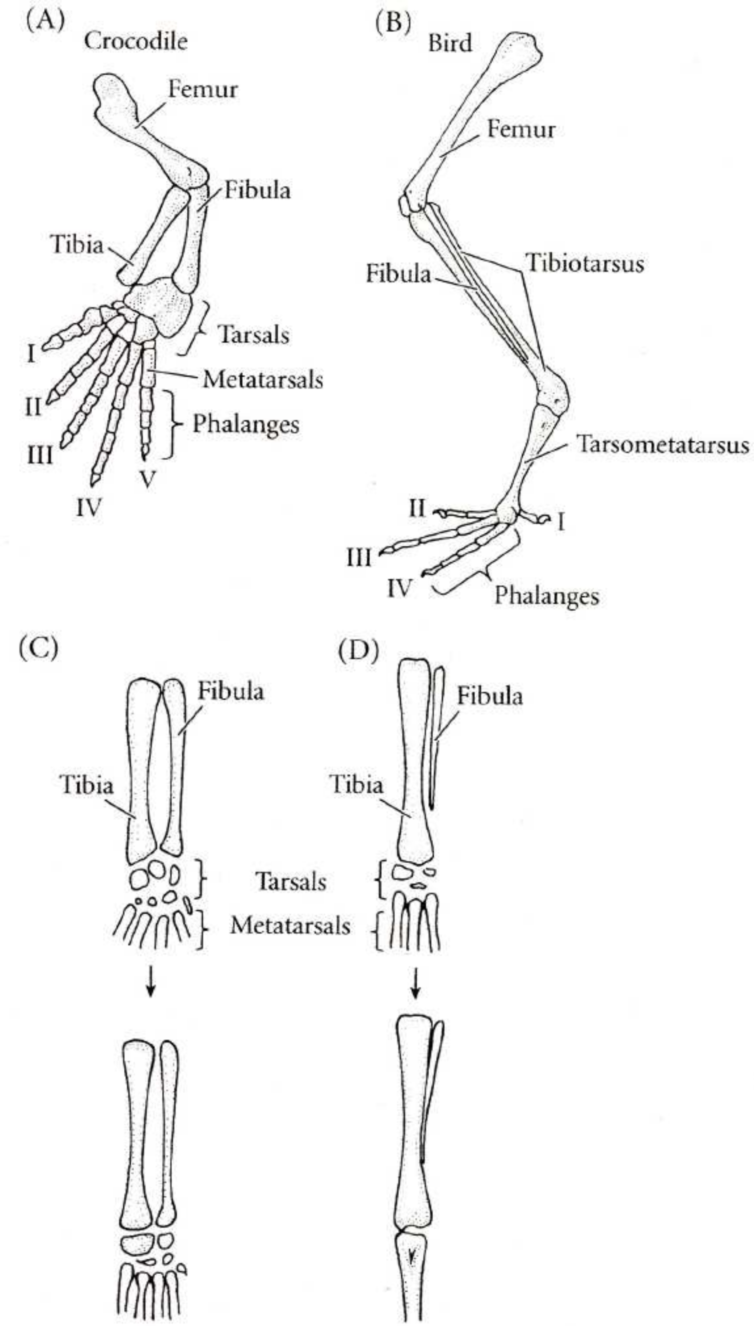


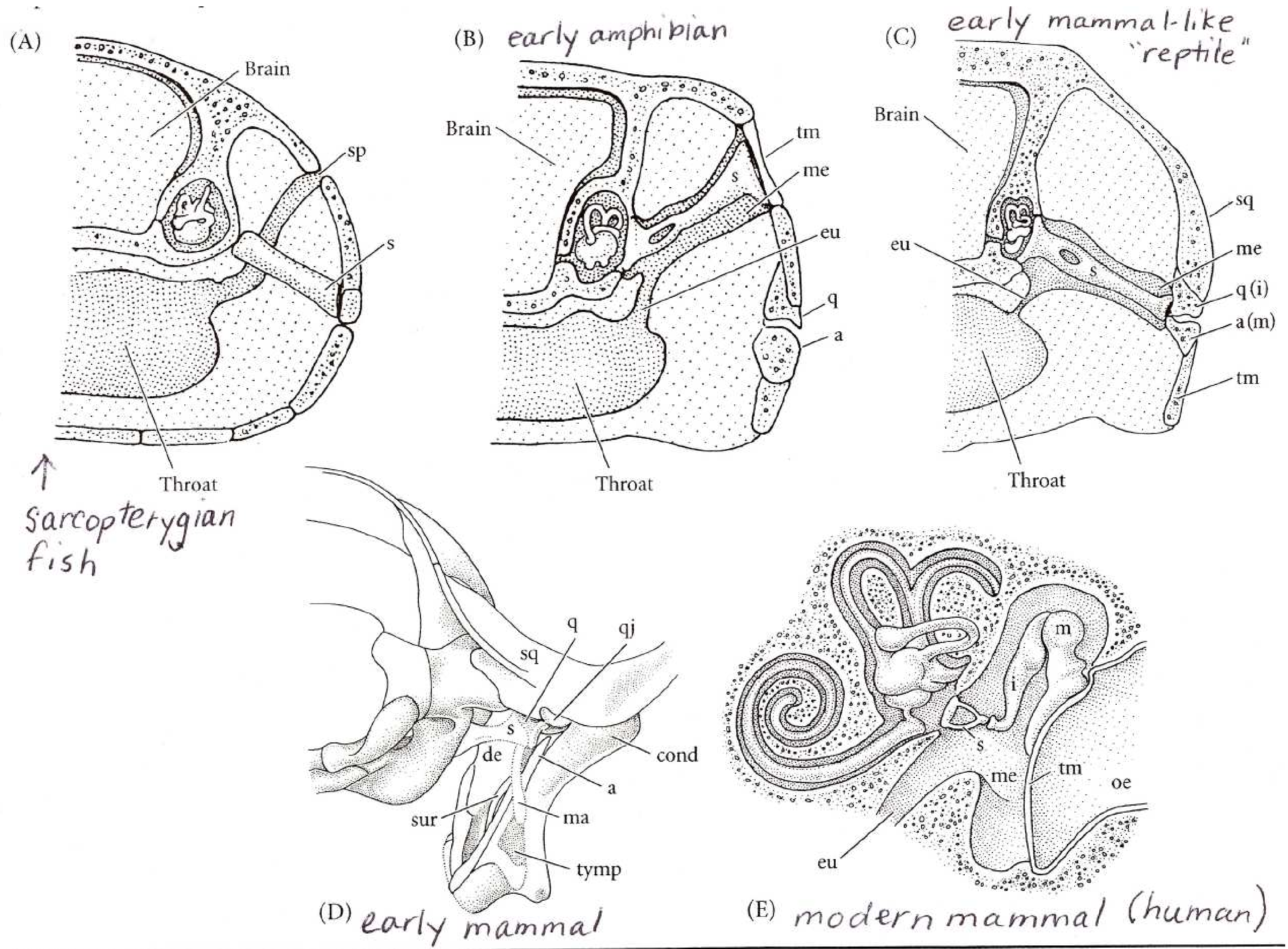
Figure 1.7
The diversification of homologous parts

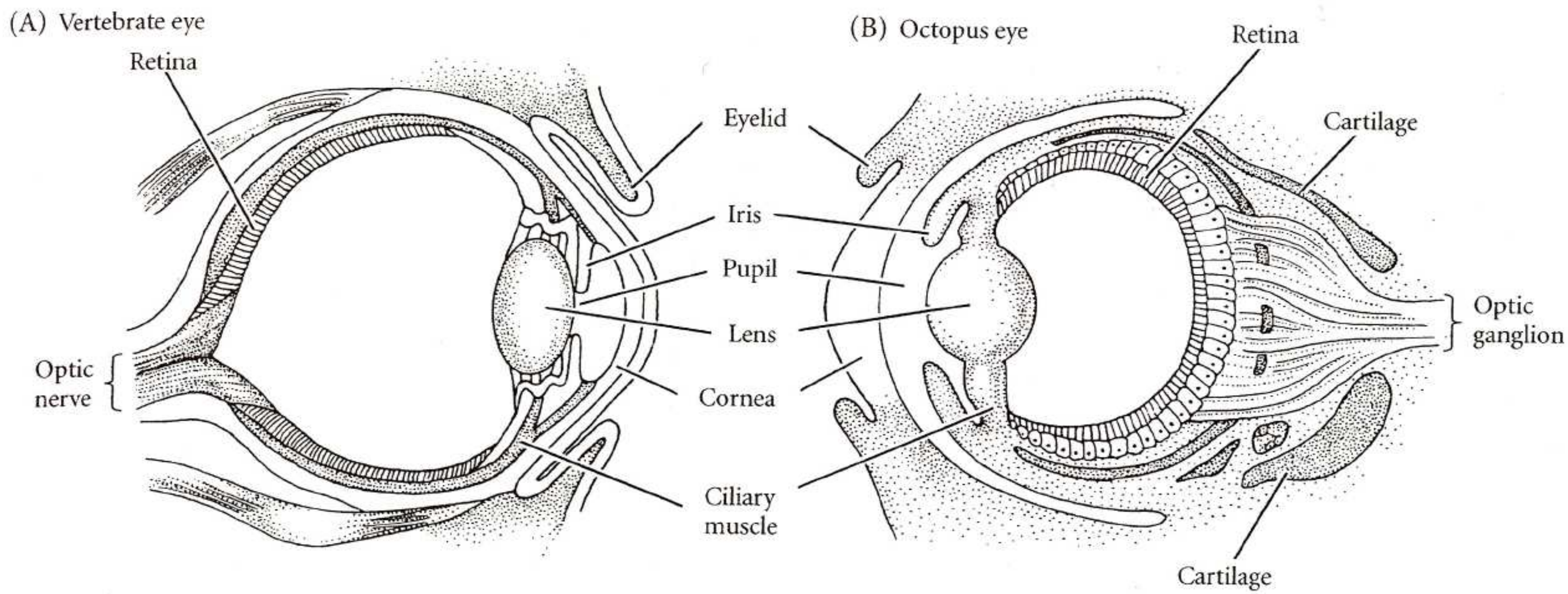
All vertebrate forelimbs are homologous structures whose anatomy has undergone considerable diversification in the evolution and adaptation of these various vertebrate lineages. Not to scale.

