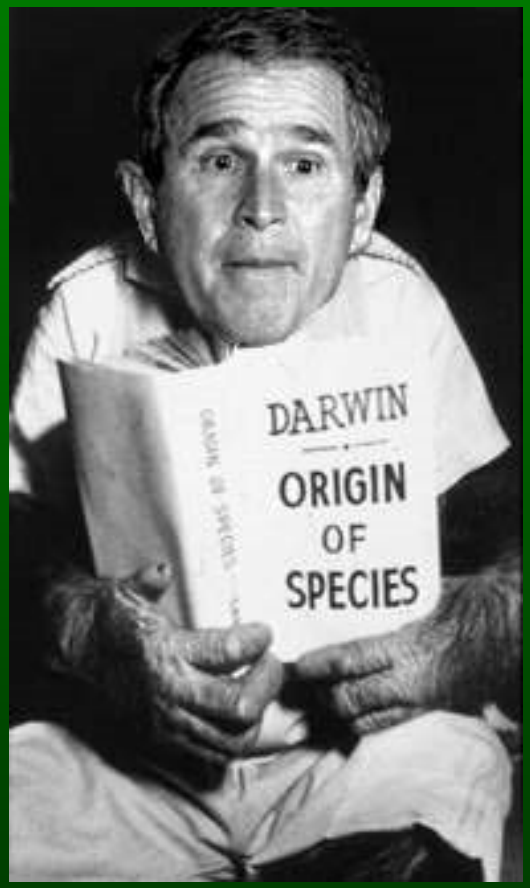
Evolution as Fact and Theory



What is a Scientific Theory?

“A well-substantiated explanation of some aspect of the natural world; an organized system of accepted knowledge that applies in a variety of circumstances to explain a specific set of phenomena.”

“A scientific theory is an established and experimentally verified fact or collection of facts about the world. Unlike the everyday use of the word theory, it is not an unproved idea, or just some theoretical speculation.”

Examples of Scientific Theories:

- Atomic theory
- Gravitational theory & Relativity
- Plate tectonic theory
- Heliocentric theory
- Evolutionary theory

Ideas Leading to Darwin's Theory

- **The prevailing view dated back to at least 350 B.C. (Aristotle):**
  - **Species are immutable yielding no change of form through time!**
  - **Earth is young**
  - **Divine creation produced all species**

