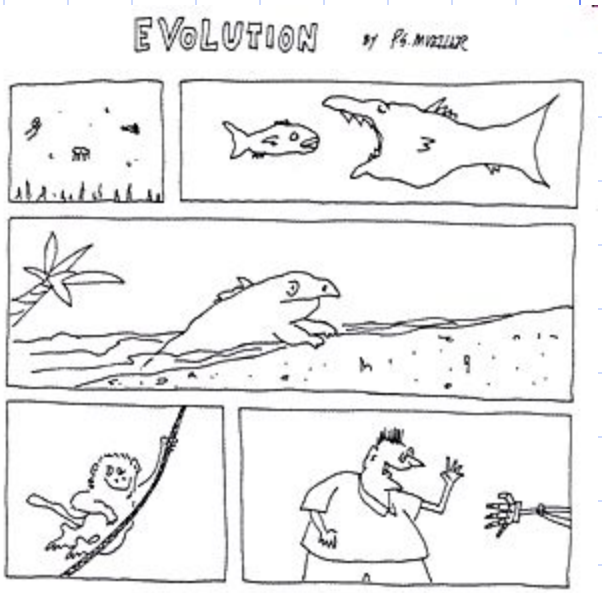
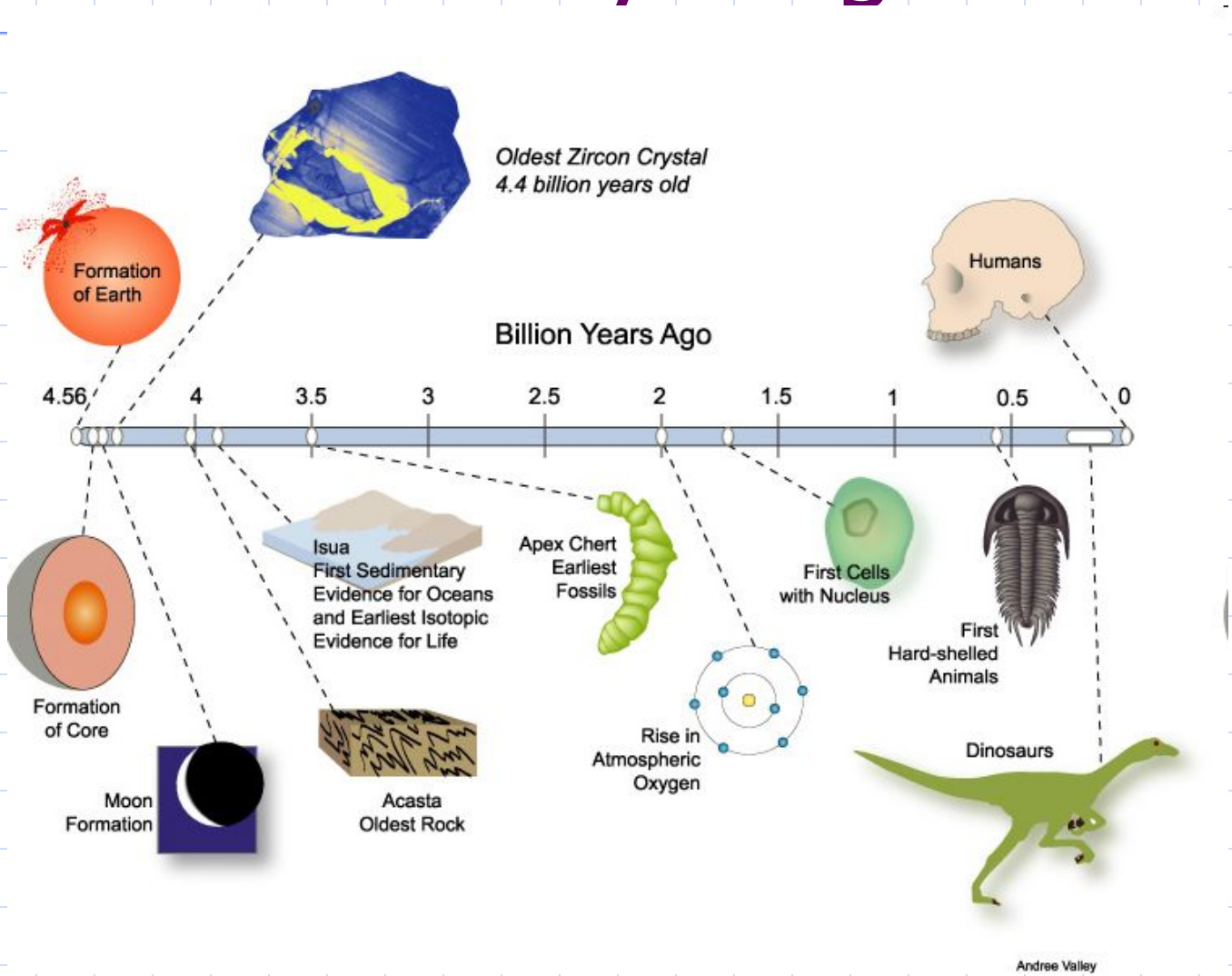
Evidence for Evolution

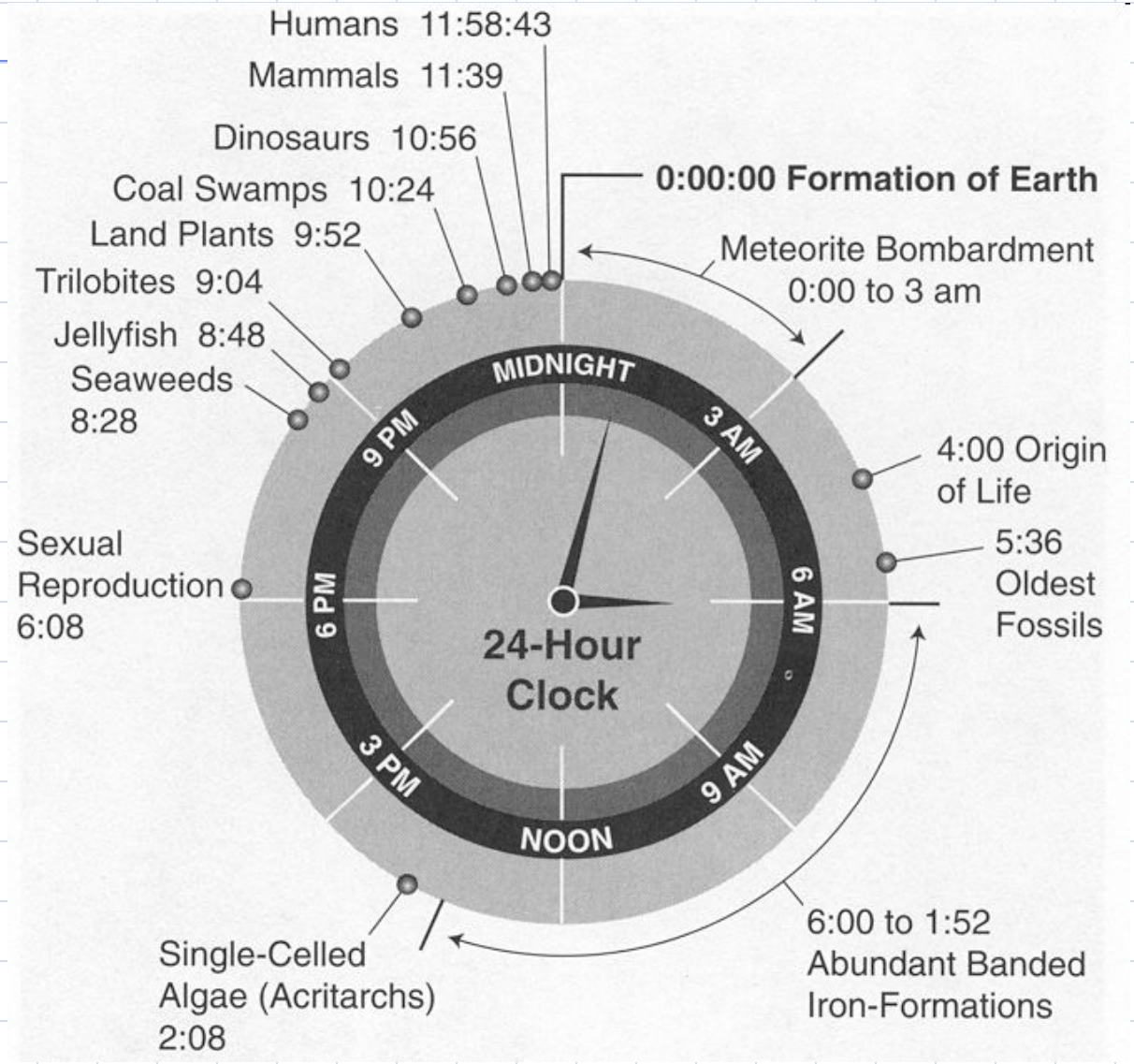
1. Paleontology
2. Comparative Anatomy
3. Embryology
4. Comparative Biochemistry
5. Geographical Distribution

