Evolution by Means of Natural Selection (Ch. 16, 19-1, 19-2, 19.3)

Historical thought

- Greek- Aristotle (3rd c. BC)- Scala Naturae- “great chain of being” or the “ladder of life”
  - Connects all living things moving toward a goal
- Literal Biblical view- the world was created in 6 days
  - Earth is 6000 years old
  - all species were created as they are today

Influence of Geology

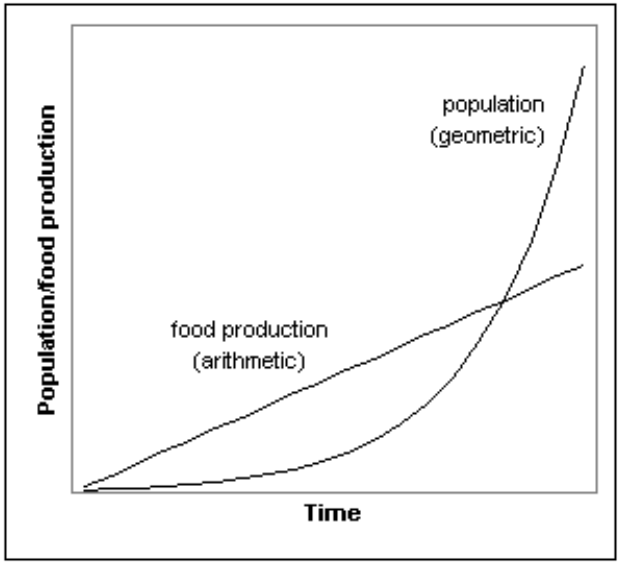
- James Hutton- gradualism
  - Things that change the earth take A LONG TIME
- Charles Lyell- current earth-shaping processes are the same as the past
  - stressed that scientists must explain past events in terms of processes that they can actually observe,
  - Wrote *Principles of Geology*, read by Darwin

Paleontology

- Def: the study of collecting and studying fossils
- William Smith
  - Each layer (stratum) of rock had unique fossil records
  - The older the strata, the more dissimilar the organisms are to present forms
- George Cuvier
  - Documented extinction as a common occurance

Thomas Malthus

- Population size link to poverty and disease
- If human population continued to grow unchecked (grows exponentially: more and more rapidly over time), it will be limited by space and food supply (grows arithmetically: equally over time)
- Population outgrows resources and competition kicks in



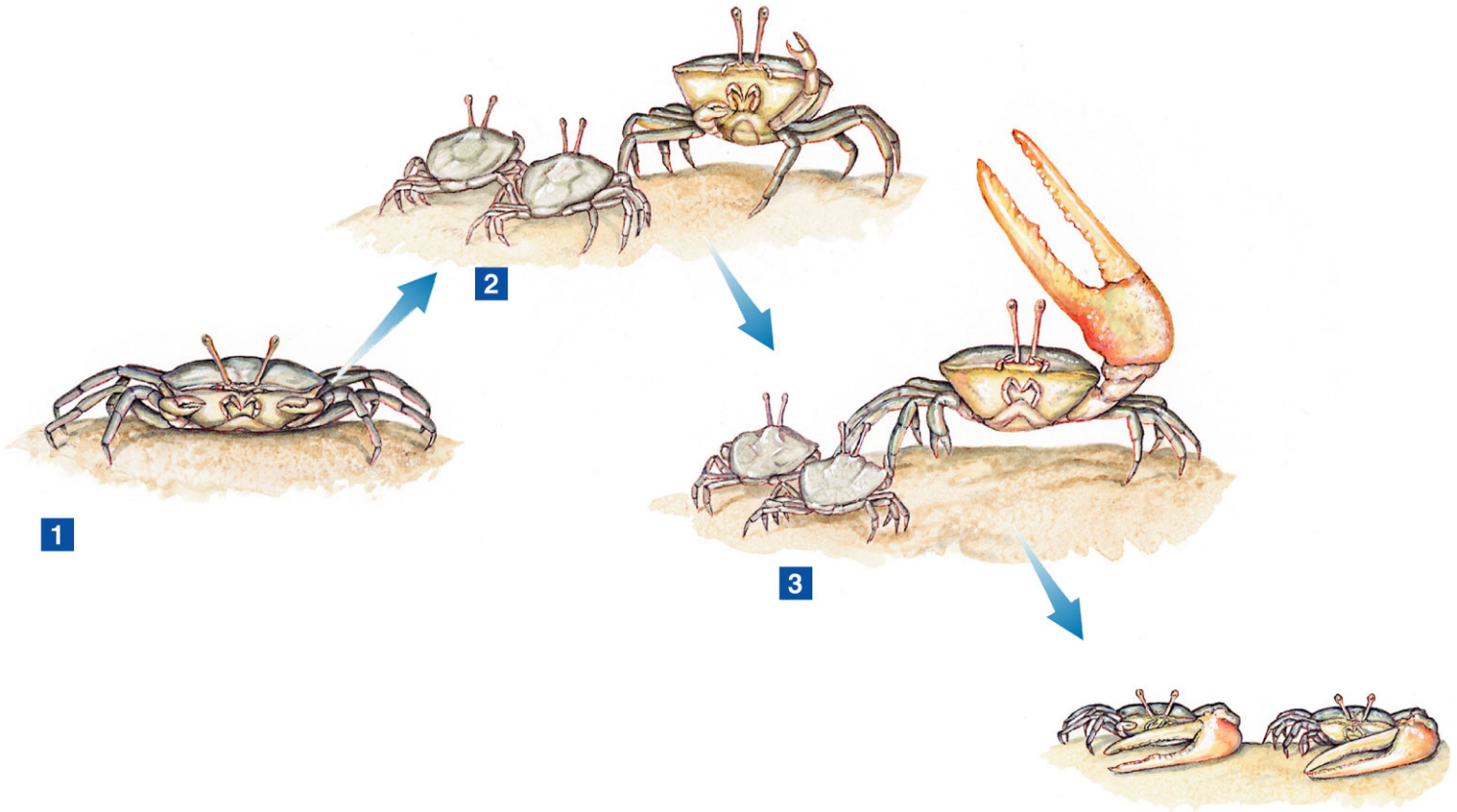
- That applies to more than just us!
  - Turtles lay hundreds of eggs, few survive
  - Trees set out hundreds of seeds, how many actually mature?
  - There is some selecting factor that decides which organisms are most fit for survival…

Lamarck's Hypothesis

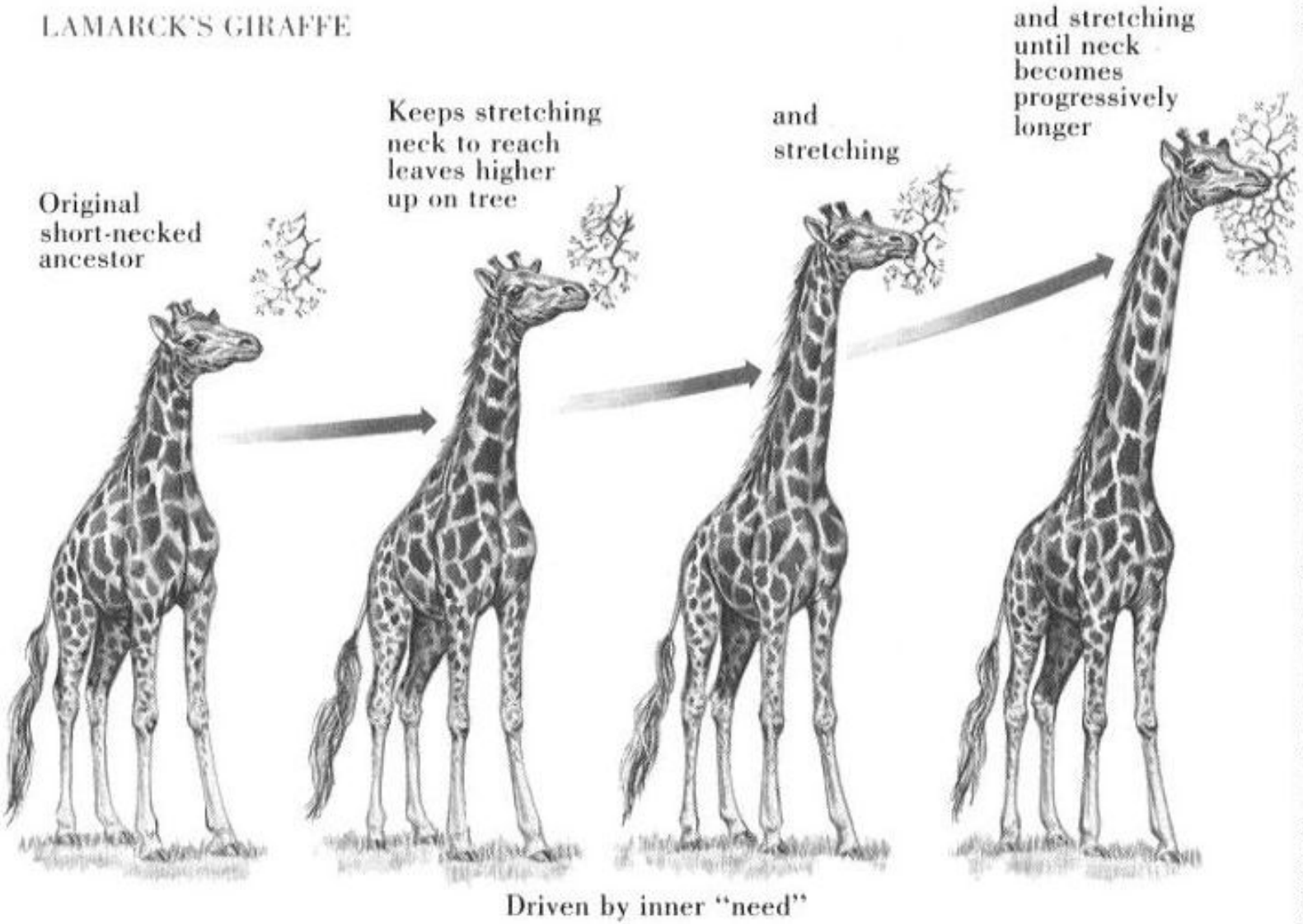
- Tendency Toward Perfection
  - organisms are continually changing and acquiring features that help them live more successfully in their environments (revisit Scala Naturae)
- Use and Disuse
  - organisms could alter the size or shape of particular organs by using their bodies in new ways
- Inheritance of acquired characteristics
  - if during its lifetime an animal somehow altered a body structure, it would pass that change on to its offspring