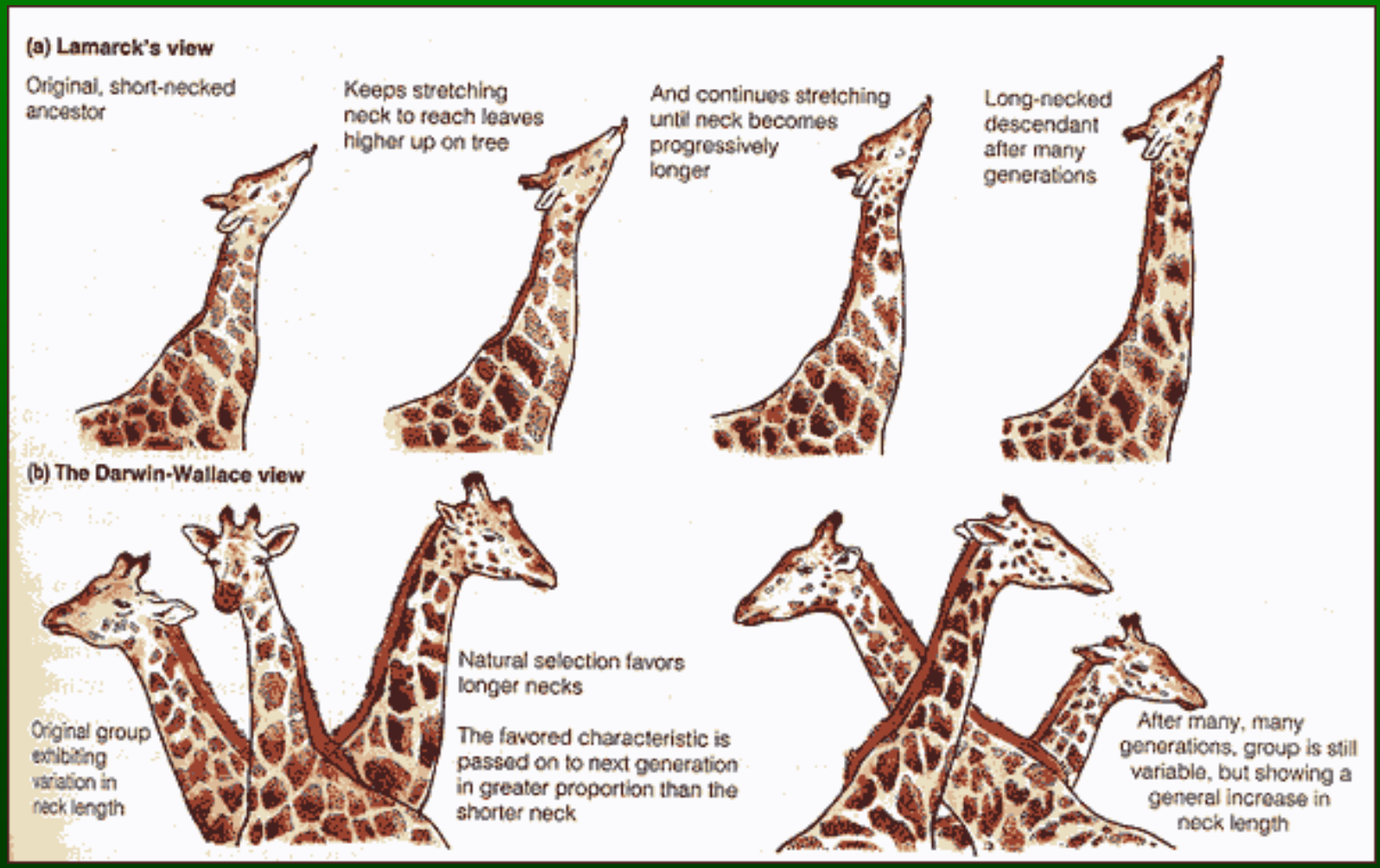
Ideas Leading to Darwin's Theory

- **Changing geological views:**
  - **1790 (James Hutton)**
    - **Proposed GRADUALISM - that landforms have been formed by the very processes that we can witness (e.g., erosion, volcanism, earthquakes)**
  - **1800 (Georges Cuvier)**
    - **One of the first paleontologists. Found fossil assemblages showing shifts in communities. Argued that this was consistent with CATASTROPHISM.**

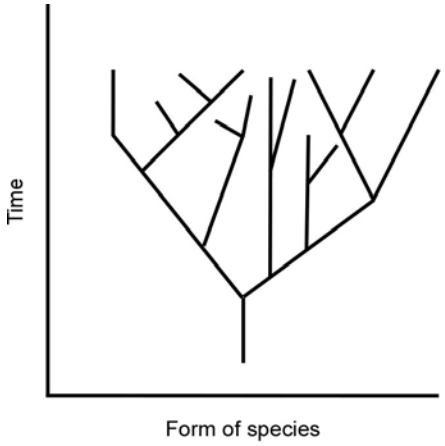
Ideas Leading to Darwin's Theory

- **Changing biological views:**
  - **1798 (Thomas Malthus)**
    - **Wrote "Essay on the Principle of Population", arguing that unchecked human population growth would lead to famine because resources would become limiting.**
  - **1809 (Jean Baptiste Lamarck)**
    - **Proposed that life has evolved, and argued for a specific mechanism (ACQUIRED CHARACTERISTICS)**