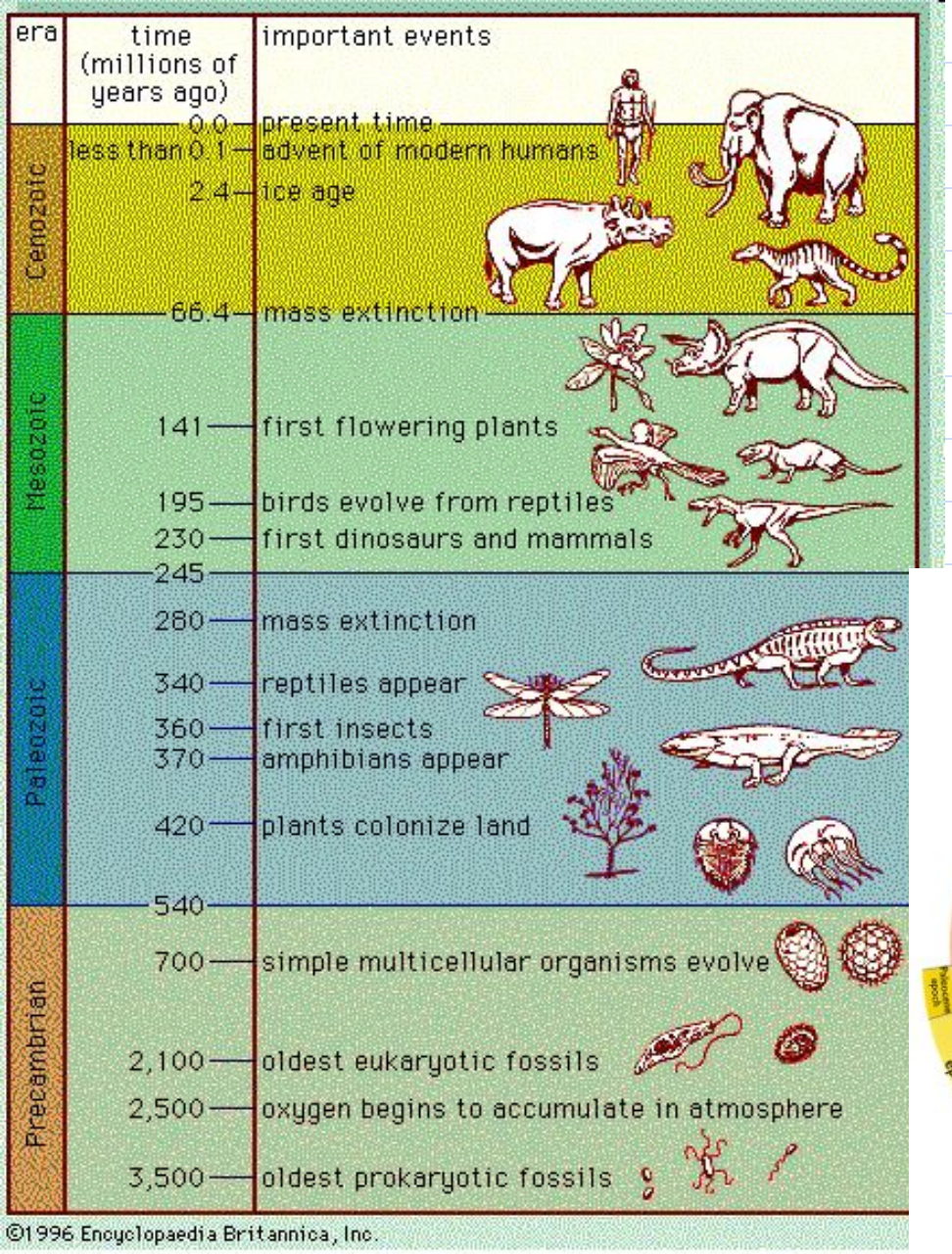


How old is everything?



The History of Earth as a Clock




era
time (millions of years ago)
important events
Cenozoic
0.0 present time
less than 0.1 advent of modern humans
2.4 ice age
66.4 mass extinction
Mesozoic
141 first flowering plants
195 birds evolve from reptiles
230 first dinosaurs and mammals
245
Paleozoic
280 mass extinction
340 reptiles appear
360 first insects
370 amphibians appear
420 plants colonize land
540
Precambrian
700 simple multicellular organisms evolve
2,100 oldest eukaryotic fossils
2,500 oxygen begins to accumulate in atmosphere
3,500 oldest prokaryotic fossils
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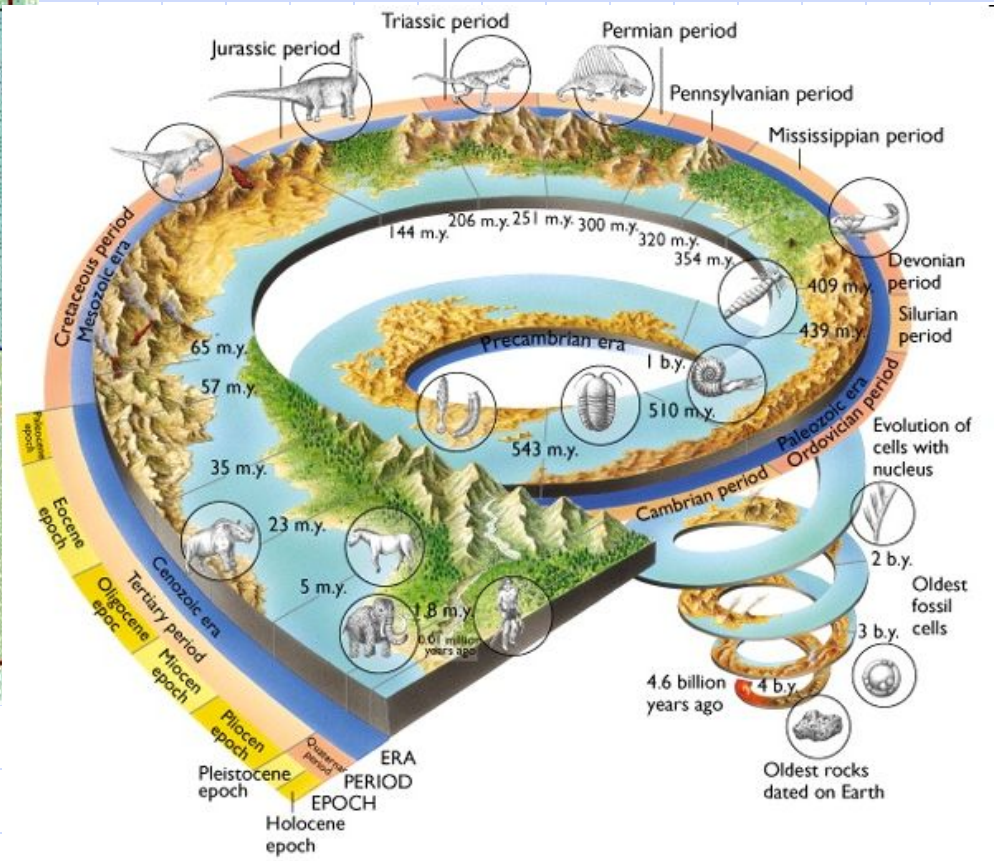
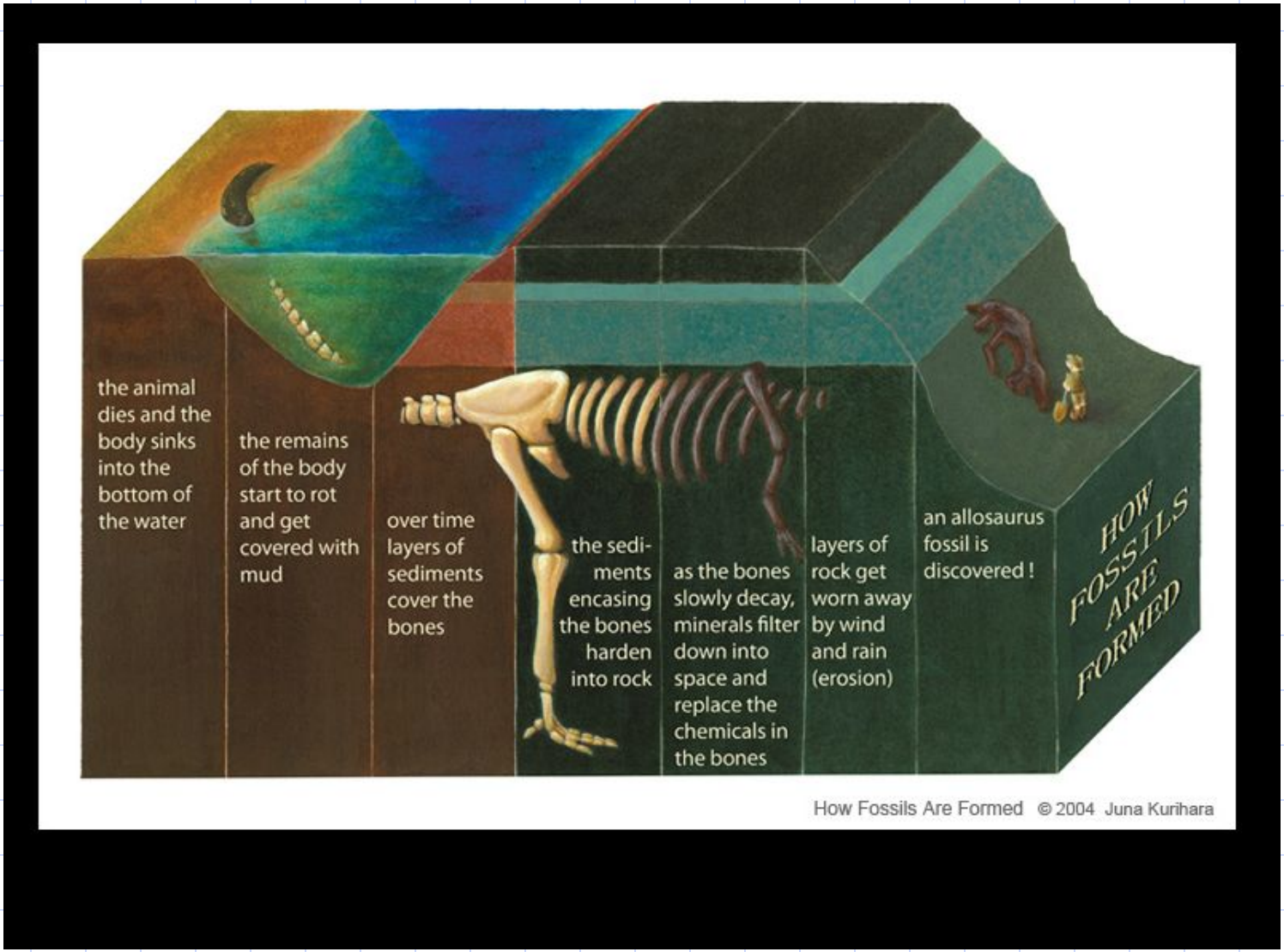