Lamarck's hypothesis

- Fiddler crabs



Lamarck's Giraffes



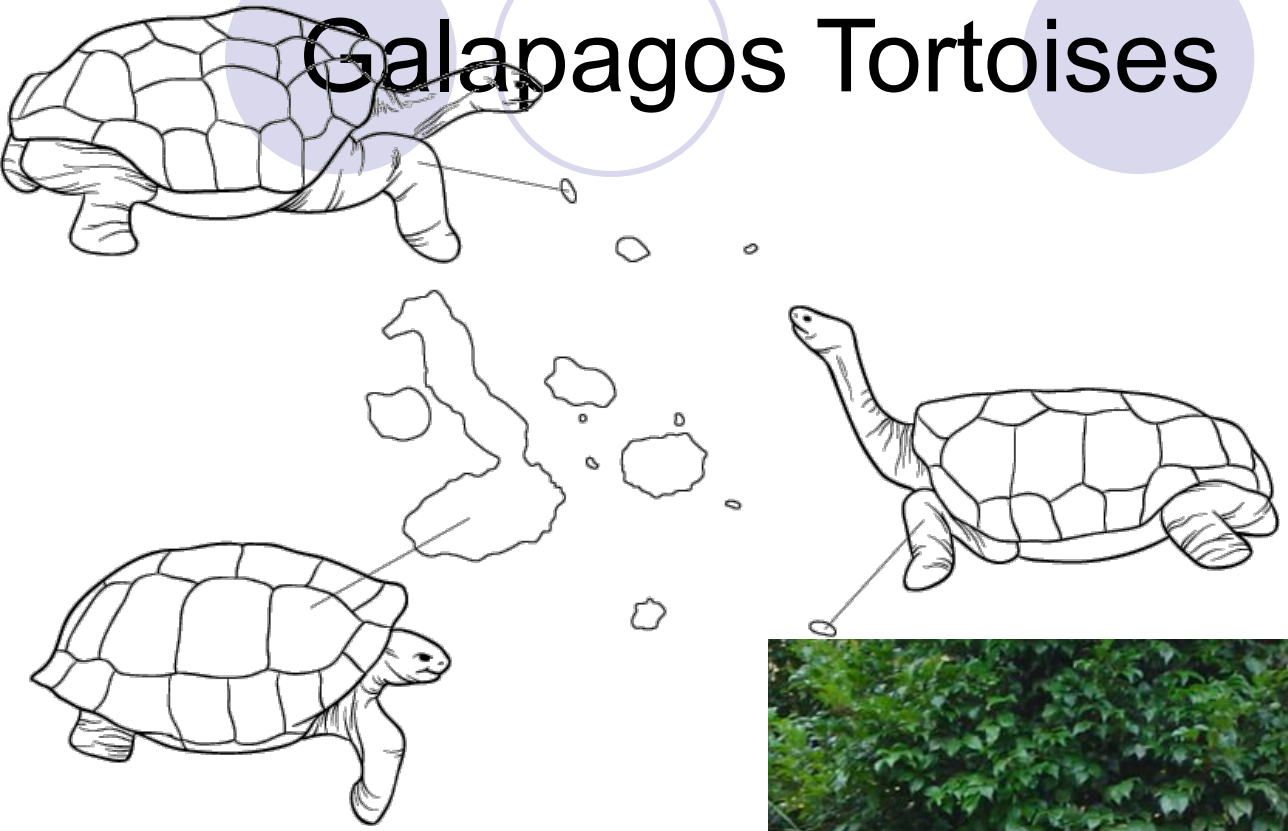
So…

- Why is Lamarck wrong?
- How did his hypothesis *positively* influence evolutionary thought?

Charles Darwin

- Darwin rode along on HMS Beagle as the resident naturalist
- Collected plants, animals, fossils, OBSERVED
- Species on the Galapagos Islands were similar to the mainland, but differ in each environment
- Variation exists within a natural or domesticated population and some of that variation is inheritable
- Similar habitats around the world do not have the same animals and plants, but they have similar characteristics for that environment

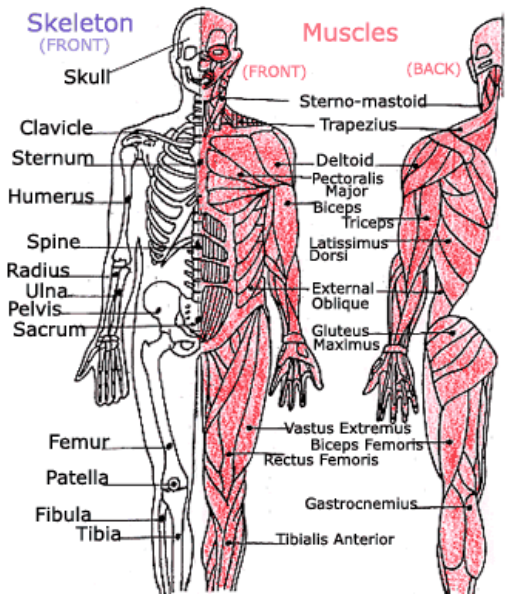
Galapagos Tortoises

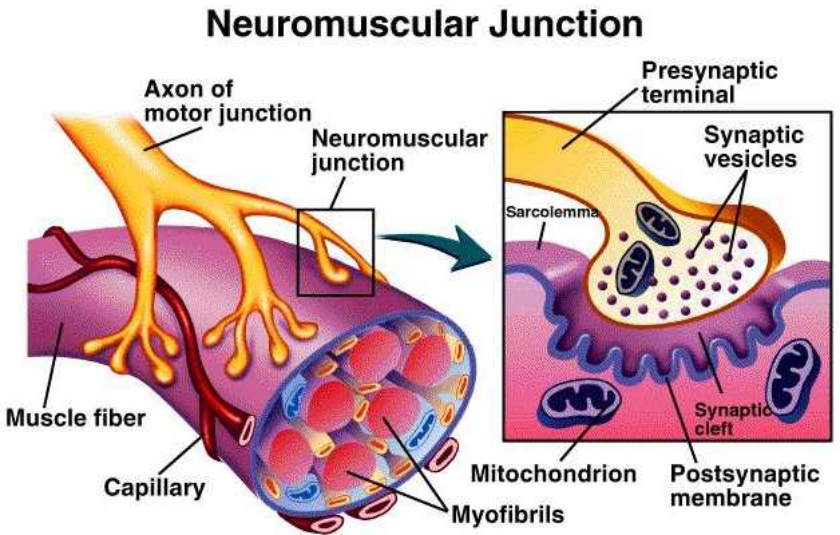


- Morphology matched function in the environment.

Definitions and Concepts:

- Morphology – the form or shape of an organism.
- Physiology - the mechanical, physical, and biochemical functions of living organisms.
  - Muscles are the morphology
  - How the muscles *work* is physiology





Definitions and Concepts:

- Adaptation – any inherited characteristic that increases an organism's chance of survival and ability to reproduce.
  - *Ex.* Monarch butterfly is poisonous to eat they have special coloration to warn predators *also viceroy butterflies copy their coloration to protect themselves*
- Fitness – the ability of an organism to survive and reproduce.

Definitions and Concepts:

- Selective Pressure – any phenomenon which alters the fitness of organisms within a given environment. It is the driving force of natural selection, and it can be divided into two types of pressure: biotic or abiotic.
  - *Ex:* predation, food supply, temperature.

The story of the Peppered Moth

- How did the industrial revolution change a species of moth?

- Peppered Moth Animation

To break it down…

- Organisms produce more offspring than can possibly survive (who stated this?) and those that do not survive…?
  - Do not reproduce
    - So they do not pass down their genes
      - That genome is wiped from the population
- Each organism has different advantages and disadvantages in the struggle for existence.
- Individuals best suited the their environment survive and reproduce most successfully

Theory of Biological Evolution by means of Natural Selection as stated in "On the Origin of Species" by Charles Darwin who combined his ideas with Malthus and Lamarck.

Summary of Darwin's Theory:

- Struggle for Existence
- Survival of the "fittest", or Natural Selection
  - Fitness- ability to survive and reproduce
  - Adaptations- can be morphological, behavioral, or physiological
  - An adaptation may be an advantage in one environment and a disadvantage in another!
- Natural Selection
  - Only acts on heritable traits
  - Does not form NEW characteristics (only mutations can do that!)
  - Is backward looking, not planned
  - acts on the individual, but the effect is on the POPULATION

Theory of Biological Evolution by means of Natural Selection

- Species alive today are descended with modification from ancestral species that lived in the distant past.
- This process by which diverse species evolved from a common ancestor unites ALL organisms on Earth into a single tree of life.

The Theory of Biological Evolution

- Published "*On the Origin of Species*" 23 years later in 1859
- Alfred Wallace- 1858 wrote paper on natural selection almost identical to Darwin's
  - Why have you never heard of him?
- Rediscovered along with Mendel's work
  - Modern Theory of Evolution incorporates population genetics, behavior, ecology, paleontology, phylogeny etc.

Evidence of Evolution 16.4 and 19.1,19.2,19.3

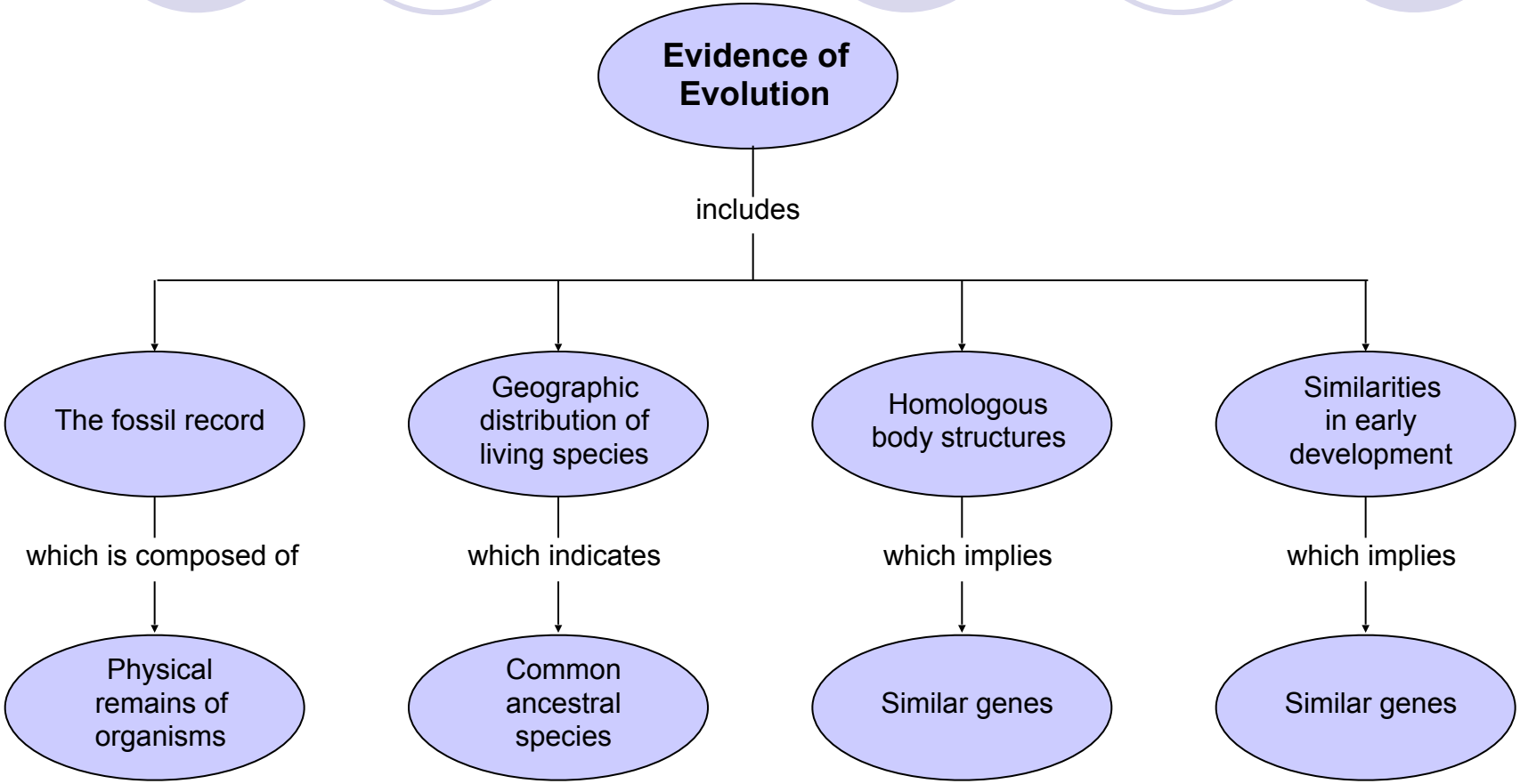


Figure 15–14 Geographic Distribution of Living Species

- Can indicate common ancestry from fossil forms that occupied continuous area.