Source: Redrawn from Ridley M. *Evolution*, 2nd edn. Malden, MA: Blackwell Science, 1996.


Crocodile
Mouse


(A)
Crocodile
Femur
Fibula
Tibia
Tarsals
Metatarsals
Phalanges
I
II
III
IV
V
(B)
Bird
Femur
Fibula
Tibiotarsus
Tarsometatarsus
II
I
III
IV
Phalanges
(C)
Fibula
Tibia
Tarsals
Metatarsals
(D)
Fibula
Tibia


(A)
Brain
sp
s
Throat
sarcopterygian fish
(B) early amphibian
Brain
tm
me
s
eu
q
a
Throat
(C) early mammal-like "reptile"
Brain
eu
sq
me
s
q (i)
a (m)
tm
Throat
(D) early mammal
q
qj
sq
s
de
cond
a
sur
ma
tymp
(E) modern mammal (human)
m
i
s
me
tm
oe
eu



(A) Vertebrate eye
Retina
Optic nerve
Eyelid
Iris
Pupil
Lens
Cornea
Ciliary muscle
(B) Octopus eye
Retina
Cartilage
Optic ganglion
Cartilage

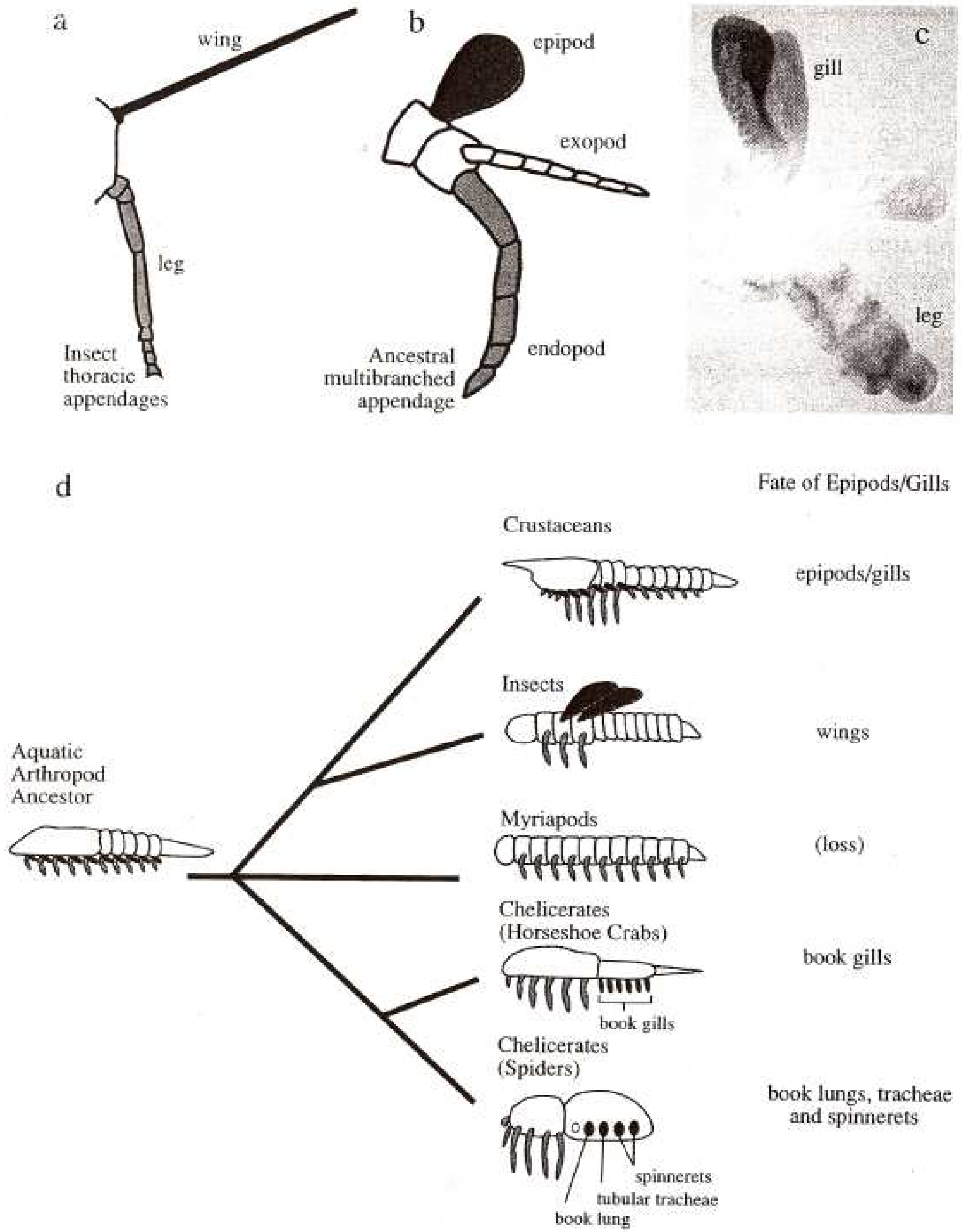
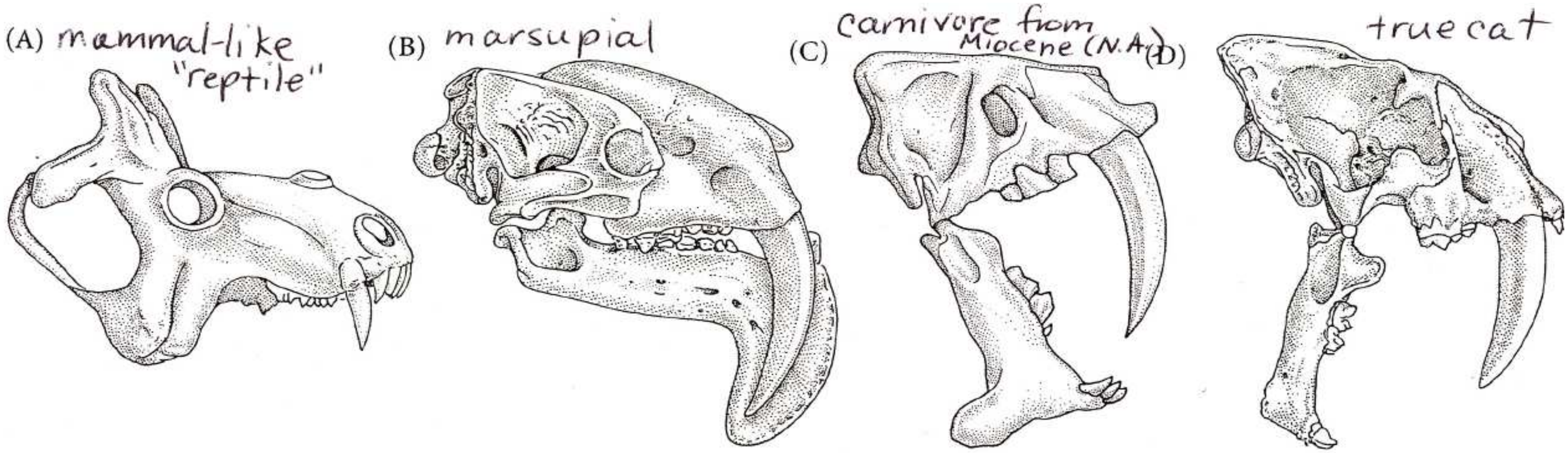


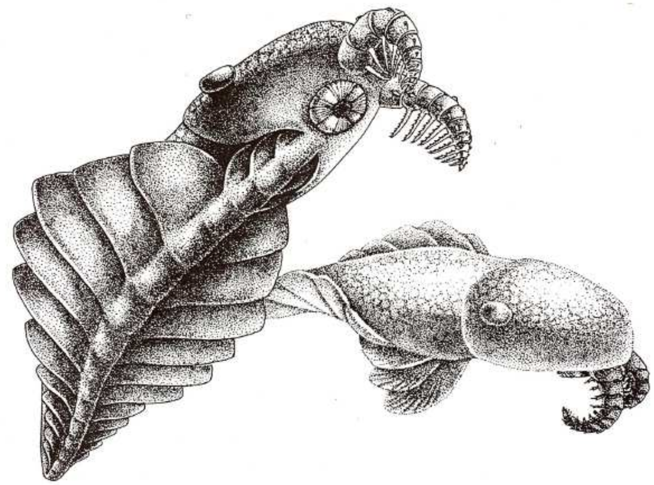
Figure 6.2
Evolutionary origin of the insect wing


(A) mammal-like "reptile"
(B) marsupial
(C) carnivore from Miocene (N.A.)
(D) true cat