Triassic period
Jurassic period
Permian period
Pennsylvanian period
Mississippian period
Devonian period
Silurian period
Ordovician period
Cambrian period
Paleozoic era
Mesozoic era
Cenozoic era
Precambrian era
Cretaceous period
144 m.y.
206 m.y.
251 m.y.
300 m.y.
320 m.y.
354 m.y.
409 m.y.
439 m.y.
1 b.y.
510 m.y.
543 m.y.
65 m.y.
57 m.y.
35 m.y.
23 m.y.
5 m.y.
1.8 m.y.
0.01 million years ago
Evolution of cells with nucleus
2 b.y.
Oldest fossil cells
3 b.y.
4 b.y.
4.6 billion years ago
Oldest rocks dated on Earth
Eocene epoch
Oligocene epoch
Miocen epoch
Pliocen epoch
Pleistocene epoch
Holocene epoch
Tertiary period
Quaternary period
ERA
PERIOD
EPOCH

Station 1: Paleontology

- the scientific investigation of prehistoric life through the study of fossils

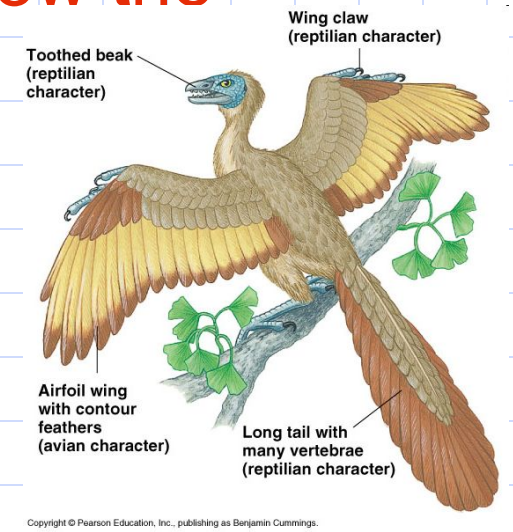
Fossils – any remains of an organism or evidence of its presence



<u>Note</u>: Only organisms that die in low oxygen locations will fossilize.

Evidence from Fossils:

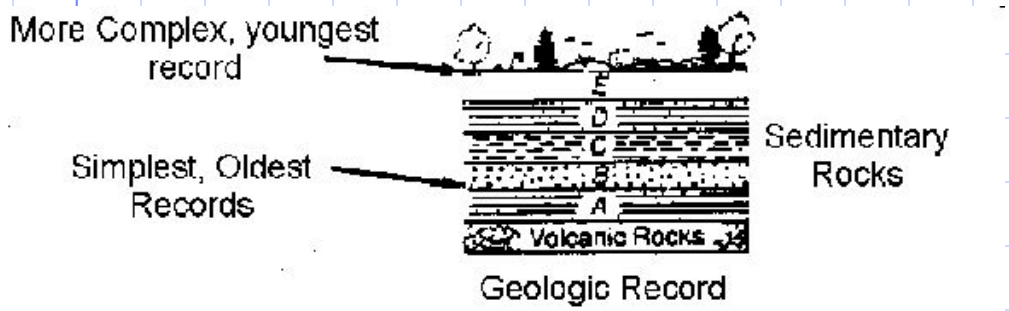
- Fossils appear in chronological order; probable ancestors appear in older rocks
- For vertebrates, fish appear first followed by amphibians, reptiles, birds and mammals
- Transitional fossils such as archaeopteryx (a link between birds and reptiles) show the intermediates between organisms.

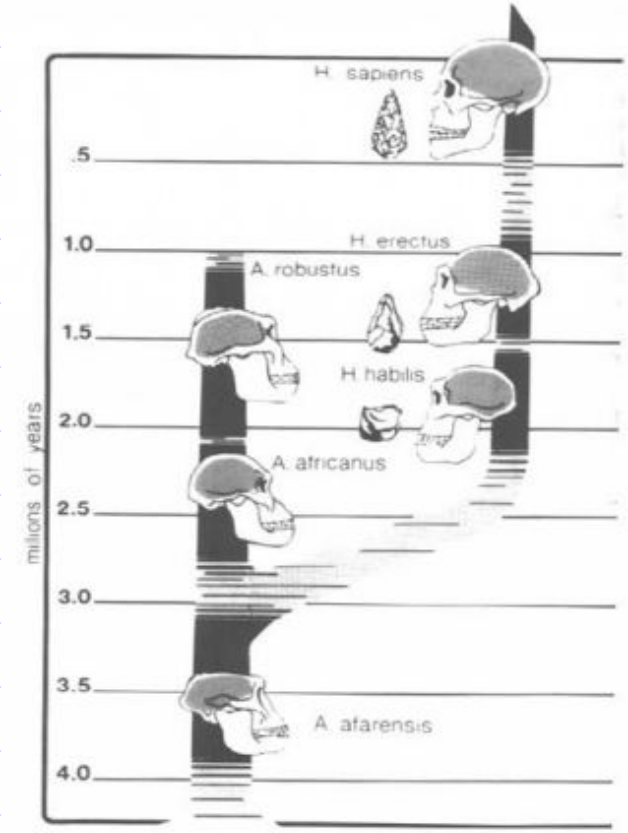


Fossils - http://www.agiweb.org/news/evolution/fossilrecord.html

Dating fossils -http://www.agiweb.org/news/evolution/datingfossilrecord.html#null

- the deeper the fossils found in sedimentary rock, the simpler the life form
- the fact that all organisms **do not** appear in the fossil record simultaneously supports the idea that organisms change slowly over time
- fossils show how individual species have evolved (changed) over time