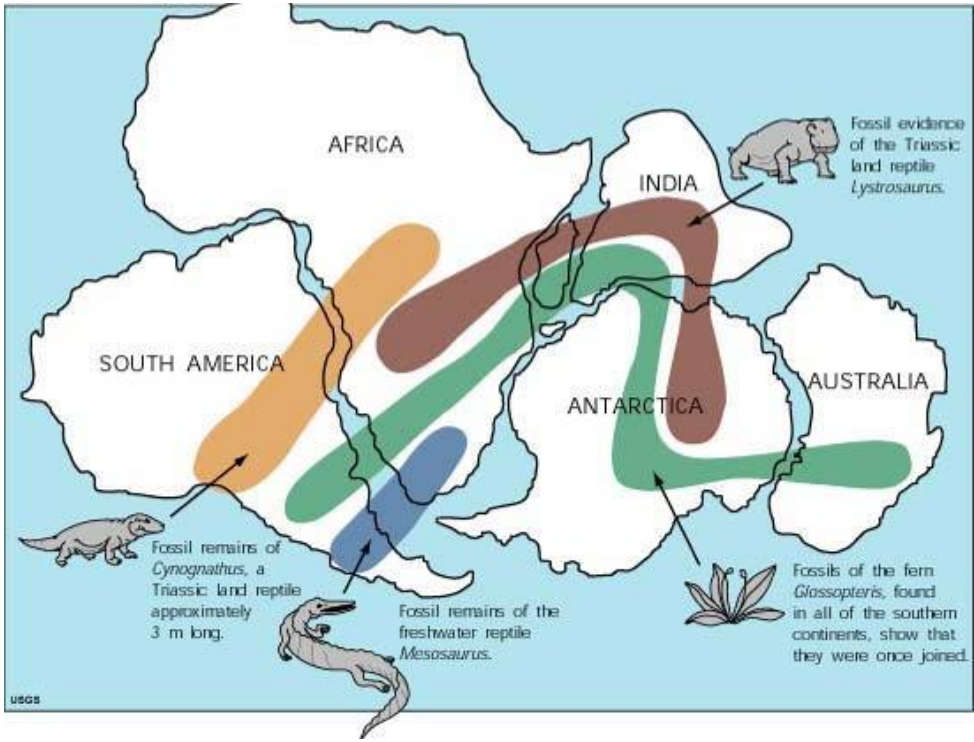
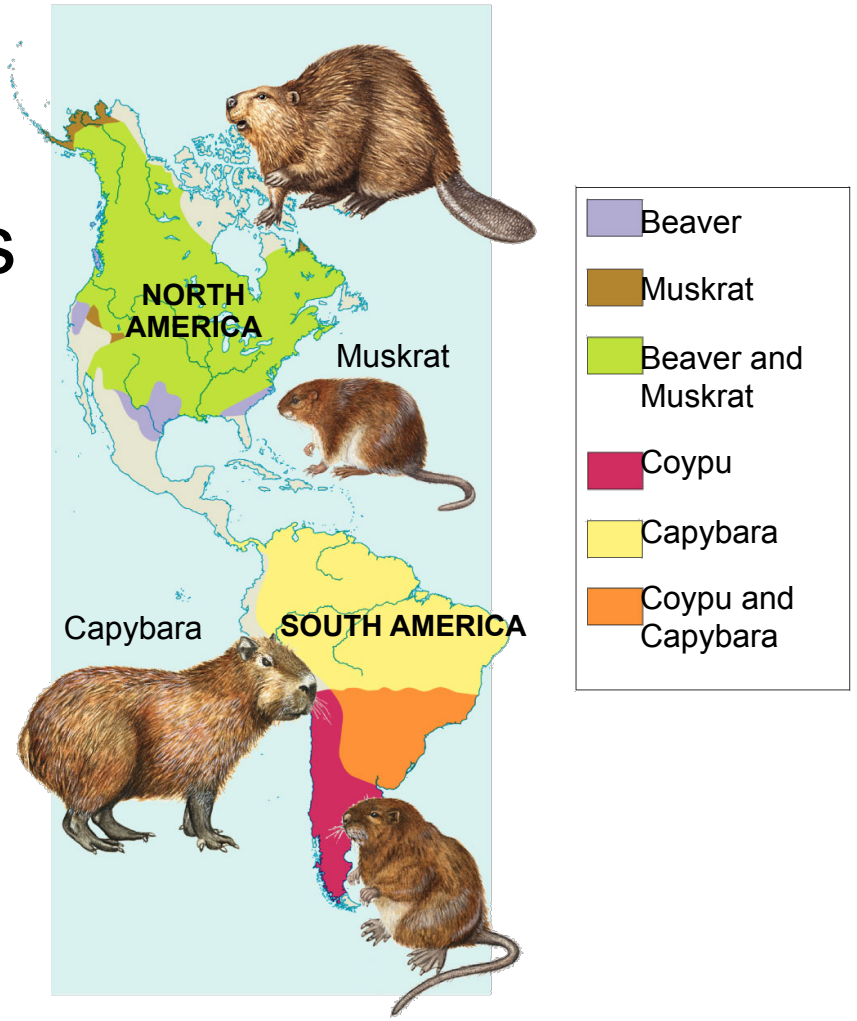


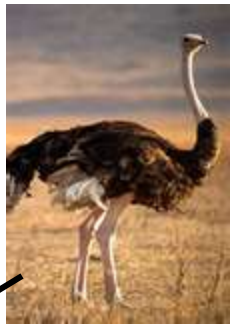
Figure 15–14 Geographic Distribution of Living Species

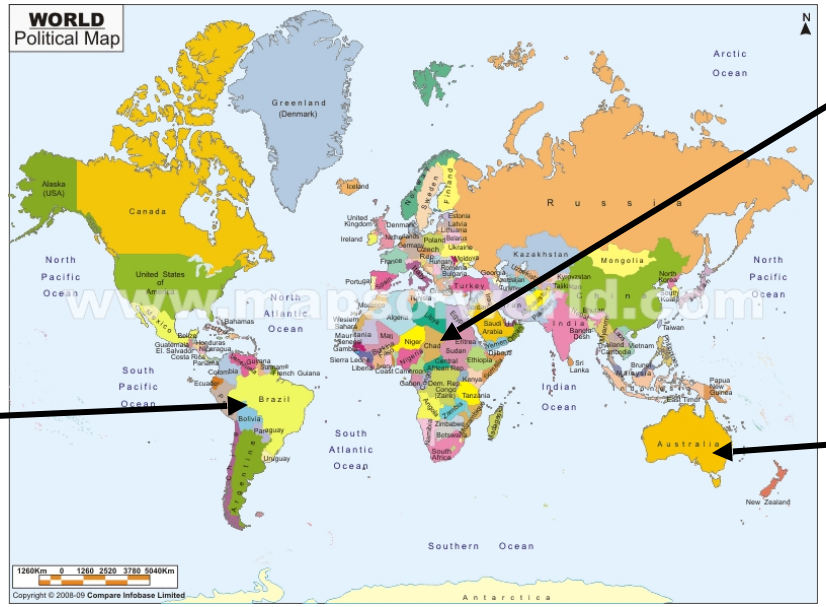
- Can indicate similar structures forming due to similar habitats (and therefore similar selective pressures)



Discuss with your neighbor…
What conclusion can you draw from the information below?

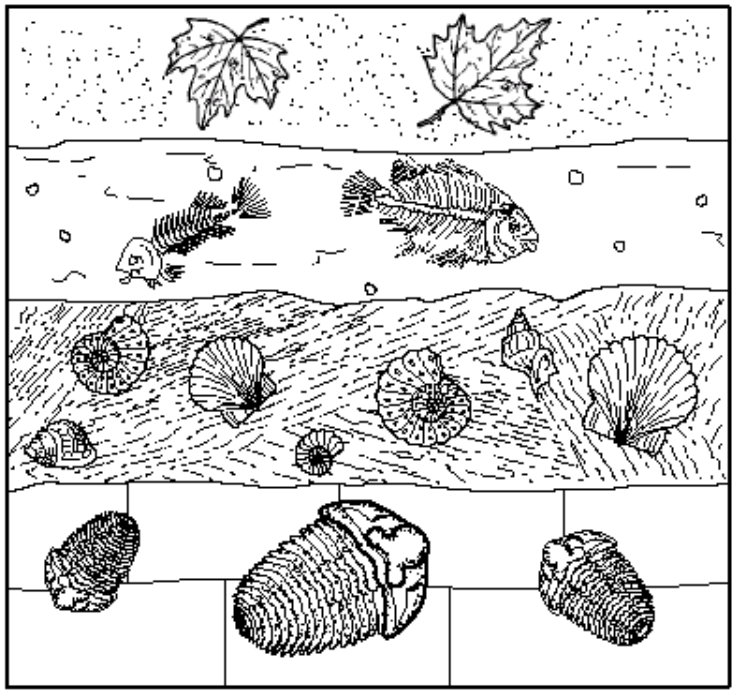
- Rhea – Native to South America
- Ostrich – Native to Africa
- Emu – Native to Australia





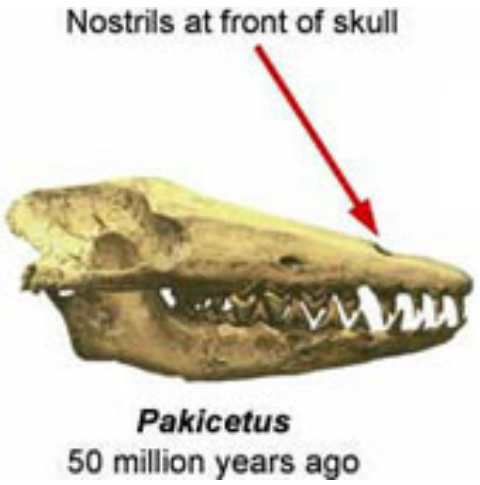
Fossil record

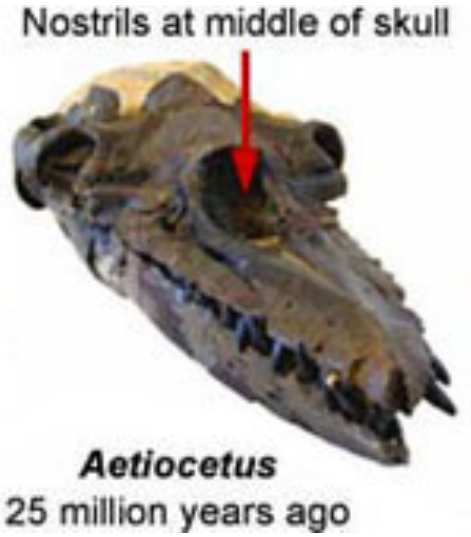
- Evidence of an old Earth
- Show extinction and intermediate fossils
- Fossils allow us to explore the morphology of the organisms of the past
- Relative dating, and radioactive dating allows us to get perspective on the age of the remains



The Fossil Record shows

- species that once existed and are now extinct.
- **transitional forms**: fossils or organisms that show the intermediate states between an ancestral form and that of its descendants.