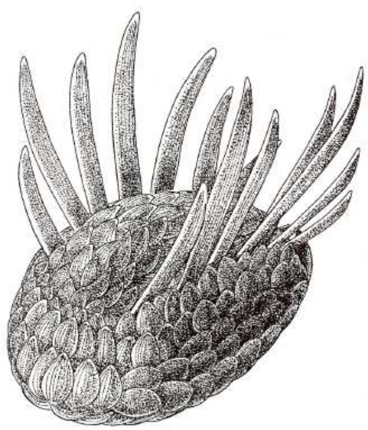
Limitations of the Body Plan Concept

- Apparent similarities in body plans need not be actual similarities at the molecular level.
- Character differences that distinguish body plans may seem fundamental but might in fact be minor.
- Many possible definitions of body plan, all somewhat vague.
- New body plan or not? The Burgess Shale and Vetustovermes.
- We will move beyond "body plan" as a basis for organizing life's diversity.

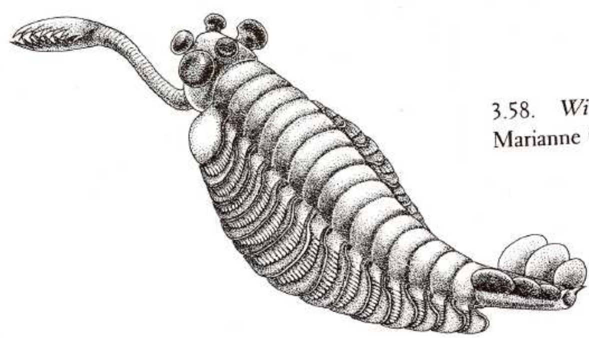
Burgess Shale Fauna



3.66. The two known species of *Anomalocaris:* top, *Anomalocaris nathorsti* as seen from below, showing the circular mouth, misidentified by Walcott as a jellyfish, and the pair of feeding appendages; bottom, *Anomalocaris canadensis* as seen from the side, in swimming position. Drawn by Marianne Collins.

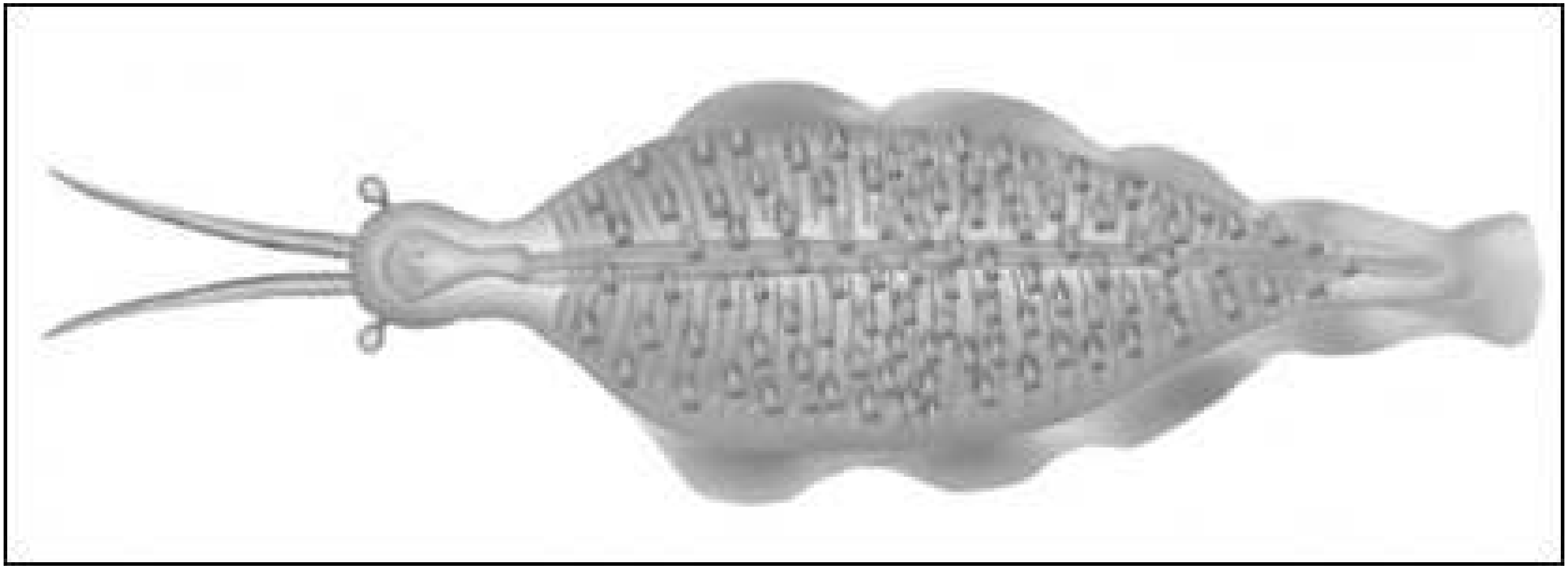


3.58. *Wiwaxia* as it might have crawled on the sea floor. Drawn by Marianne Collins.