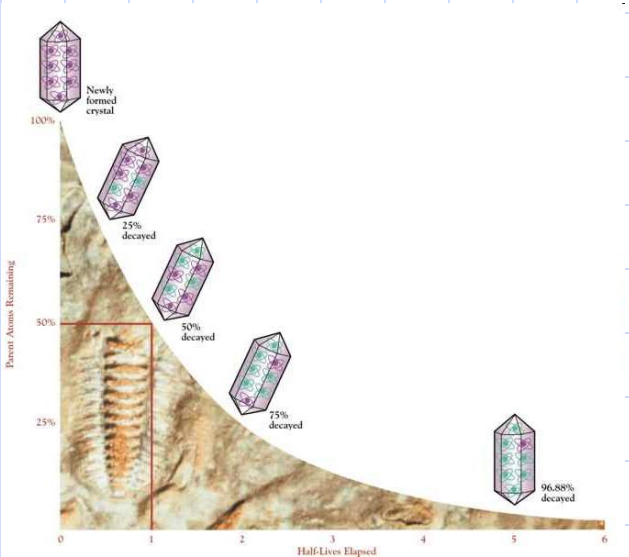
How fossils are dated: RADIOMETRIC DATING

- Radioisotopes are atoms that undergo radioactive decay.
- decay changes 'parent' isotope into 'daughter' isotope
- Carbon dating (1:15 min)
  http://www.youtube.com/watch?v=IW8fh7JFPnU&feature=related

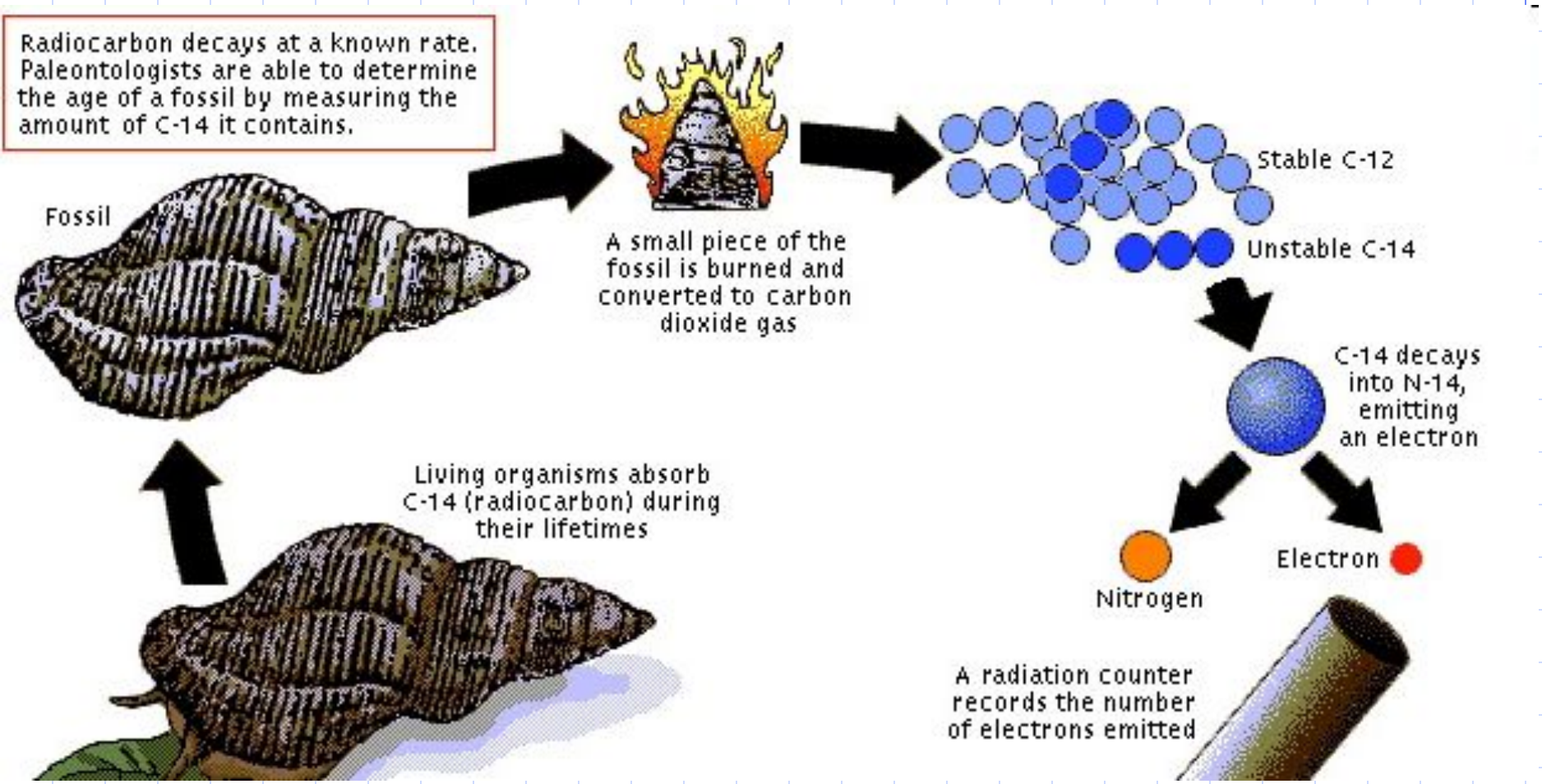
eg. Most C atoms have 6 protons and 6 neutrons and are not radioactive. However, a small fraction of carbon atoms are radioactive. They have a nucleus containing 6 protons and 8 neutrons. When these radioactive carbon 14 isotopes undergo decay, they release a high energy particle, and one of the neutrons changes to a proton. The daughter isotopes are nitrogen atoms, each containing 7 protons and 7 neutrons.

- each radioisotope has a constant rate of decay (always decays at same rate) and this is called its 'half-life‘

- Half-life: the time it takes for half of a sample (50%) to decay
- As the number of parent isotope atoms *decreases*, the number of daughter isotope atoms *increases*
- So by measuring the amounts of these isotopes and using the half-life, it is possible to determine *absolute time*
- Radiometric dating is used as a predictable clock and used to measure the age of rock
- eg. C14--used to measure age of objects less than 100 000 years old (since it has a short half life of 5730 years)
- eg. U:Pb ratios are used for 10 million to 4.6 billion since half life is longer (713 million years)



Brief summary of Carbon dating:



(1:51 min) http://www.youtube.com/watch?v=GfiNewvZA4I&feature=related

Paleontology Summary

- Fossils show the order in which organisms evolved
- Fossils allow us to determine how long ago an organism existed

Station 2:
Comparative Anatomy

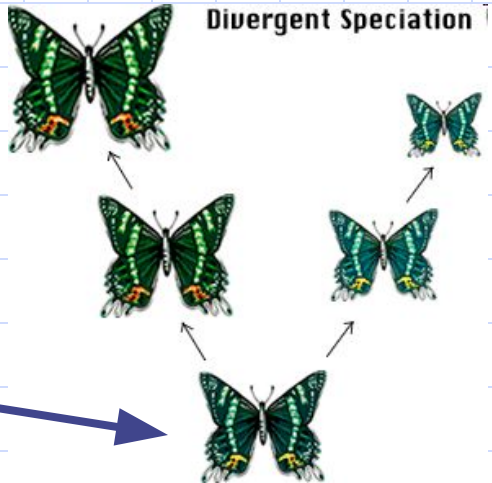
- looking for structures that are similar in appearance

Homologous and Analogous Structures:

Homologous Structures:

- *body parts in different species have the same evolutionary origin but serve different functions in modern species*
- - homologous structures are a result of DIVERGENT EVOLUTION