EXAMINING FOSSIL ACTIVITY

Horse cards

- Arrange the horse fossils in order looking at several morphological characteristics.
- Be able to defend your answer.

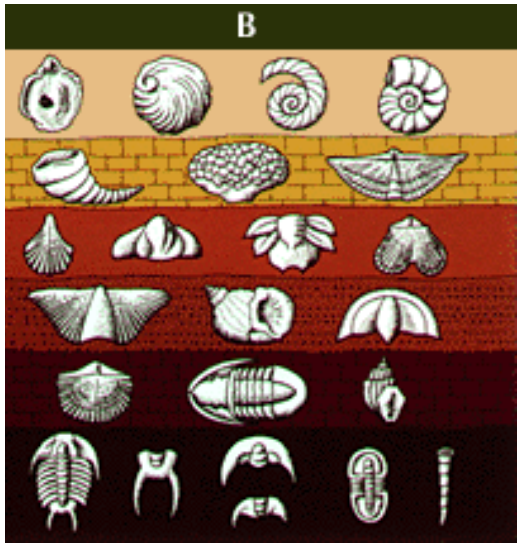
- Do oldest on the left, most recent on the right

Horse Evolution

Hyracotherium	*Mesohippus*	*Merychippus*	*Pliohippus*	*Equus*
Early Eocene	Oligocene	Late Miocene	Pliocene	Pleistocene
				
				
				

Have you noticed that organisms can be different within the fossil record?

- Gradualism – slight changes within a population over time (subtle)
- Punctuated equilibrium – a quick change in a population (dramatic - indicates a major event)
- Stasis – the idea that during periods of time, little if any change is observed within a population



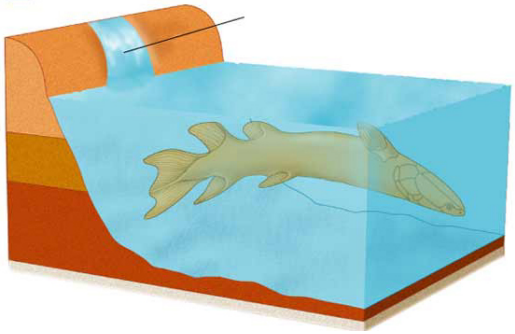
Fossil formation

- A fossil can be as large and complete as an entire, perfectly preserved animal, or as small and incomplete as a tiny fragment of a jawbone or leaf.
- There are fossil eggs, fossil footprints, and even fossilized animal droppings.
- For a fossil to form, either the remains of the organism or some trace of its presence must be preserved.
- For every organism that leaves a fossil, many more die without leaving a trace.

Fossil formation

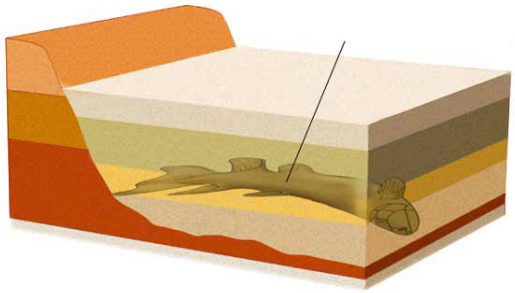
Water carries small rock particles to lakes and seas.

1



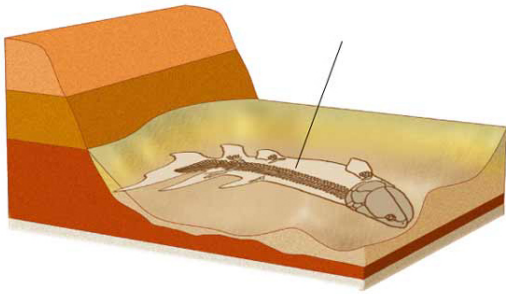
Dead organisms are buried by layers of sediment, which forms new rock.

2



The preserved remains may later be discovered and studied.

3

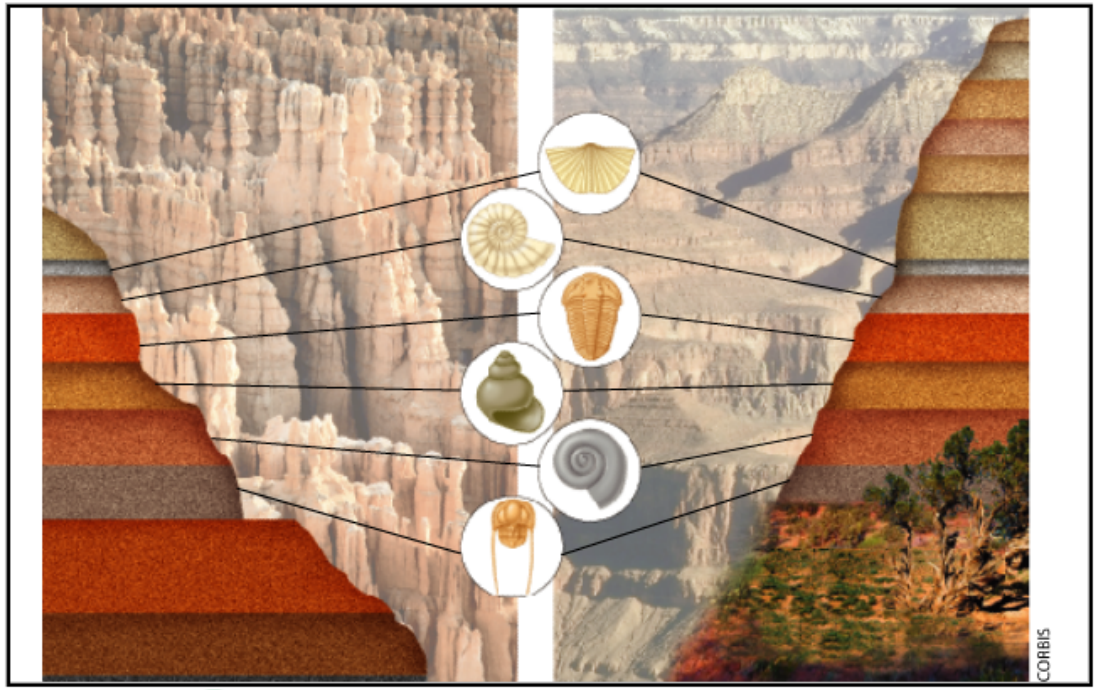


Fossil formation

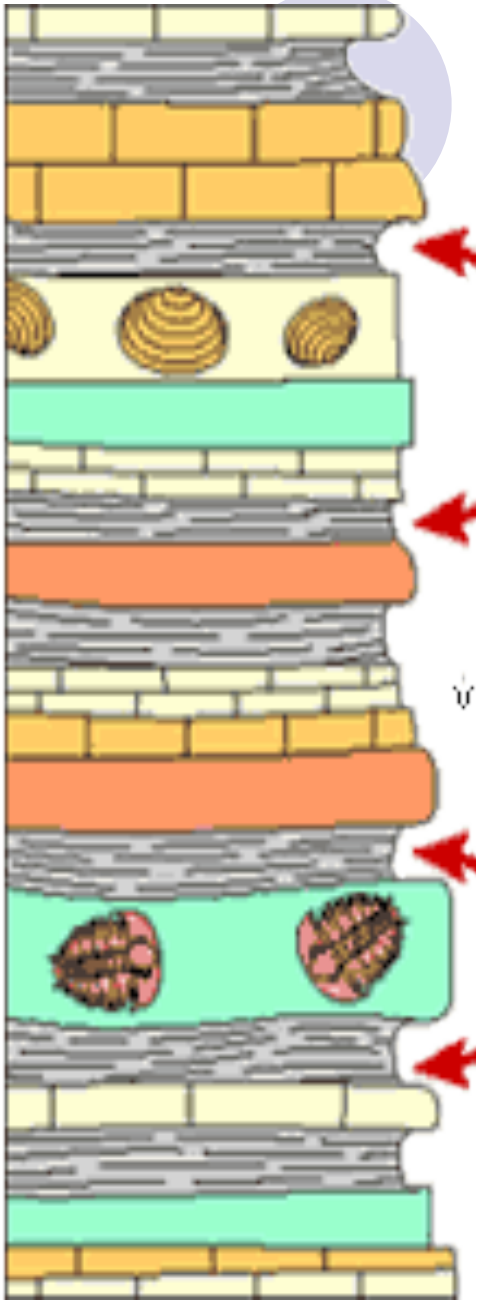
- When a fossil is discovered, rarely is it of a complete organism.
- More often paleontologists must reconstruct an extinct species from a few fossil pieces—remains of bone, a shell, or leaves.
- When paleontologists study a fossil, they look for anatomical (structural) similarities—and differences—between the fossil and living organisms.

Relative Dating

- uses the layers of fossils
- older fossils are found below more recent ones
- living organisms resemble fossils although differences may be evident



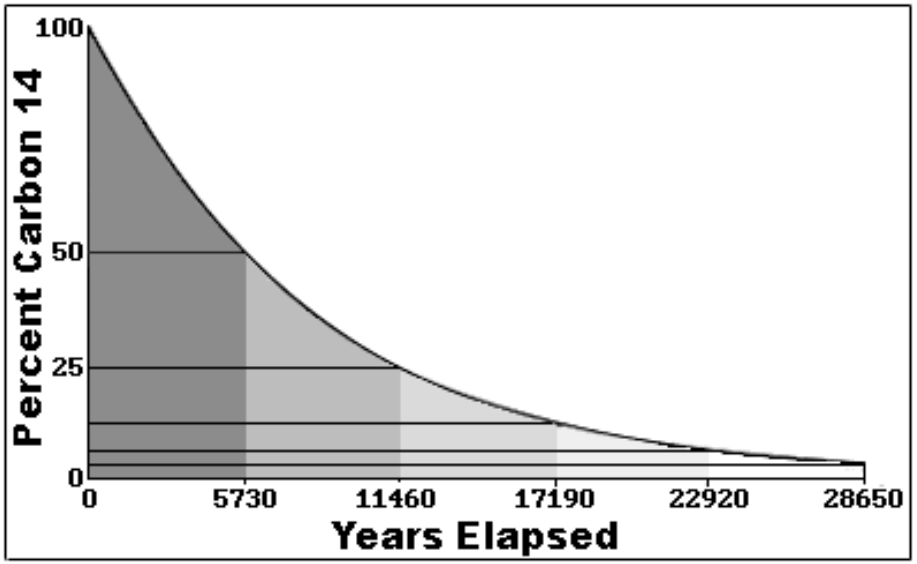
Relative Dating **In relative dating, a paleontologist estimates a fossil's age in comparison with that of other fossils.** Each of these fossils is an index fossil. It enables scientists to date the rock layer in which it is found. Scientists can also use index fossils to date rocks from different locations.