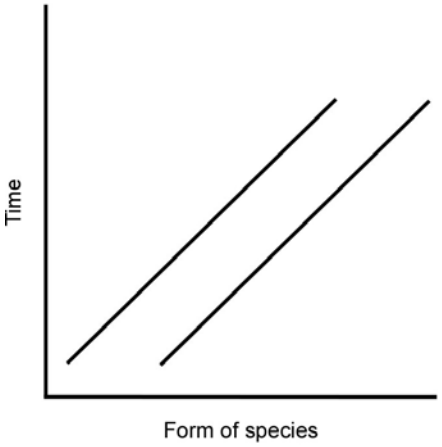
Lamark's vs. Darwin's Theory



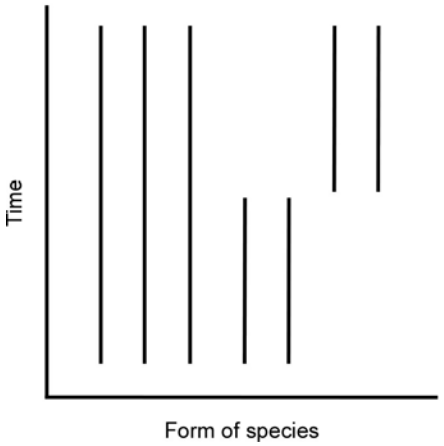
Three theories of the history of life



Evolution



Transformation

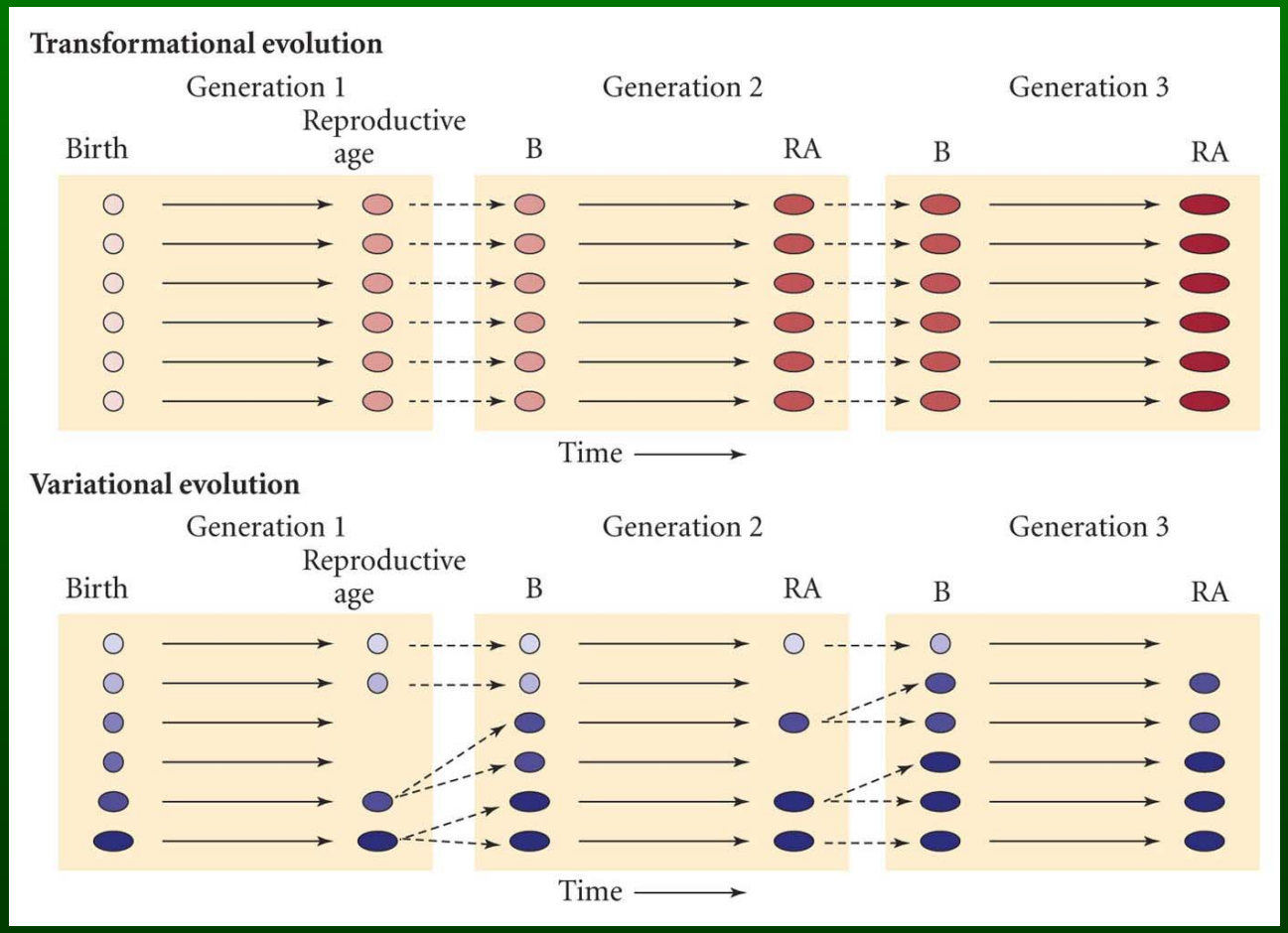


Creationism

Which theories allow for **extinction** and **divergence** events?

The Logic of Darwin's Theory

- **Through time, this will result in a change in the makeup of the population.**