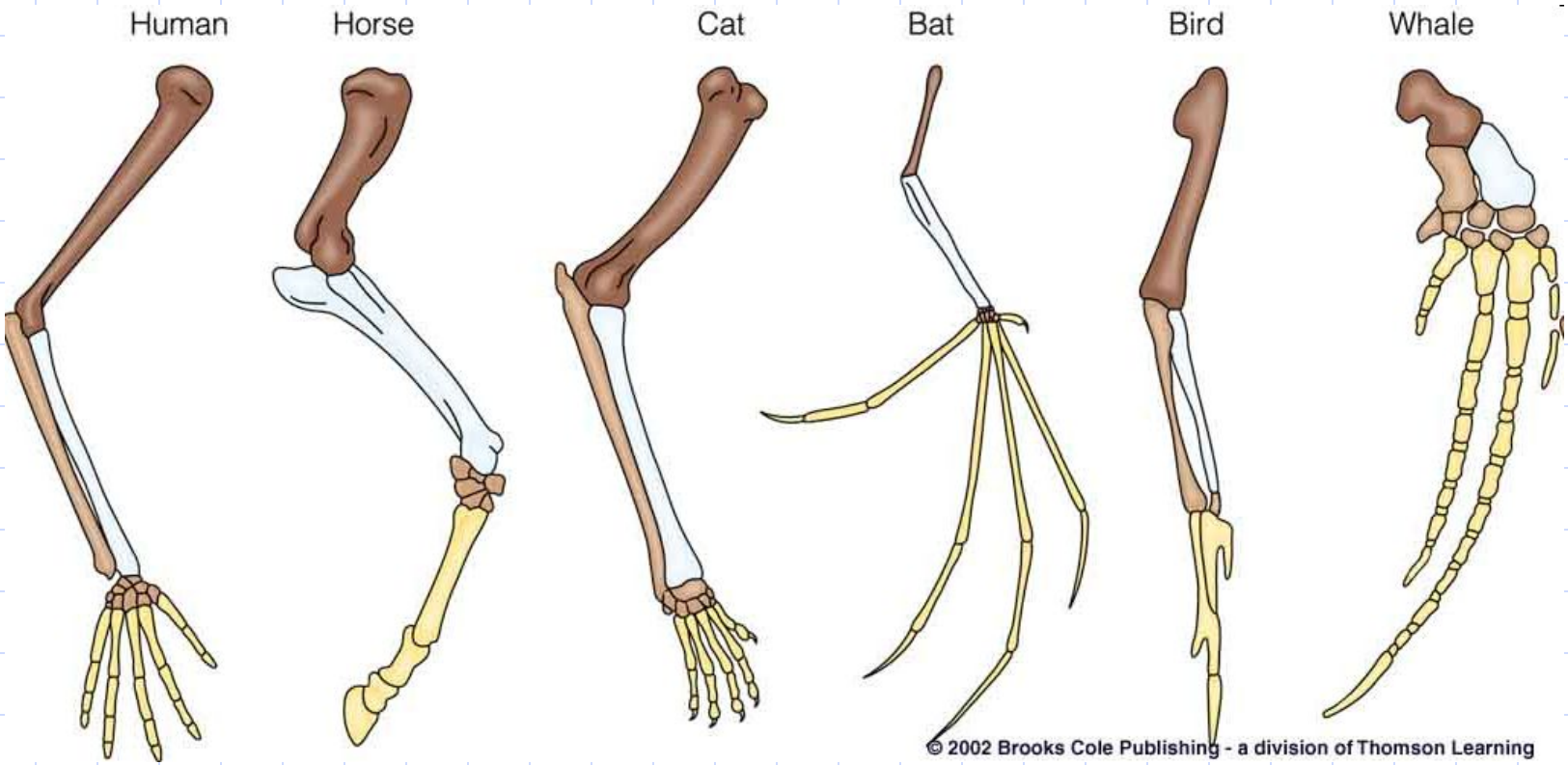
(related species evolve different traits)



Common ancestor

Example:

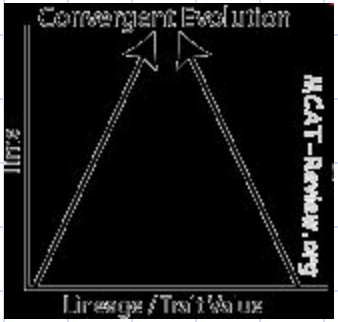
human forearm, horse's leg, whale flipper and bird wing all evolved from chordates



Analogous structures

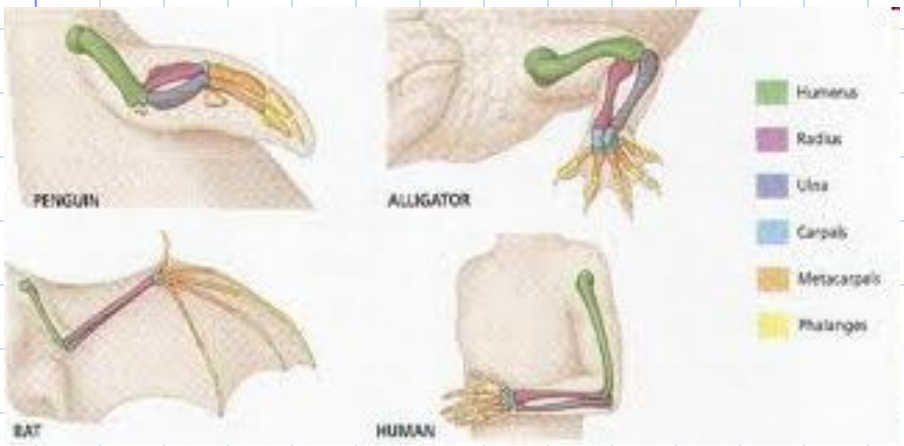
- *Different structures that have a common function between unrelated species due to similar environments, and thus similar selection pressures*
- analogous structures are a result of CONVERGENT EVOLUTION

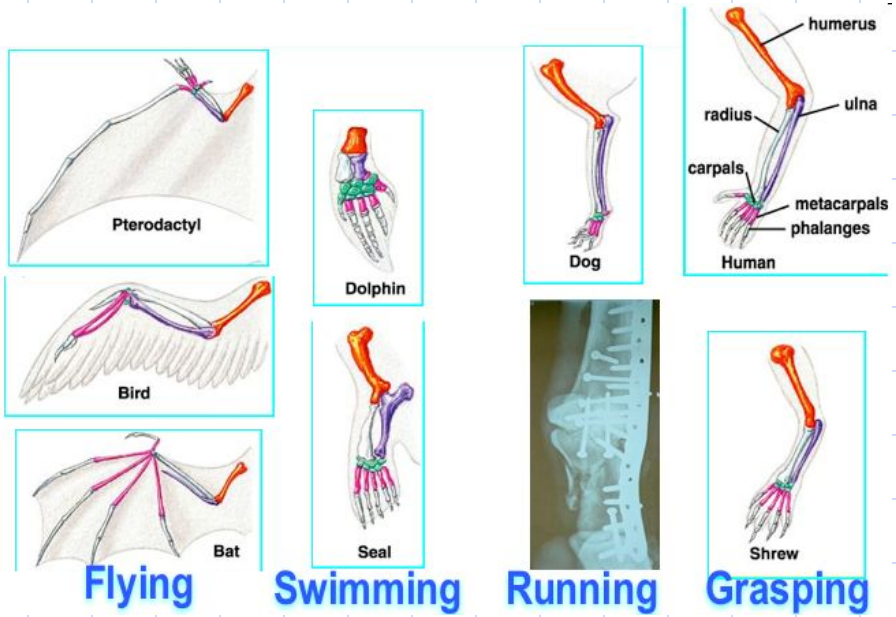
  (different species evolve similar traits)



Examples:

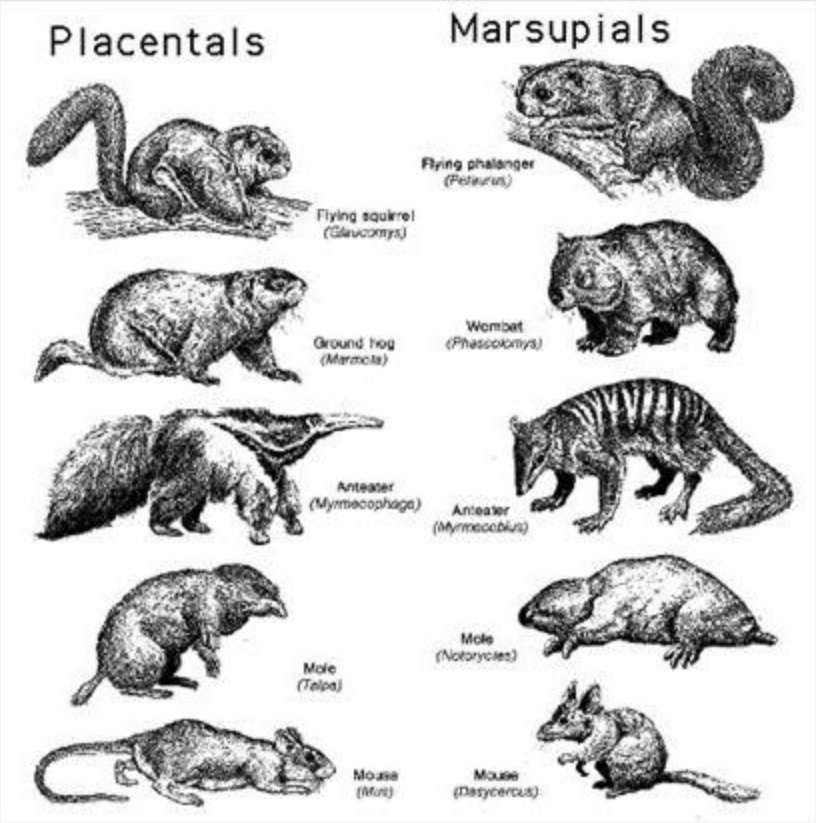
1) wing of a butterfly and a wing of a bat
2) streamlined bodies of dolphins (mammals) and sharks (fish)
3) anteaters and aardvarks