What conclusions and inferences can you draw from this figure?

Radioactive Dating

- using carbon dating on rocks and fossils to determine a more accurate time frame in which the organism lived.



← We know how long it takes for radioactive carbon to decay. By identifying how much is left in a sample, we can give it an age.

How old is the Earth?

- The fossil record is used to determine the Earth's age.
- Evidence has been collected and scientists have created the Geologic Time Scale which identifies major events in time.
- The Earth is estimated to be 4.6 billion years old

Geologic Time Scale

- Divisions defined by marked changes in the fossil record (mass extinctions)
- Paleozoic (paleo- old)
  - Marine invertebrates and vertebrates (fish)
  - Land vertebrates such as amphibians and reptiles
  - End with mass extinction
- Mesozoic (meso-middle)
  - Age of reptiles, flowering plants arrived, early mammals
  - End with mass extinction of megafauna
- Cenozoic (present)
  - Age of Mammals

Geologic Time Scale

Era	Period	Time (millions of years ago)	Key Events
Cenozoic	Quaternary	1.8–present	Glaciations; mammals increased; humans
	Tertiary	65–1.8	Mammals diversified; grasses
Mesozoic	Cretaceous	145–65	Aquatic reptiles diversified; flowering plants; mass extinction
	Jurassic	208–145	Dinosaurs diversified; birds
	Triassic	245–208	Dinosaurs; small mammals; cone-bearing plants
Paleozoic	Permian	290–245	Reptiles diversified; seed plants; mass extinction
	Carboniferous	363–290	Reptiles; winged insects diversified; coal swamps
	Devonian	410–363	Fishes diversified; land vertebrates (primitive amphibians)
	Silurian	440–410	Land plants; land animals (arthropods)
	Ordovician	505–440	Aquatic arthropods; mollusks; vertebrates (jawless fishes)
	Cambrian	544–505	Marine invertebrates diversified; most animal phyla evolved
Precambrian Time		650–544	Anaerobic, then photosynthetic prokaryotes; eukaryotes, then multicellular life

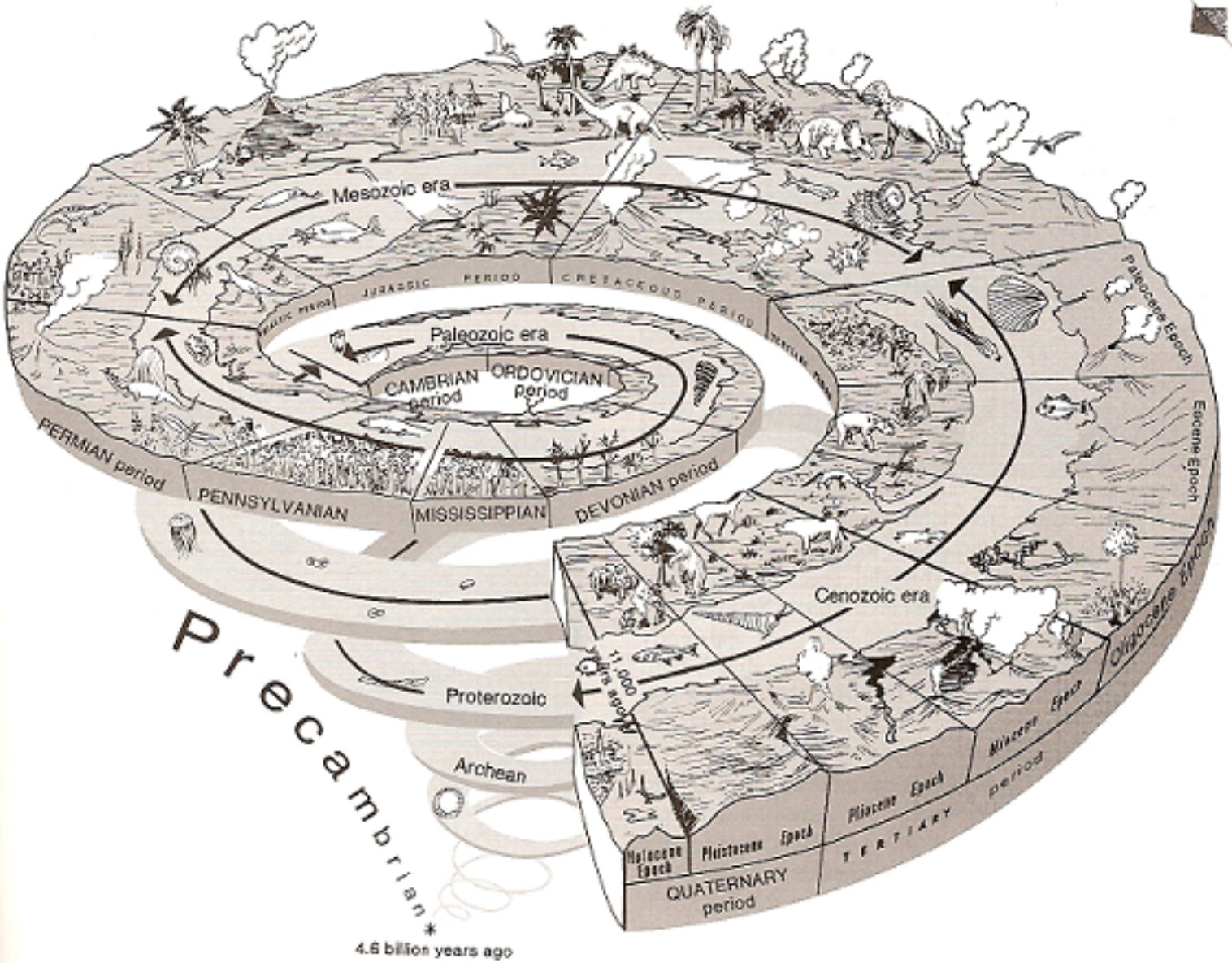


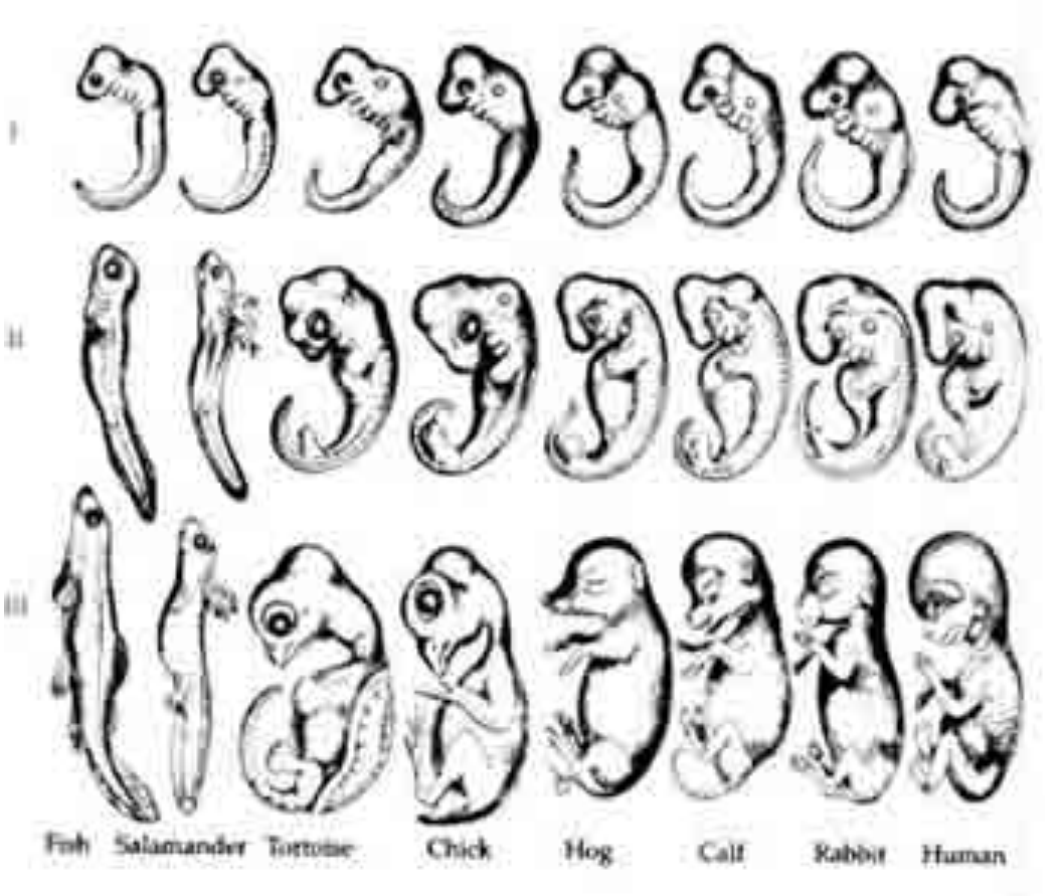
FIGURE 1.29 Geologic time. The gathering of cosmic gases under gravity's pull created Earth some 4.6 billion years ago. Yet life became neither abundant nor complicated until the Cambrian period, about 544 million years ago, when the first vertebrates appeared.

Source: After U.S. Geological Survey publication, Geologic Time.

Geologic Time, BIO: (19.1) p. 542-543
PRE-BIO: p. 453-454

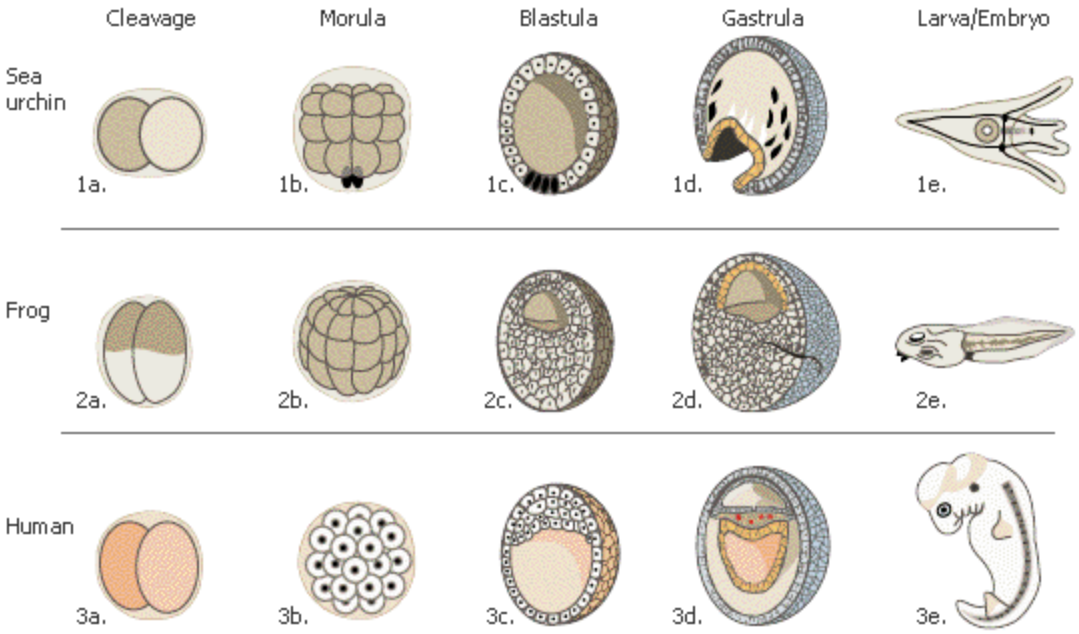
Embryology

- Similarity in early embryonic stages shows relatedness.
- While this early comparison was later found to be doctored, it holds a little truth
- Ernst Haeckel