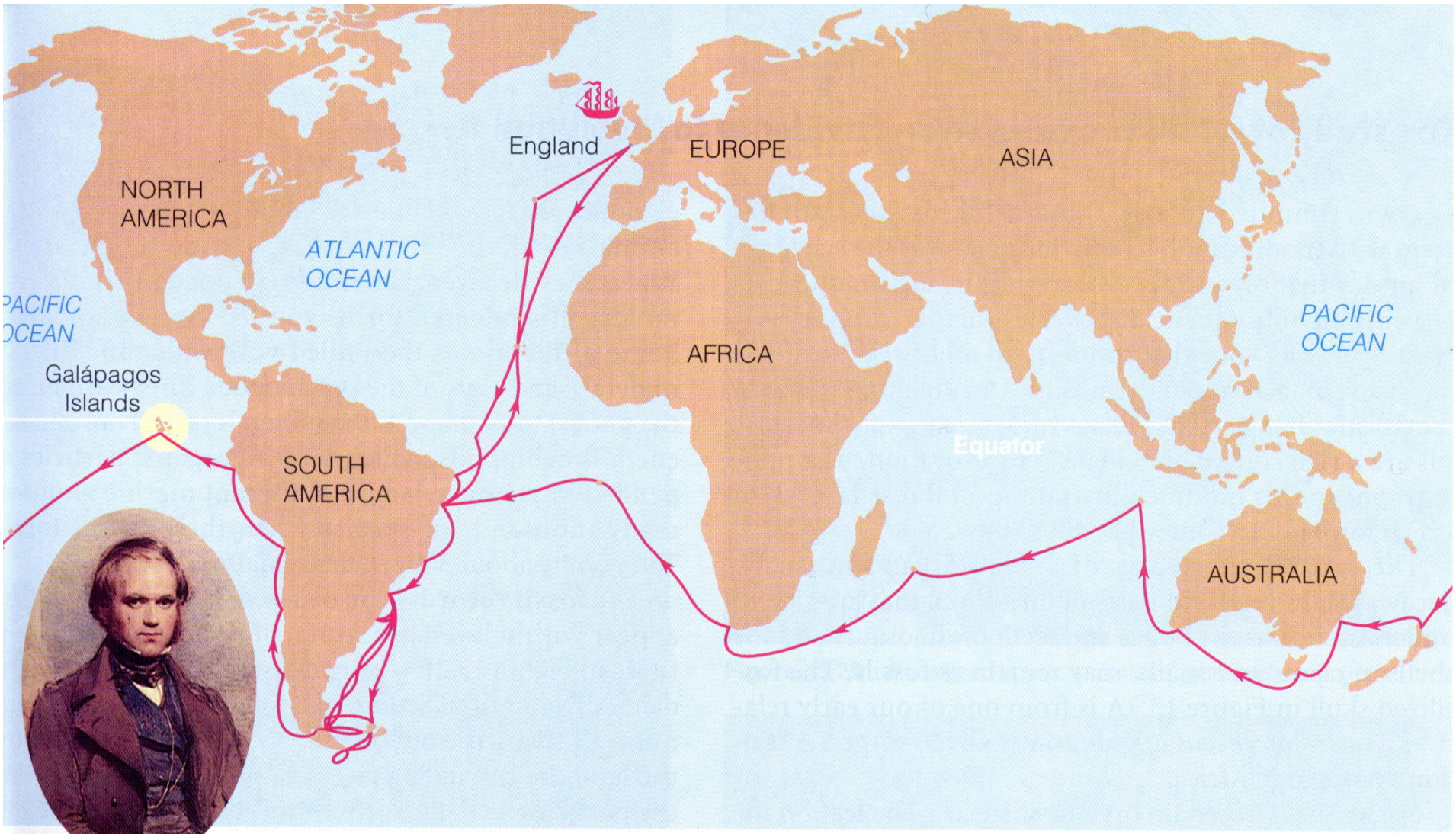