Convergent evolution

Niche	Placental Mammals	Australian Marsupials
Burrower	Mole	Marsupial mole
Anteater	Anteater	Numbat (anteater)
Mouse	Mouse	Marsupial mouse
Climber	Lemur	Spotted cuscus
Glider	Flying squirrel	Flying phalanger
Cat	Bobcat	Tasmanian "tiger cat"
Wolf	Wolf	Tasmanian wolf



Vestigial Structures:

- *Vestigial structures serve no useful purpose in a living organism, but may have served a purpose in the past or in a related organism.*
- Top 10 useless limbs: http://www.livescience.com/11317-top-10-useless-limbs-vestigial-organs.html

- Examples:
  - appendix and ear muscles in humans
  - wings in flightless insects
  - eyes in blind animals (bats)

Example: Whales have a pelvic bone, which indicate that their ancestors had hind legs and lived on land (remember that whales are mammals)

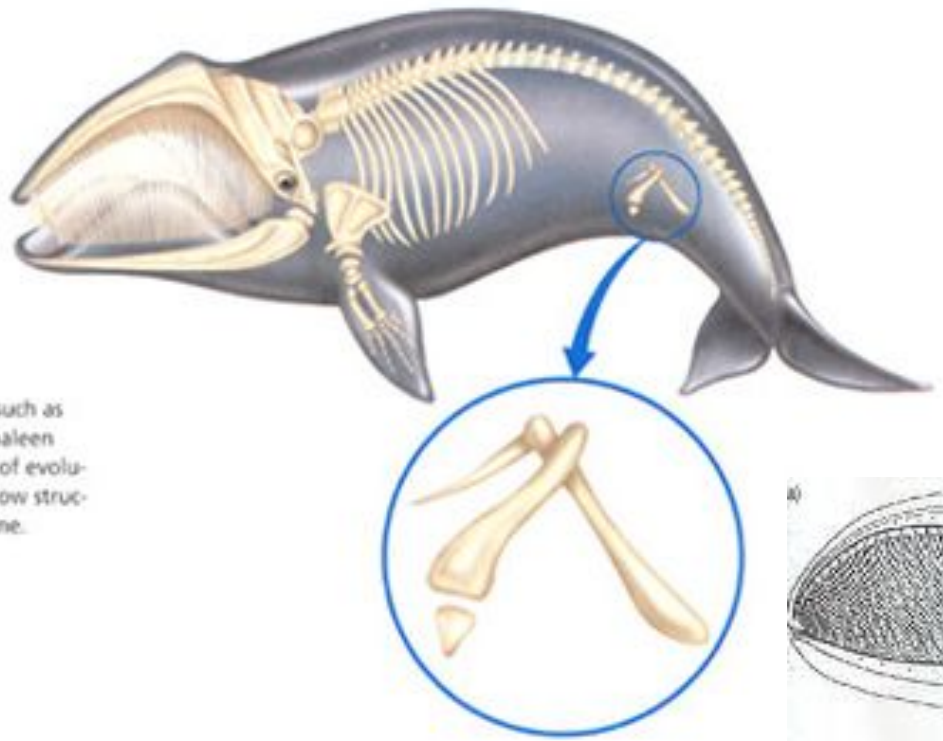
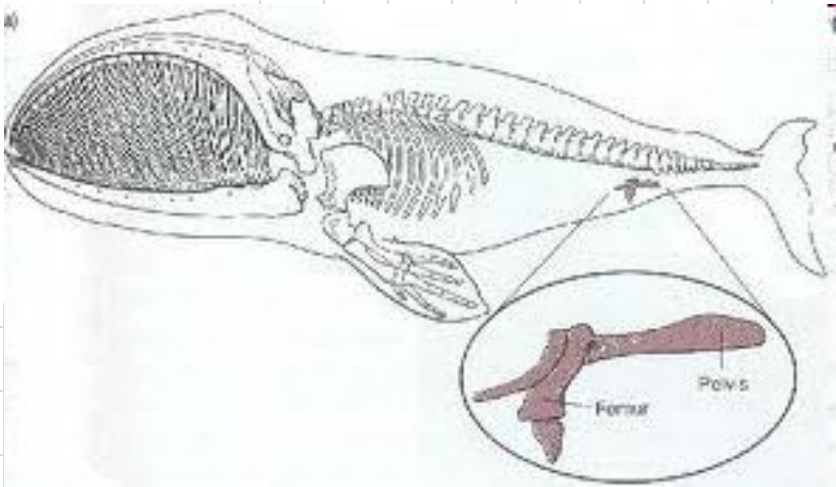


Figure 15.8
Vestigial structures, such as pelvic bones in the baleen whale, are evidence of evolution because they show structural change over time.



Comparative Anatomy Summary

- Organisms with homologous structures are more likely to be related than those with analogous features, even with their similarities.
- Vestigial structures indicate common ancestry with those organisms that have a functional version of the structure

Station 3:
Embryology

- the studying of developing forms of embryos

Evidence from Embryology:

- During fetal development, similarities can be seen between the development of the embryos.
- All vertebrate embryos follow a common developmental path due to their common ancestry.
- All have a set of very similar genes that define their basic body plan.