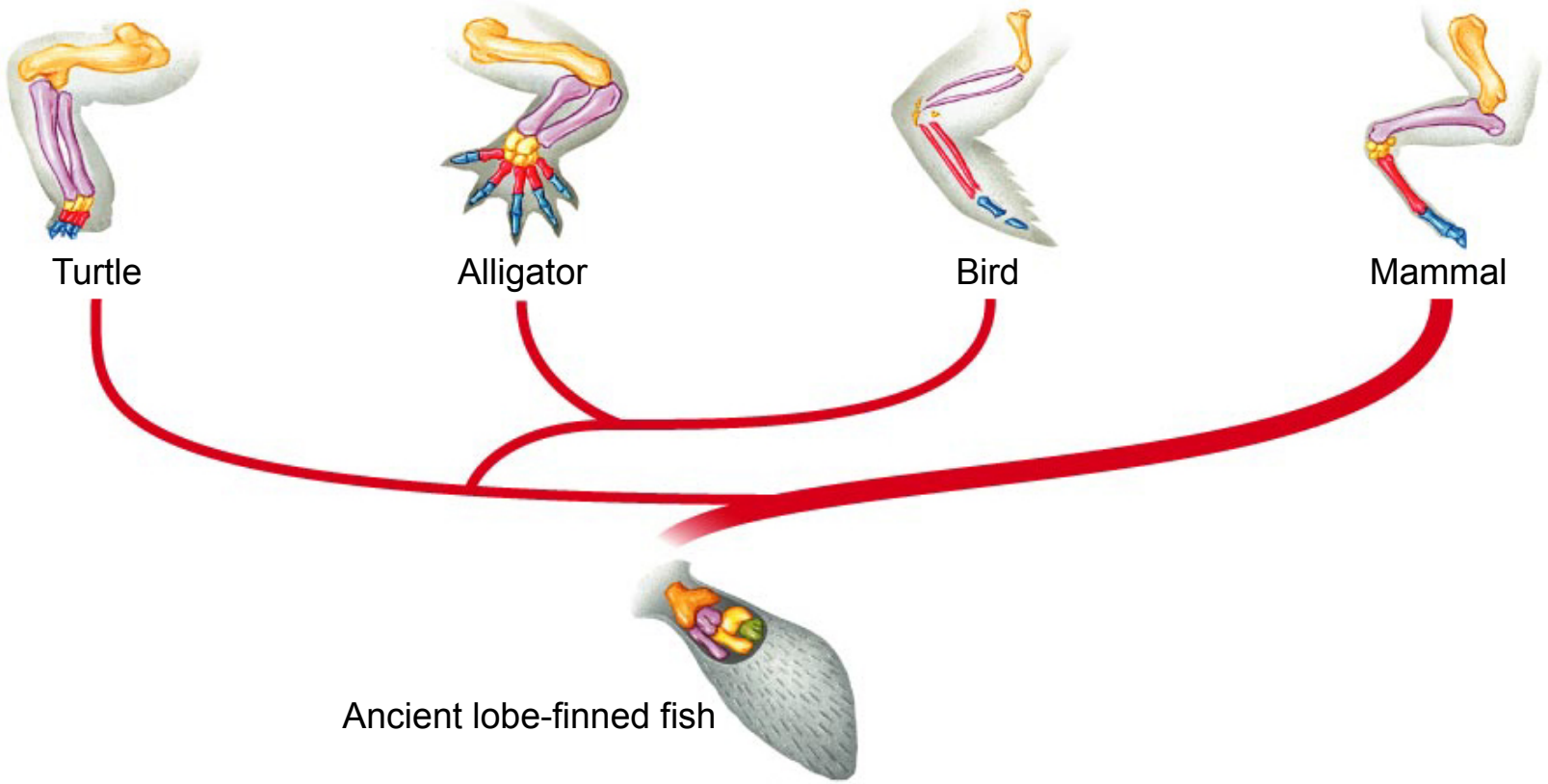


Embryology

- Related organisms share a common early embryology
  - The more closely related, the more related their embryological stages are.
  - When we explore invertebrates and vertebrates, we will explore comparative embryology in detail

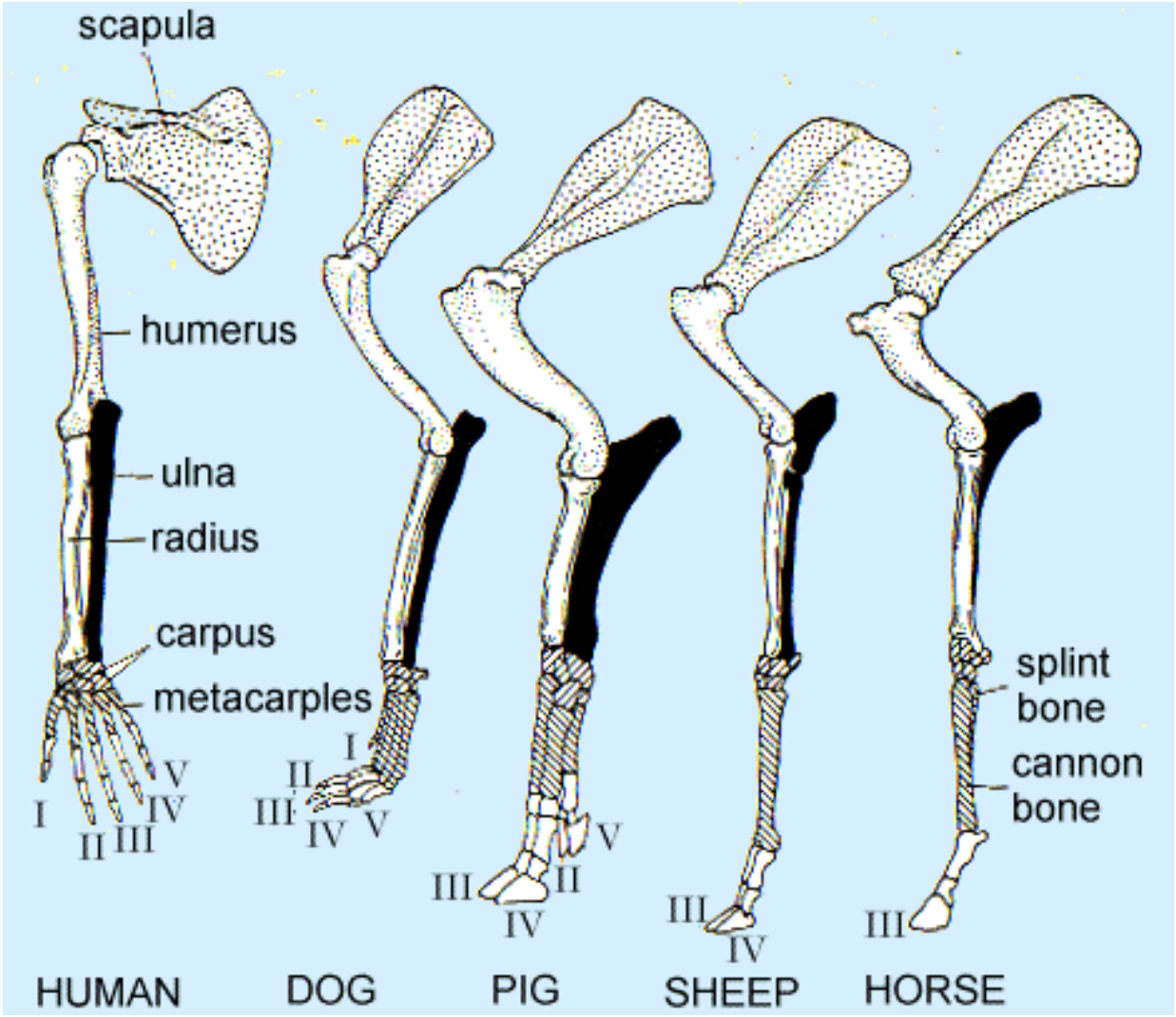


Homologous structures



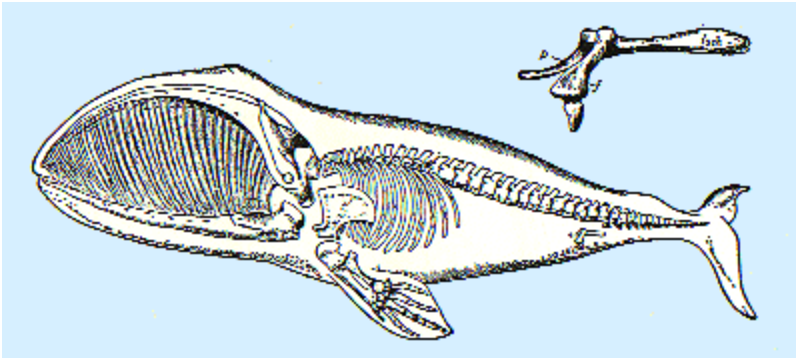
- Structures that arise from the same area of the embryo, but give rise to different mature forms; common structure, not common function.

Homology in mammalian appendages



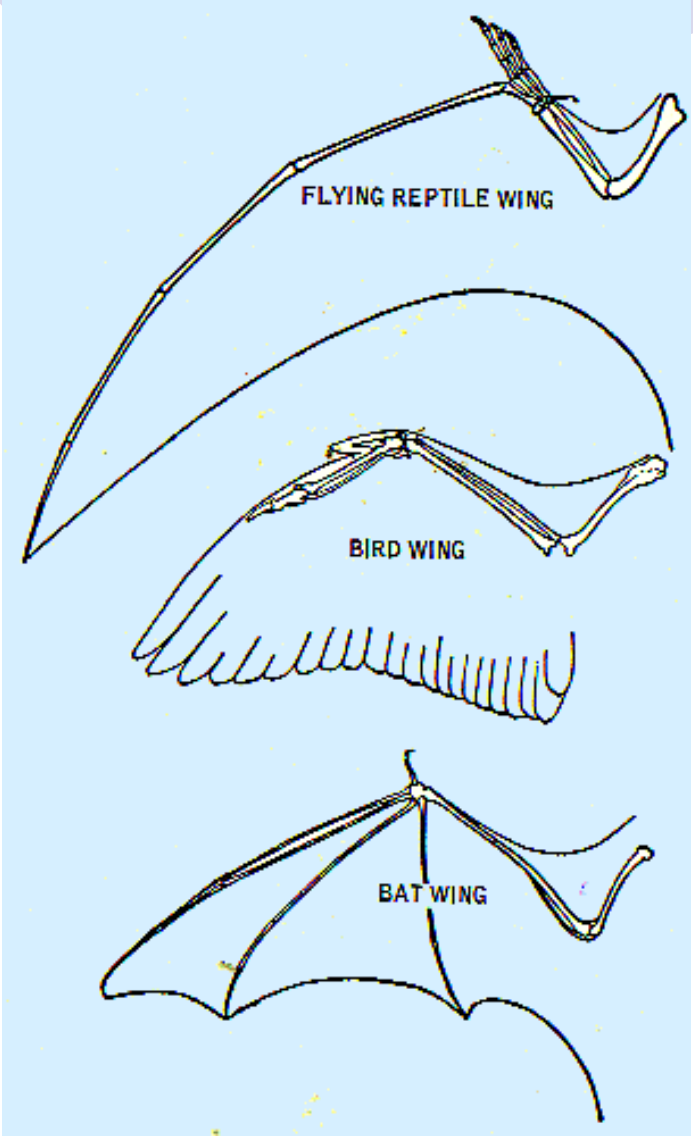
Vestigial Organs

- Inherited from ancestors but have lost much or all of their original function
- Pelvic girdle in whales and snakes
- Appendix in humans
- Eye spots in cave-dwelling animals