3.21. *Opabinia,* showing the frontal nozzle with terminal claw, five eyes on the head, body sections with gills on top, and the tail piece in three segments. Drawn by Marianne Collins.

Vetustovermes



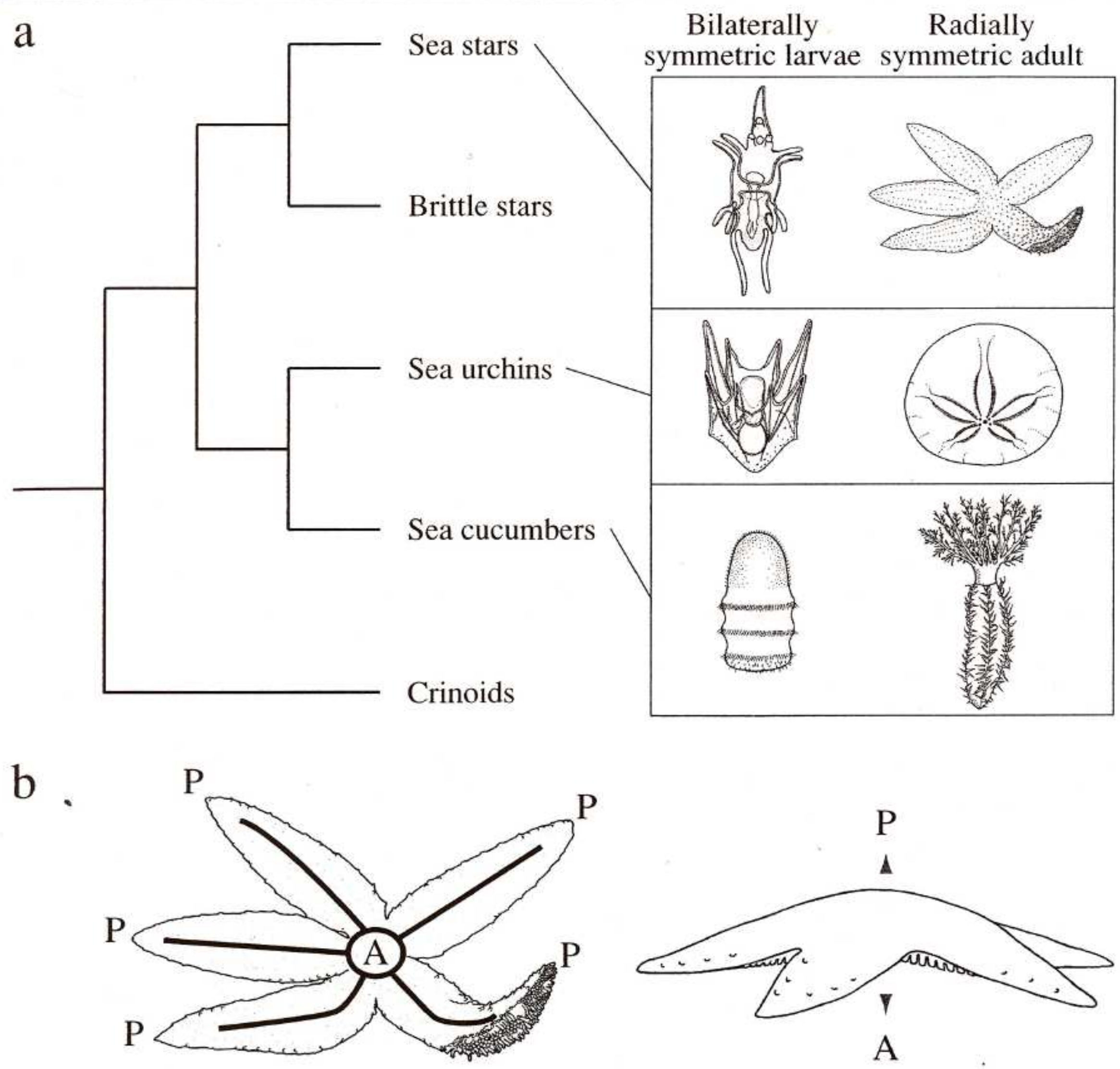
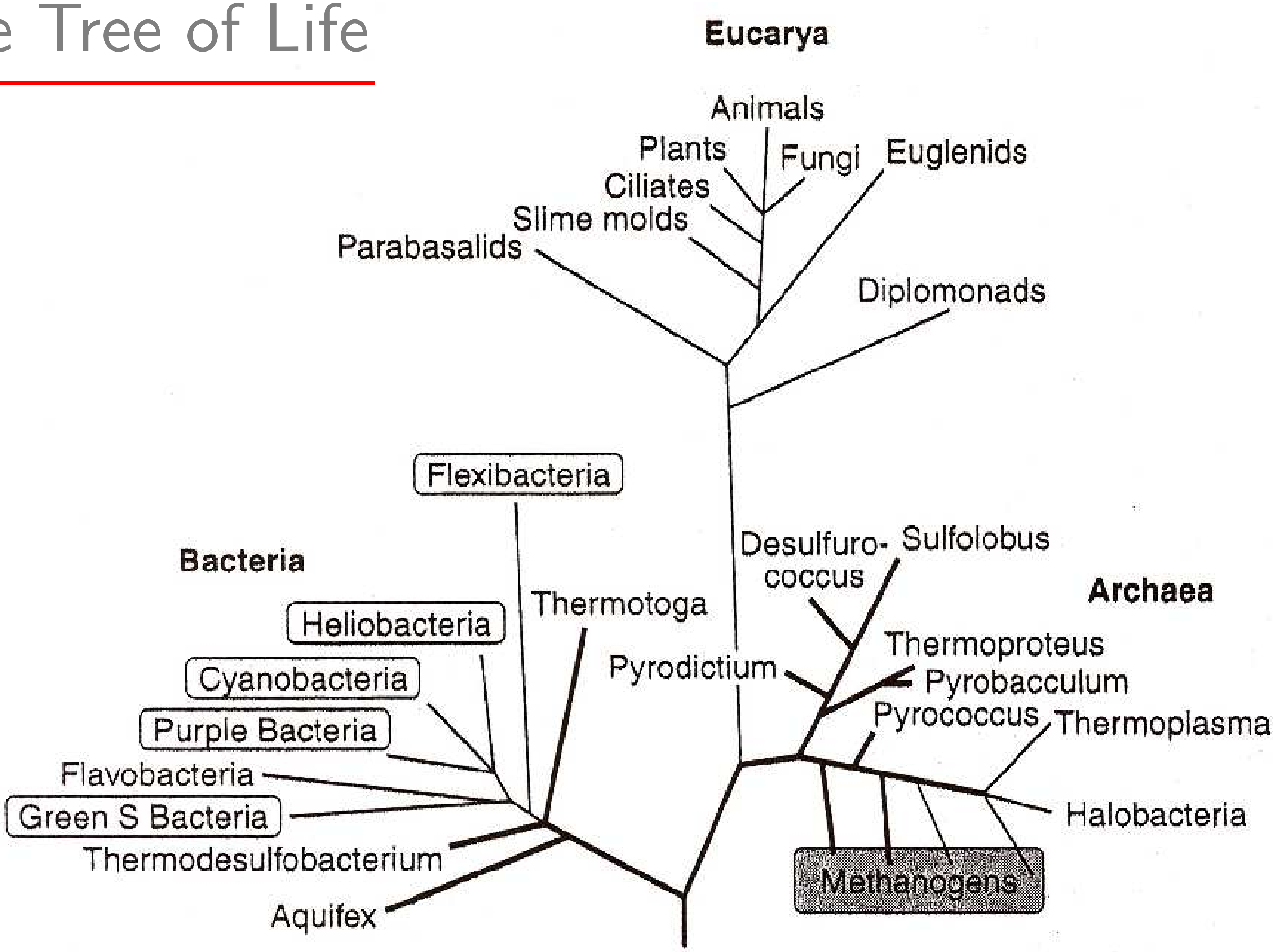