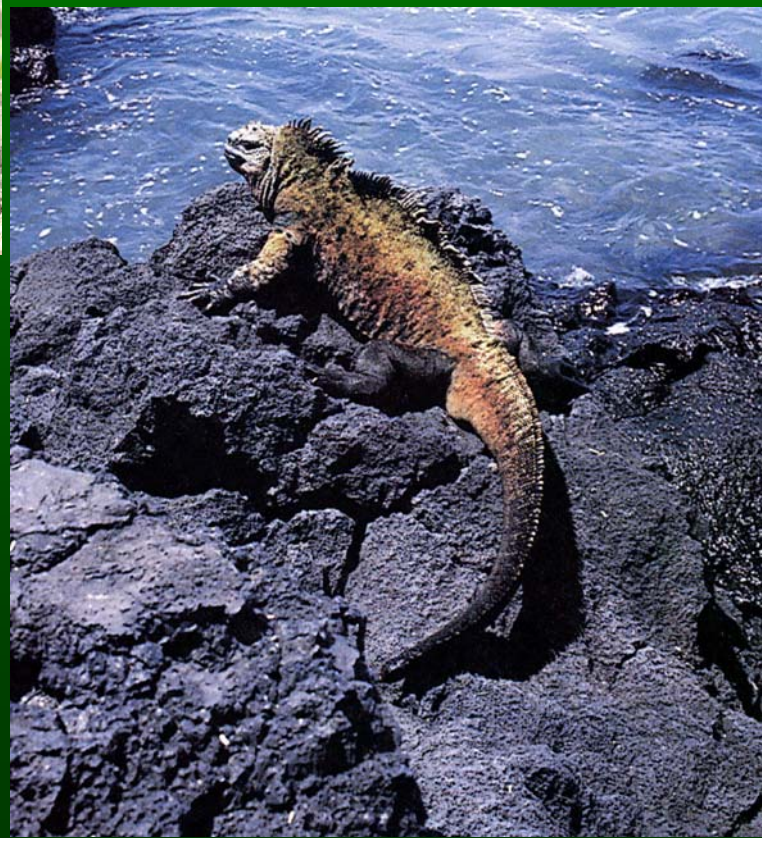