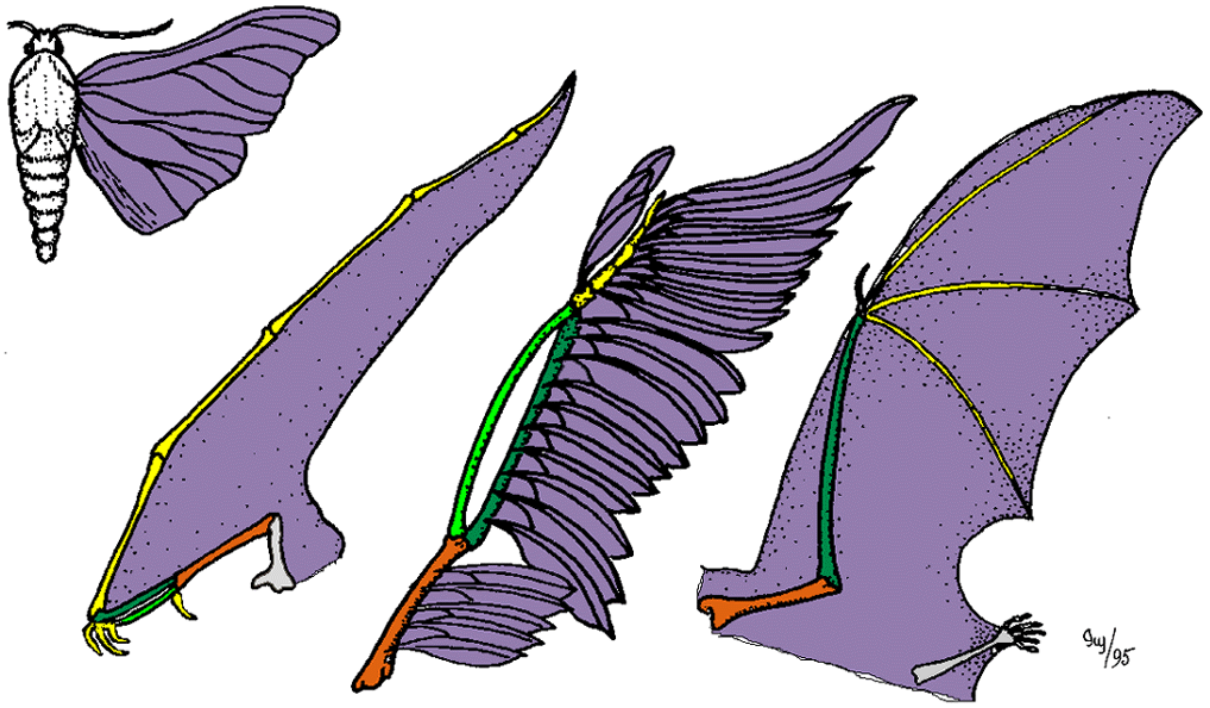


Analogous Structures

- Common function, not common structure
- Archeopteryx- “finger wing” extended single digit
- Bird wing- “arm wing” all “arm” is part of wing
- Bat wing- “hand wing” the wing is made up of several elongated digits



Let's practice: Analogous & Homologous structures



Homologous, Analogous or Vestigial?

Dolphins (which are mammals) and fish both have similar body shapes adapted for moving in water.

Analogous

Homologous, Analogous or Vestigial?

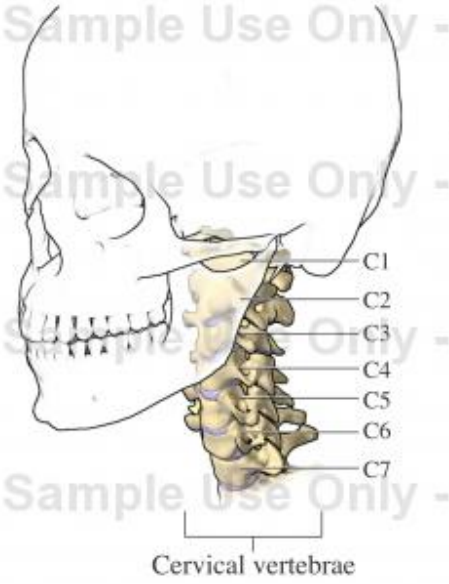
This species of cave-dwelling salamander has eyebuds, but is completely blind.

Vestigial

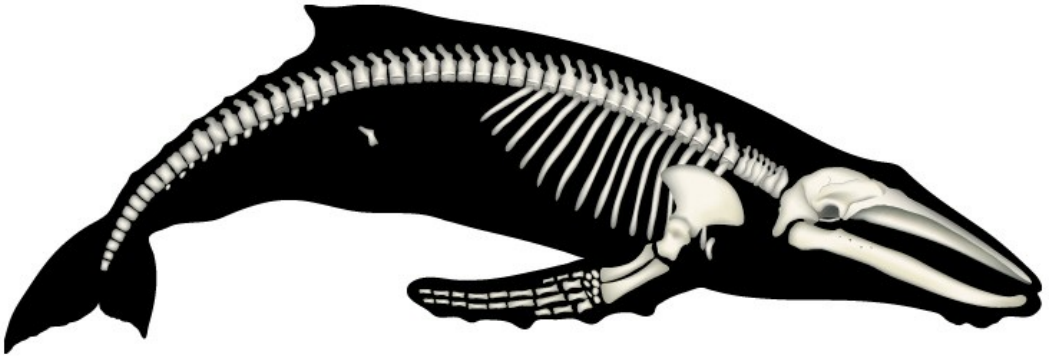
Homologous, Analogous or Vestigial?

Giraffe – 7 neck bones

Homologous



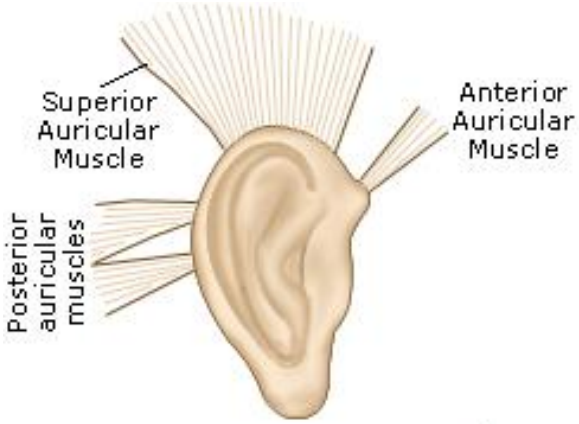
Human – 7 neck bones



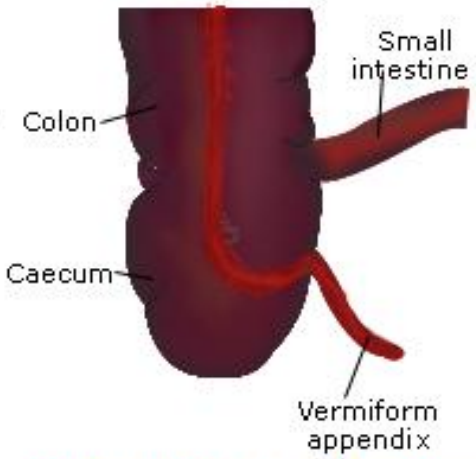
Whale – 7 neck bones

Homologous, Analogous or Vestigial?

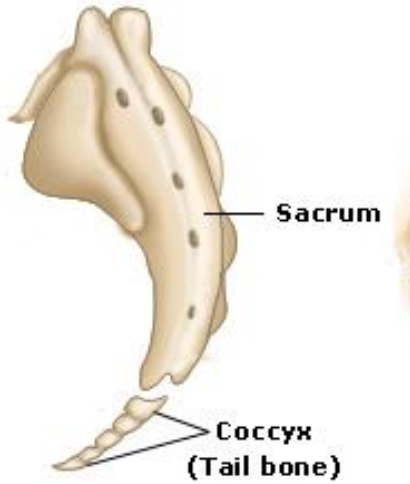
The ear muscles, appendix, and tailbone in humans. Vestigial



Vestigial auricular muscles of the pinna in man



Vestigial caecum and vermiform appendix in man



Tail bone in human being

Homologous, Analogous or Vestigial?

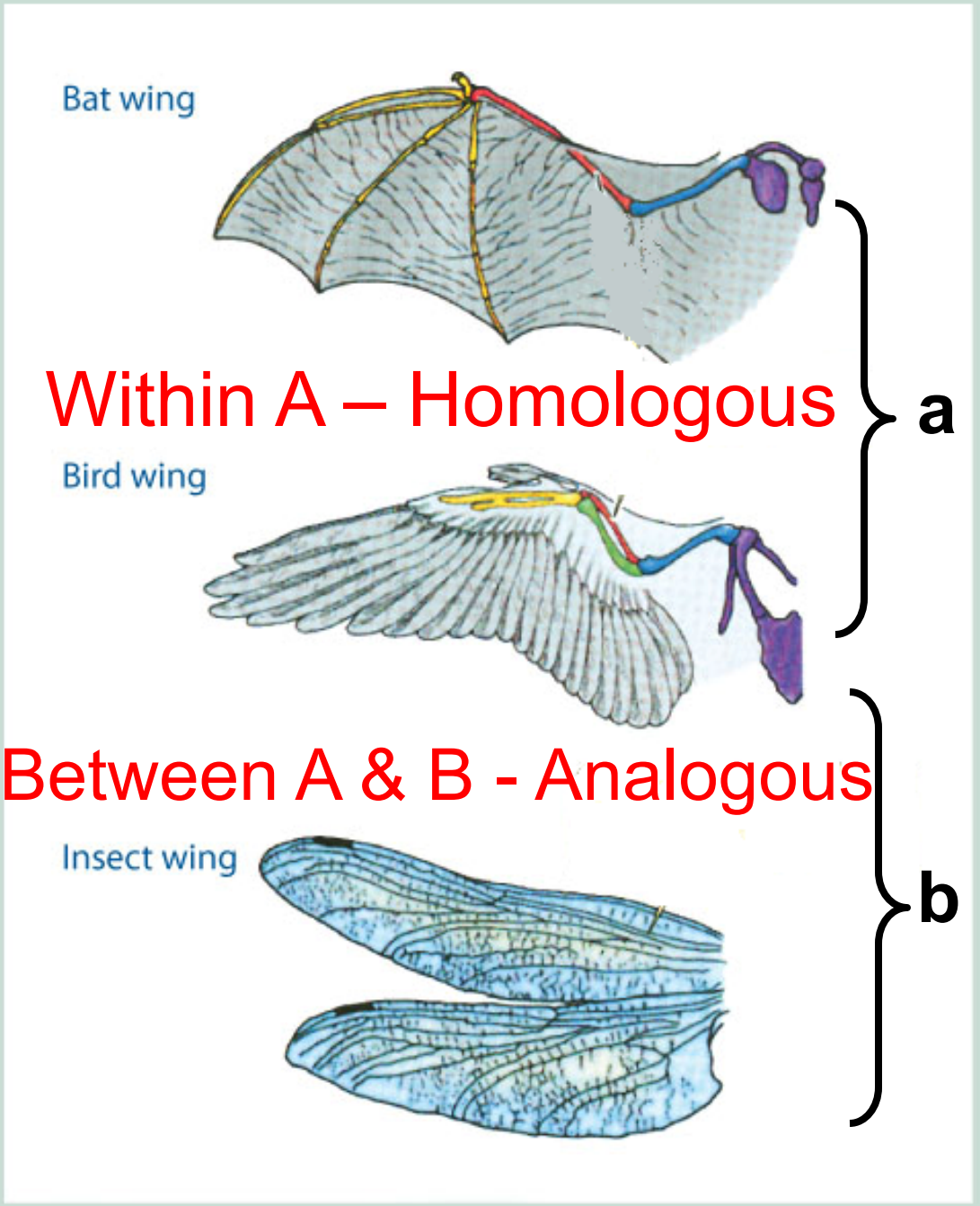
Indicates that two organisms probably have a common ancestor.