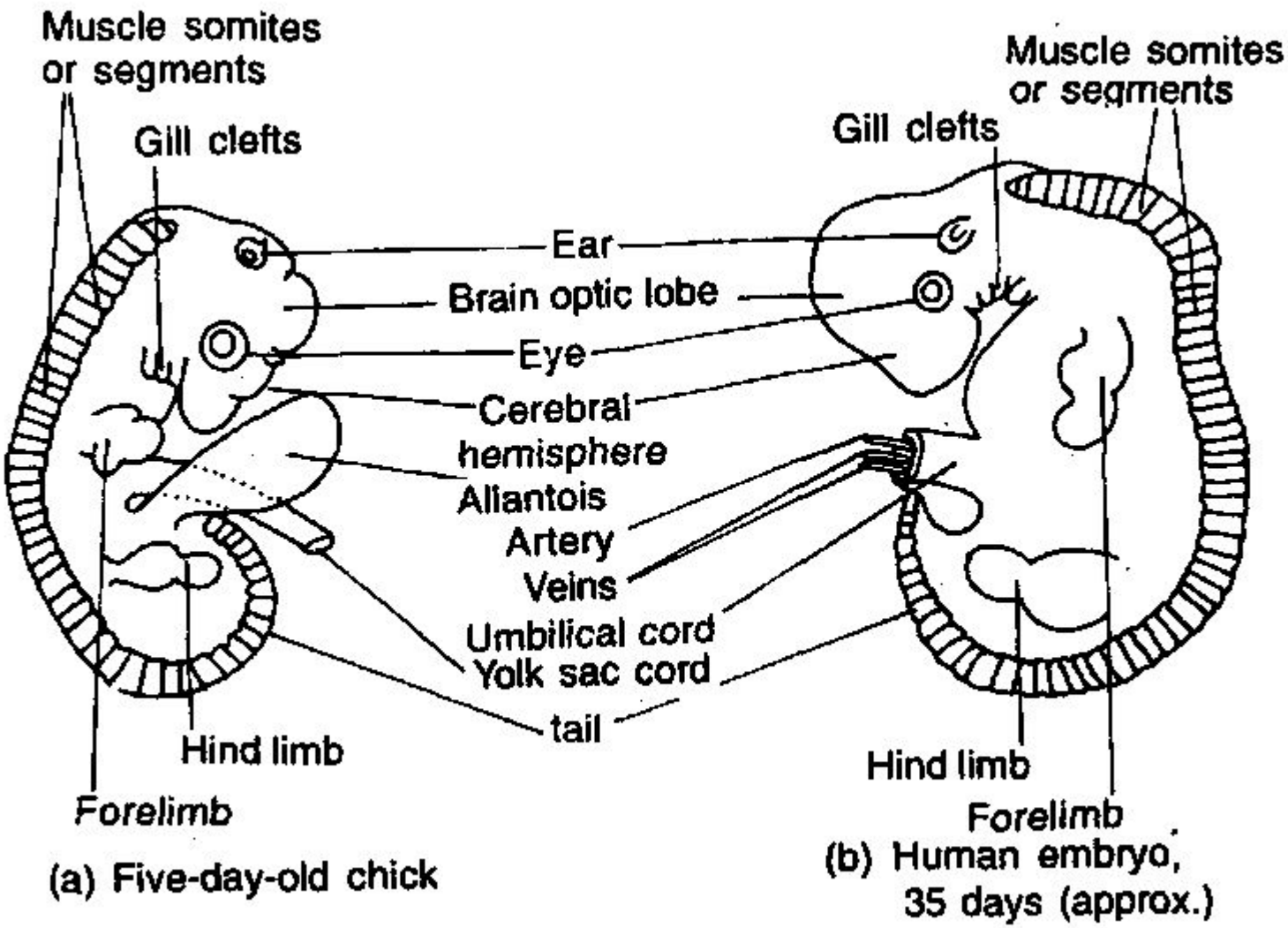
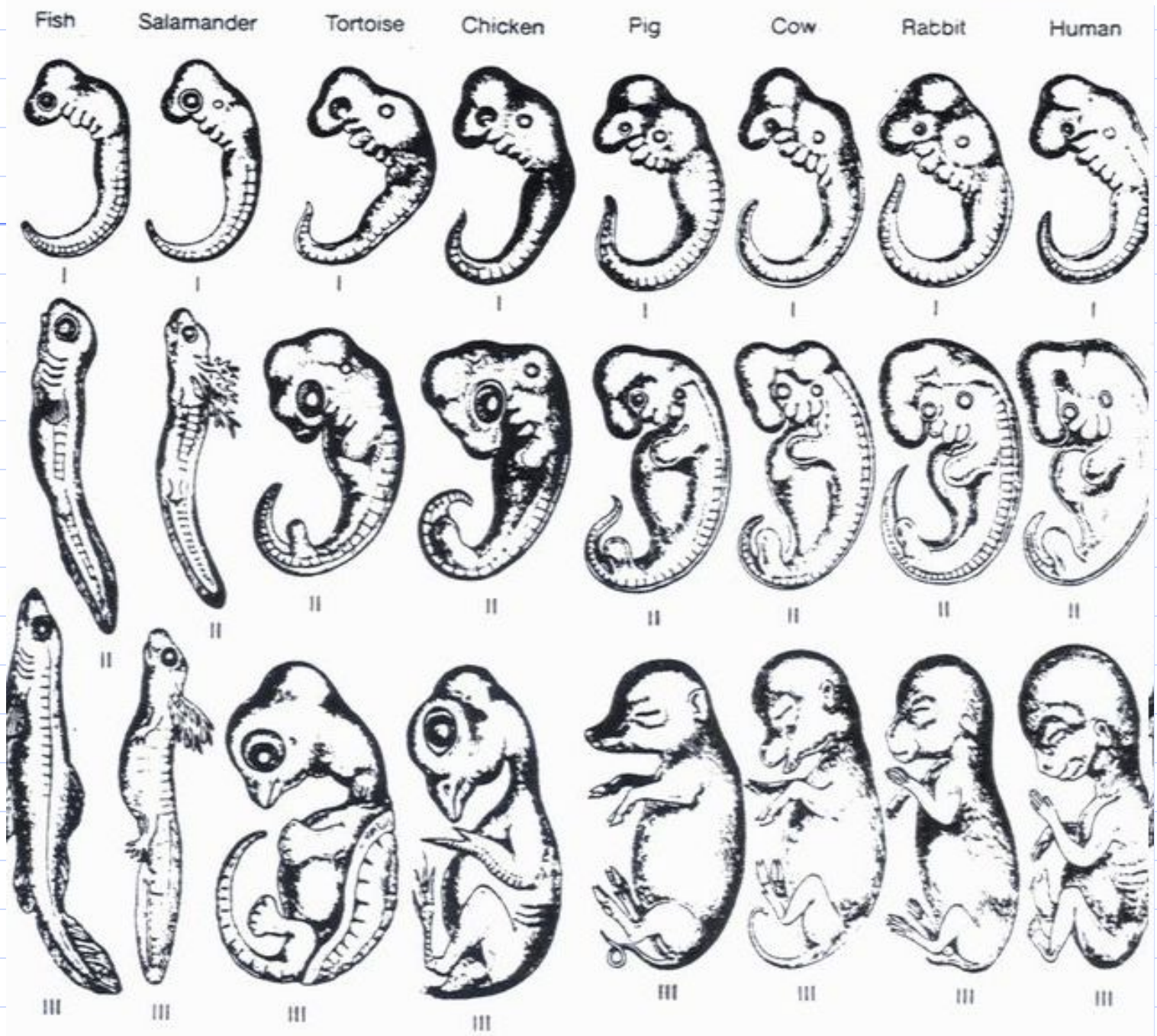


Fig. 9.13 Early embryos of (a) bird and (b) human.


Fish
Salamander
Tortoise
Chicken
Pig
Cow
Rabbit
Human
I
II
III

Embryology Summary

- The more closely related two organisms are, the more likely their embryos are to resemble each other for longer periods of time.

Station 4:
Comparative Biochemistry

- determining and comparing DNA base sequences and amino acid sequences from different animals

Evidence:

- A. Universality of genetic code supports theory of evolution (A, T, C, G)

		2nd base			
		U	C	A	G
1st base	U	UUU (Phe/F) Phenylalanine	UCU (Ser/S) Serine	UAU (Tyr/Y) Tyrosine	UGU (Cys/C) Cysteine
		UUC (Phe/F) Phenylalanine	UCC (Ser/S) Serine	UAC (Tyr/Y) Tyrosine	UGC (Cys/C) Cysteine
		UUA (Leu/L) Leucine	UCA (Ser/S) Serine	UAA Ochre (*Stop*)	UGA Opal (*Stop*)
		UUG (Leu/L) Leucine	UCG (Ser/S) Serine	UAG Amber (*Stop*)	UGG (Trp/W) Tryptophan
	C	CUU (Leu/L) Leucine	CCU (Pro/P) Proline	CAU (His/H) Histidine	CGU (Arg/R) Arginine
		CUC (Leu/L) Leucine	CCC (Pro/P) Proline	CAC (His/H) Histidine	CGC (Arg/R) Arginine
		CUA (Leu/L) Leucine	CCA (Pro/P) Proline	CAA (Gln/Q) Glutamine	CGA (Arg/R) Arginine
		CUG (Leu/L) Leucine	CCG (Pro/P) Proline	CAG (Gln/Q) Glutamine	CGG (Arg/R) Arginine
	A	AUU (Ile/I) Isoleucine	ACU (Thr/T) Threonine	AAU (Asn/N) Asparagine	AGU (Ser/S) Serine
		AUC (Ile/I) Isoleucine	ACC (Thr/T) Threonine	AAC (Asn/N) Asparagine	AGC (Ser/S) Serine
		AUA (Ile/I) Isoleucine	ACA (Thr/T) Threonine	AAA (Lys/K) Lysine	AGA (Arg/R) Arginine
		AUG[A] (Met/M) Methionine	ACG (Thr/T) Threonine	AAG (Lys/K) Lysine	AGG (Arg/R) Arginine
	G	GUU (Val/V) Valine	GCU (Ala/A) Alanine	GAU (Asp/D) Aspartic acid	GGU (Gly/G) Glycine
		GUC (Val/V) Valine	GCC (Ala/A) Alanine	GAC (Asp/D) Aspartic acid	GGC (Gly/G) Glycine
		GUA (Val/V) Valine	GCA (Ala/A) Alanine	GAA (Glu/E) Glutamic acid	GGA (Gly/G) Glycine
		GUG (Val/V) Valine	GCG (Ala/A) Alanine	GAG (Glu/E) Glutamic acid	GGG (Gly/G) Glycine

nonpolar | polar | basic | acidic | (stop codon)

- B. Similar chemistry and structure of chromosomes in Eukaryotes
- C. Chlorophyll is the same basic molecule in all photosynthetic organisms
- D. Cytochrome C is respiratory enzyme in all eukaryotic organisms

•Consists of a central ring structure with an iron atom in the center, and a protein chain about 100 amino acids long
•The more closely related organisms are, the more similar their amino acids in cyt. c are.
•Comparisons of human and other organism's cytochrome
•Cytochrome C may be used to construct a "tree of life“

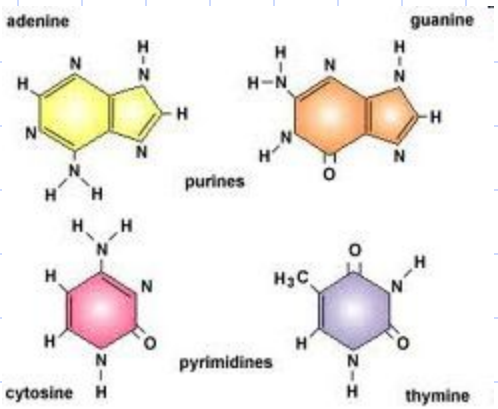
(3 min) http://www.youtube.com/watch?v=RLV_fSXO6So