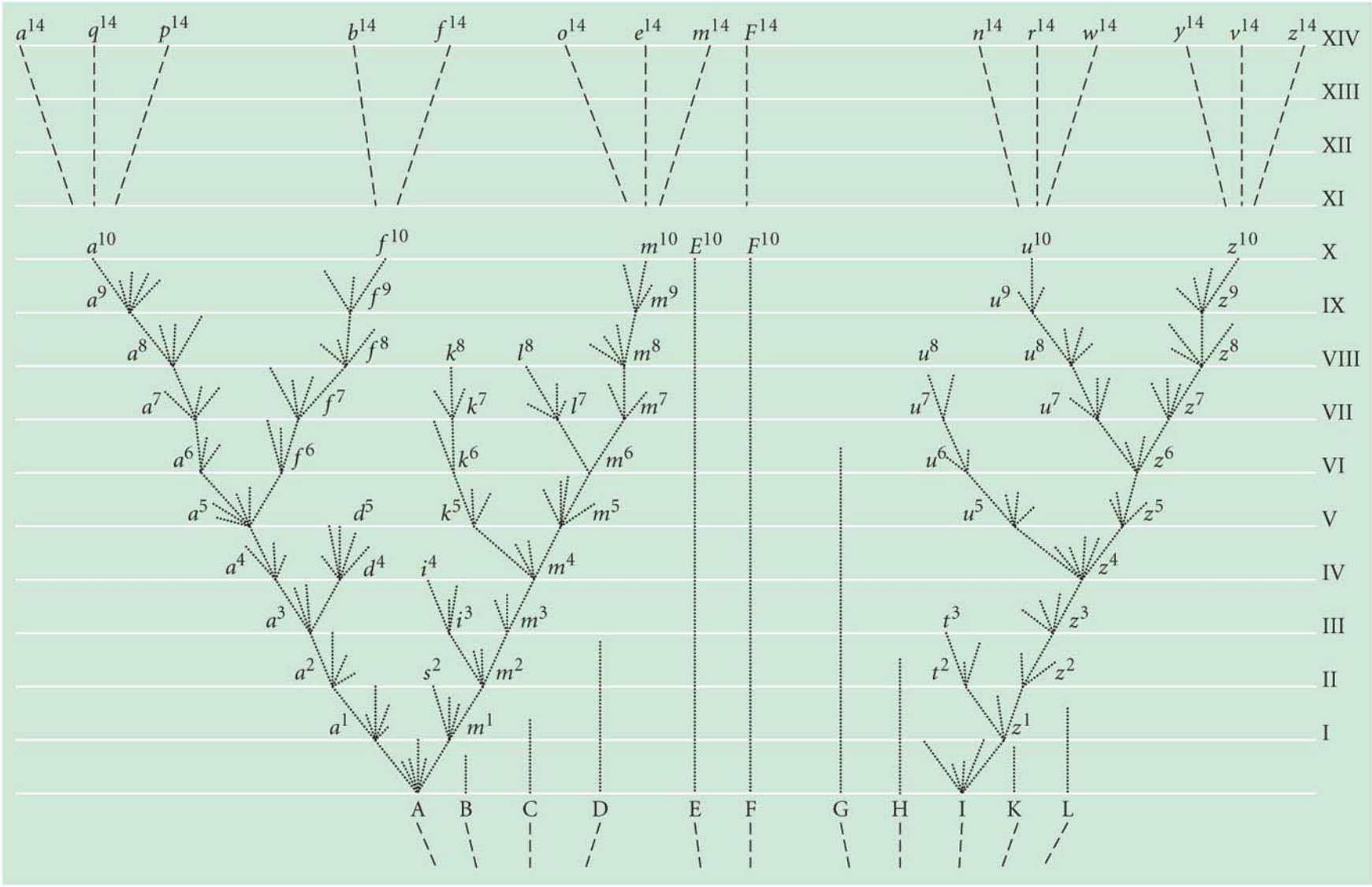
Figure 13.1B Charles Darwin in 1840

Figure 13.1C The voyage of the *Beagle* (1831–1836)