Homologous

Homologous, Analogous or Vestigial?

Compare the entire wing.

What about the yellow bones?

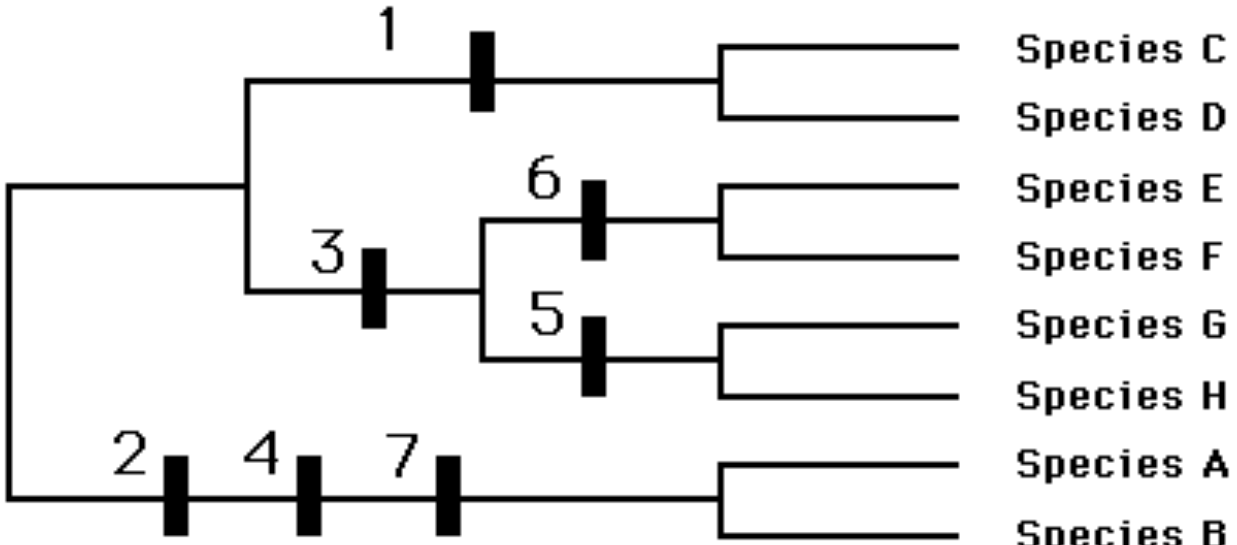


Common Ancestry

- Common embryology, homologous structures, and DNA comparisons indicate that all living things are related in differing degrees.
- Linking organisms together and classifying them based on relatedness is a hot topic among biologists today.

Relatedness based on DNA Analysis

```
                1   2    3        4              5      6  7
Species A   ACCAGCCTGTGCATCGATGACGACTAAGTGATACCATAAAGACT
Species B   ACCAGCCTGTGCATCGATGACGACTAAGTGATACCATAAAGACT
Species C   ACGAGCATGTGCATCGATGCCGACTAAGTGATACCATAATGACT
Species D   ACGAGCATGTGCATCGATGCCGACTAAGTGATACCATAATGACT
Species E   ACCAGCATGTGTATCGATGCCGACTAAGTGATACCAAAATGACT
Species F   ACCAGCATGTGTATCGATGCCGACTAAGTGATACCAAAATGACT
Species G   ACCAGCATGTGTATCGATGCCGACTAAGTGCTACCATAATGACT
Species H   ACCAGCATGTGTATCGATGCCGACTAAGTGCTACCATAATGACT
```



We can also compare **amino acid sequences** by looking at how many **differences** there are

Cytochrome c Amino-Acid Sequences

AA #	Horse	Chicken	Tuna	Frog	Human	Shark	Turtle	Monkey	Rabbit
42	Q	Q	Q	Q	Q	Q	Q	Q	Q
43	A	A	A	A	A	A	A	A	A
44	P	E	E	A	P	Q	E	P	V
46	F	F	Y	F	Y	F	F	Y	F
47	T	S	S	S	S	S	S	S	S
49	T	T	T	T	T	T	T	T	T
50	D	D	D	D	A	D	E	A	D
53	K	K	K	K	K	K	K	K	K
54	N	N	S	N	N	S	N	N	N
55	K	K	K	K	K	K	K	K	K
56	G	G	G	G	G	G	G	G	G
57	I	I	I	I	I	I	I	I	I
58	T	T	V	T	I	T	T	T	T
60	K	G	N	G	G	Q	G	G	G
61	E	E	N	E	E	Q	E	E	E
62	E	D	D	D	D	E	E	D	D
63	T	T	T	T	T	T	T	T	T
64	L	L	L	L	L	L	L	L	L
65	M	M	M	M	M	R	M	M	M
66	E	E	E	E	E	I	E	E	E
100	K	D	S	S	K	K	D	K	K
101	A	A	A	A	A	T	A	A	A
102	T	T	T	C	T	A	T	T	T
103	N	S	S	S	N	A	S	N	N
104	E	K	—	K	E	S	K	E	E

The debate with bats…

- There are two kinds of bats,
  - Microbats

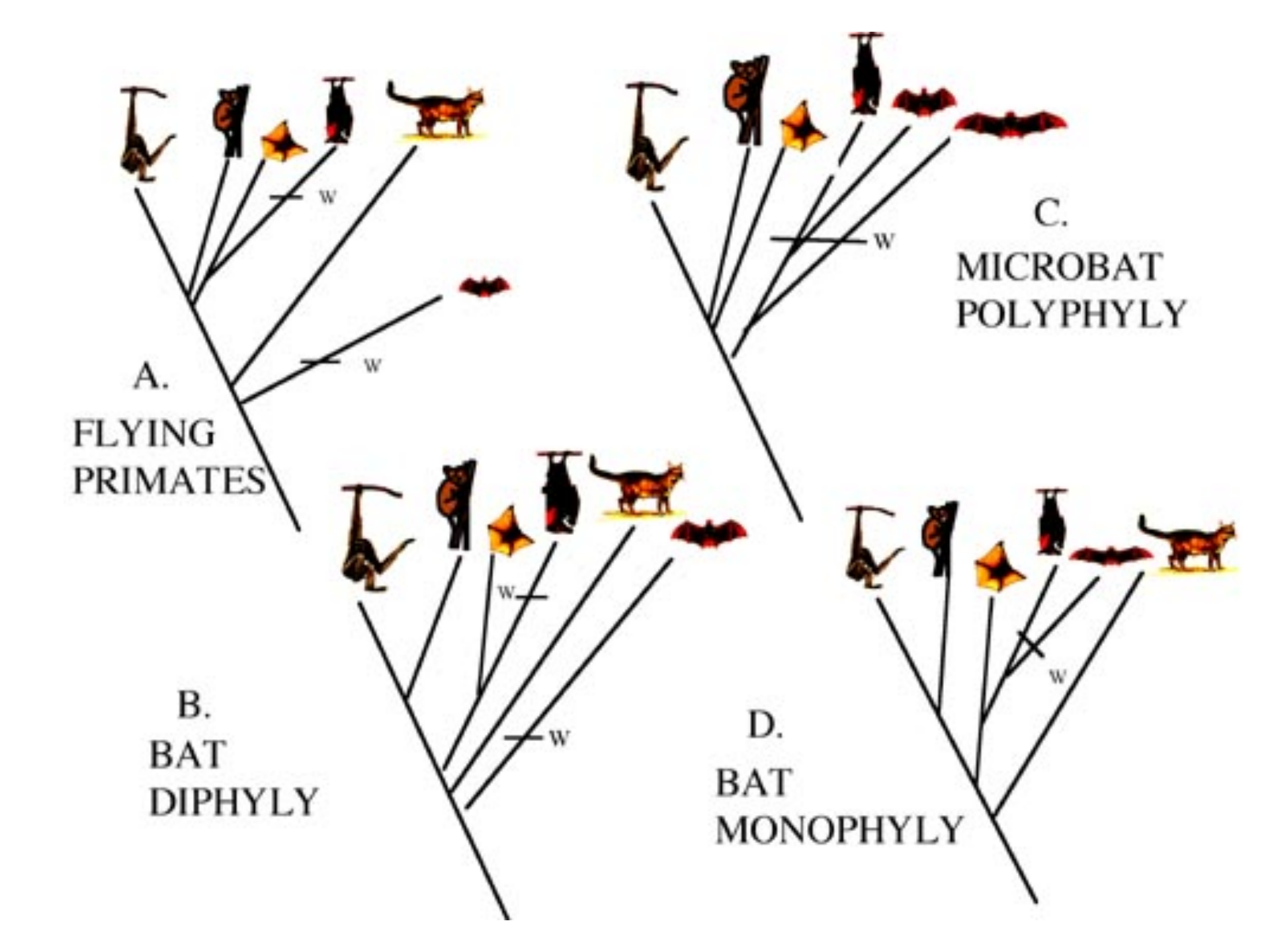
  - And megabats

Are they from the same lineage?

- Mammalogists have debated for years over the phylogeny (the evolutionary family tree) of *Chiroptera*, the bat group.
- Did flying mammals evolve once or twice?
  - Comparing morphologies, physiologies, and DNA…
    - Some say it is a monophyletic group (same lineage)
    - Some say it is diphyletic (they did NOT diverge from each other)
    - Some say that bats are monophyletic, but microbats are two lineages within the entire bat lineage

KEY

- Primates (prosimians and anthropoids)
- Colugo (flying lemur- Dermatpera)
- Megabat/flying foxes
- Microbats
- Other mammals (outgroup)


w
w
A.
FLYING
PRIMATES
w
w
C.
MICROBAT
POLYPHYLY
w
w
B.
BAT
DIPHYLY
w
D.
BAT
MONOPHYLY

- These phylogenetic trees are constructed using
  - Morphologies (skull, teeth, digits)
  - Physiologies (down to how they defecate!)
  - DNA data
  - Protein data