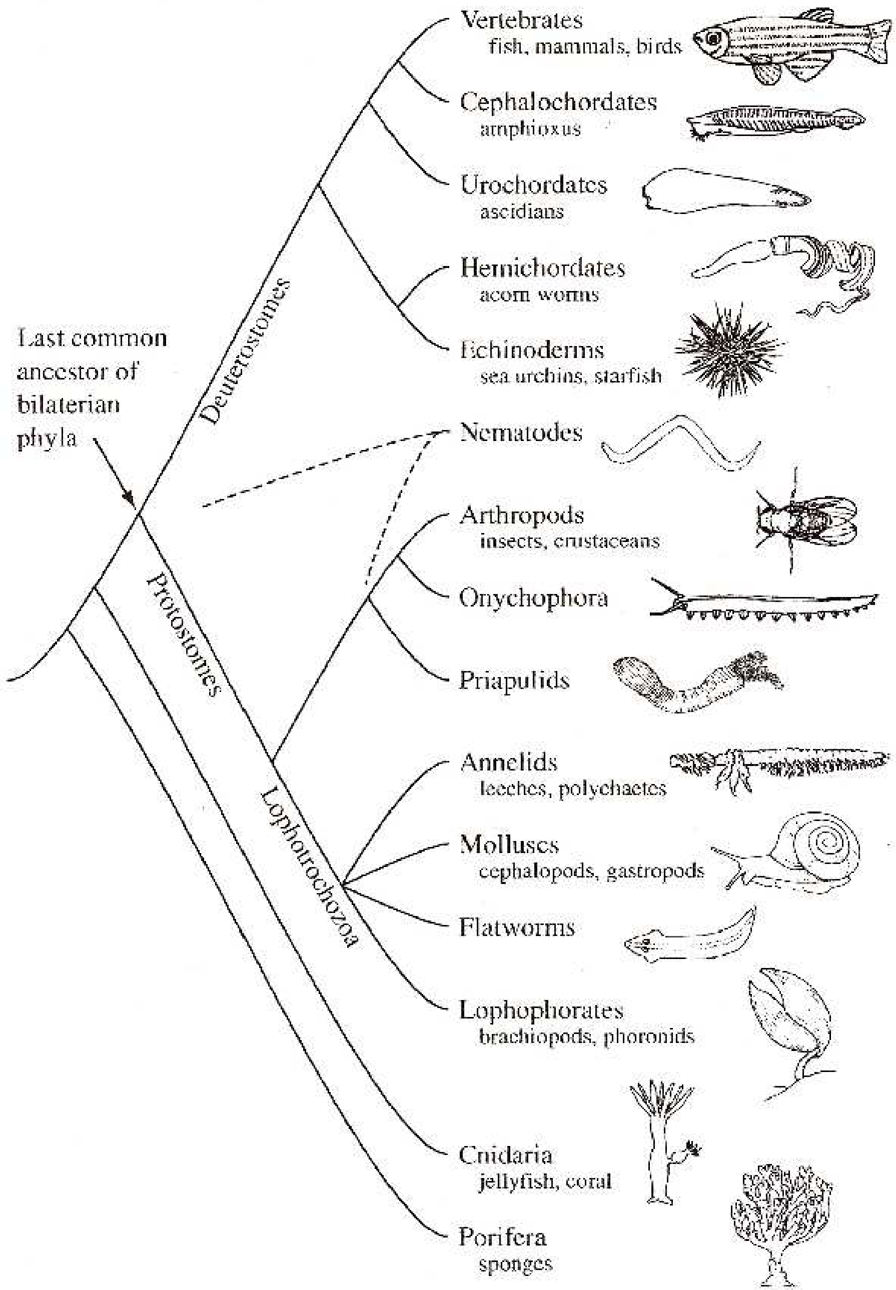
Figure 6.16
Evolution of the radially symmetric echinoderm body plan