Galapagos Animals



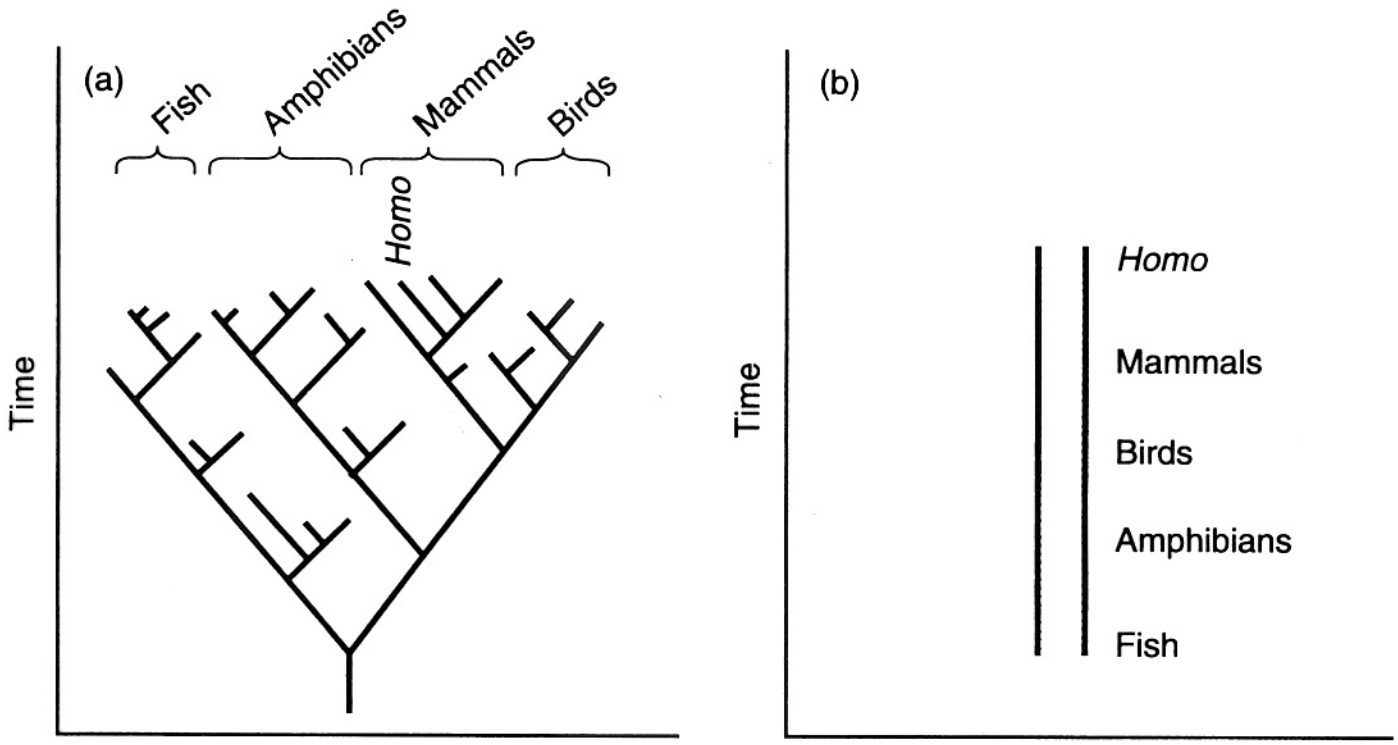
Darwin’s representation of hypothetical phylogenetic relationships



Only Figure in Darwin’s Origin of the Species, 1859.