- E. Enzymes - similar or identical enzymes are common to large groups of animals
  1. trypsin - protein splitting enzyme - many animals from protozoans to mammals
  2. amylase - starch-splitting enzyme found in everything from sponges to humans
- F. Nucleic Acid comparisons (DNA fingerprinting) - the more closely related two organisms are, the more similar is their DNA, e.g. identical twins
  - DNA fingerprinting is now the preferred way to study the evolution of life
  - it documents changes in genes (i.e. nucleotide sequences)
  - Comparison of mitochondrial DNA sequences in primates - chimpanzees are the most closely related to humans, lemurs are the first primates

Comparative Biochemistry Summary

- Provides the strongest evidence to support the theory of evolution.
- *The more closely related organisms are, the more similar their biochemical makeup.*

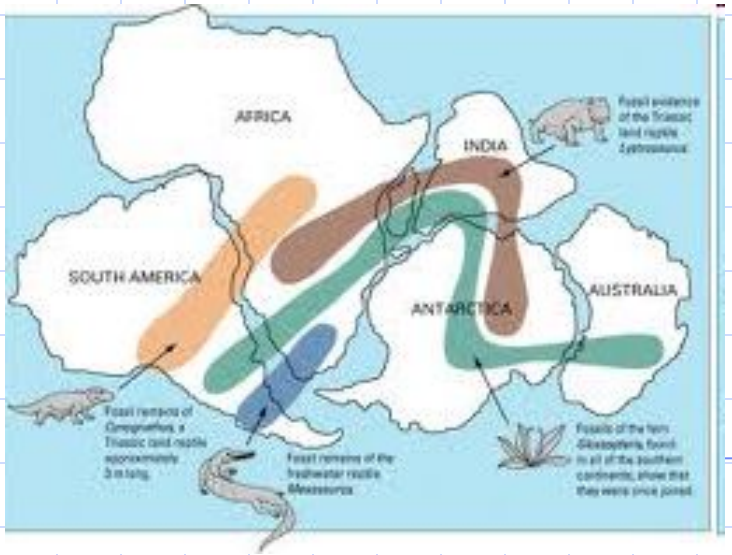
  (e.g. identical twins)
- The *less closely related species are*, the *more differences* there are in their DNA base or amino acid sequences, as there would be more time for mutations to accumulate.

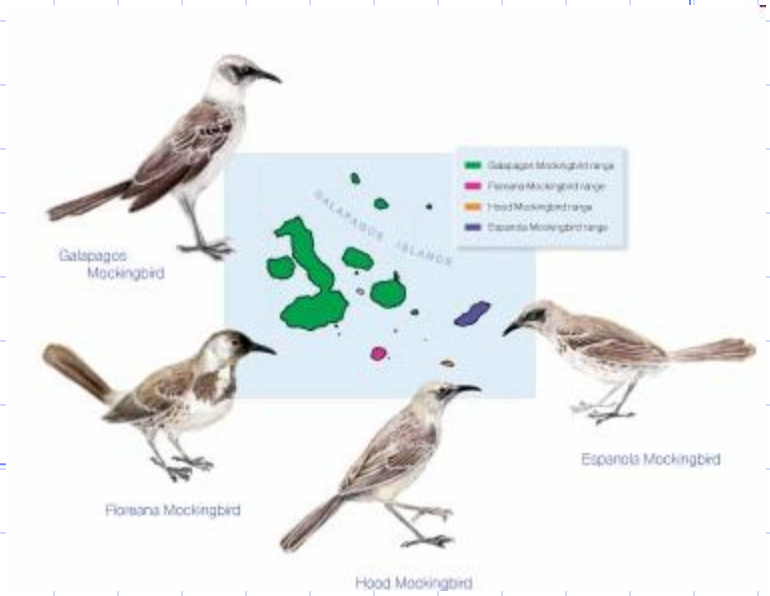


Species	Sequence of Amino Acids in the Same Part of the Hemoglobin Molecules
Human	Lys–Glu–His–Iso
Horse	Arg–Lys–His–Lys
Gorilla	Lys–Glu–His–Lys
Chimpanzee	Lys–Glu–His–Iso
Zebra	Arg–Lys–His–Arg

Station 5:
Geographical Distribution

the natural arrangement and location of the various forms of animals and plants in the different regions of the earth

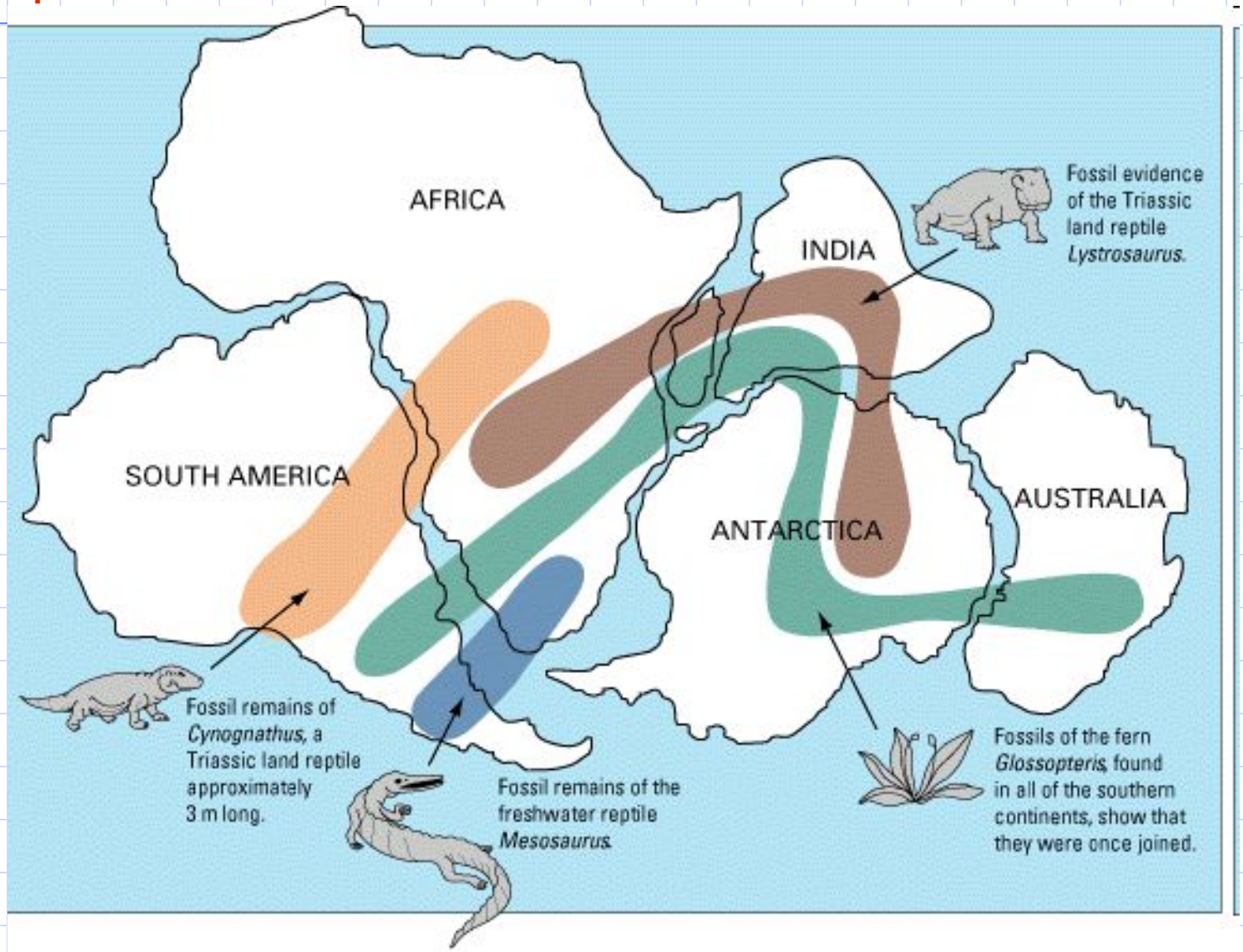




Geographical Distribution

- (4:40 min) http://www.youtube.com/watch?v=0iW5HUrEkc8
- the closer the island is to the mainland the more closely related the island and mainland species are
- the older the islands, the longer they've been inhabited (more life = more variety of species)
- species can become geographically isolated from one another (mountain ranges, Pangea)

Fossil distribution of these 4 species matches the arrangements of the Earth's land masses at the time the species were alive.



- Example: marsupial mammals were once more common than placental
- Over time, placental mammals displaced marsupial mammals in most areas. Due to a geographic barrier (Australia separated from continent) placental mammals were not able to establish themselves in Australia, where marsupial mammals are present.
- Numerous marsupial mammals are analagous to placental mammals we find in other parts of the world.

Geographical Distribution Summary

- If one species is the descendent of another, then there had to be some geographical continuity from where the parent species is found to where the child species is found – they had to be able to get there.