(**a**) Echinoderm lineages have bilaterally symmetric larvae and radially symmetric adults. (**b**) Two hypotheses regarding the orientation of the ancestral bilaterian A/P axis in the adult echinoderm body plan: (**left**) multiplication of the bilaterian A/P axis may have created the radial nerve cords that extend down each echinoderm arm; (**right**) the ancestral bilaterian A/P axis may have evolved into the echinoderm oral–aboral axis.

The Tree of Life



The Major Animal Groups



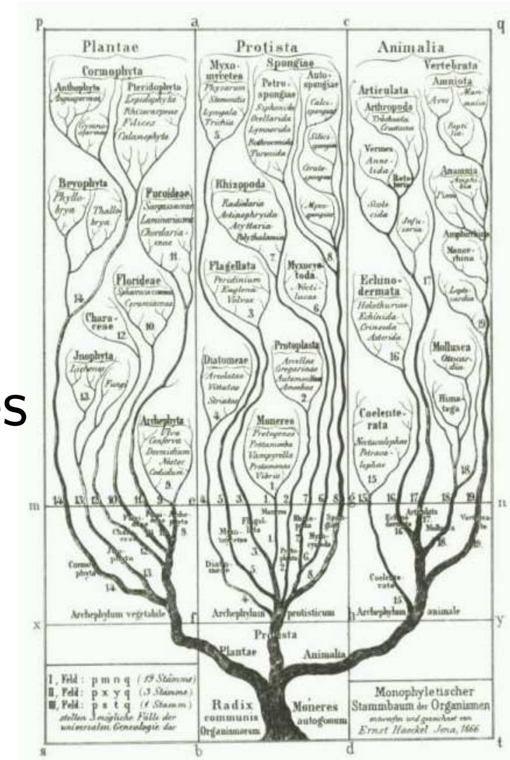
Making Sense of the Diversity of Life

- Punchline: By looking at observable traits, we can understand the relationships among organisms. But we must be careful about how we do so.

- The Tree of Life

  This is the theme of the course: What do the relationships in this tree mean? What does a branching point mean? How do we build such trees from data?

  We will discuss how to interpret such trees, the challenges in doing so, and the evolutionary processes that explain the relationships in such trees.



Announcements

- Read your syllabus carefully
- Pick up first assignment sheet (reading and writing)
- A time availability sheet will be passed out after class; please indicate your free and preferred times as instructed.