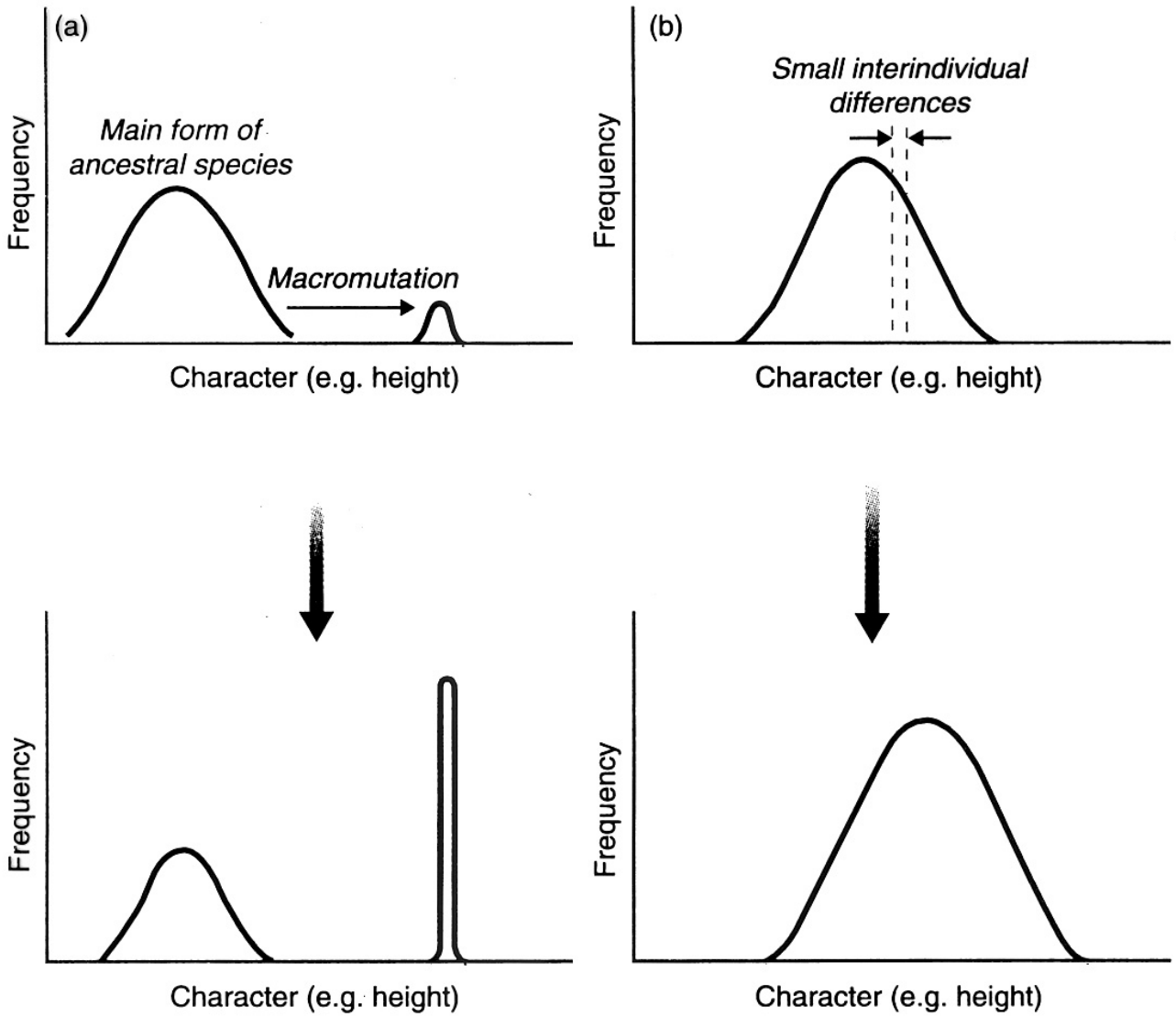
The Cone of Complexity is NOT a linear model!

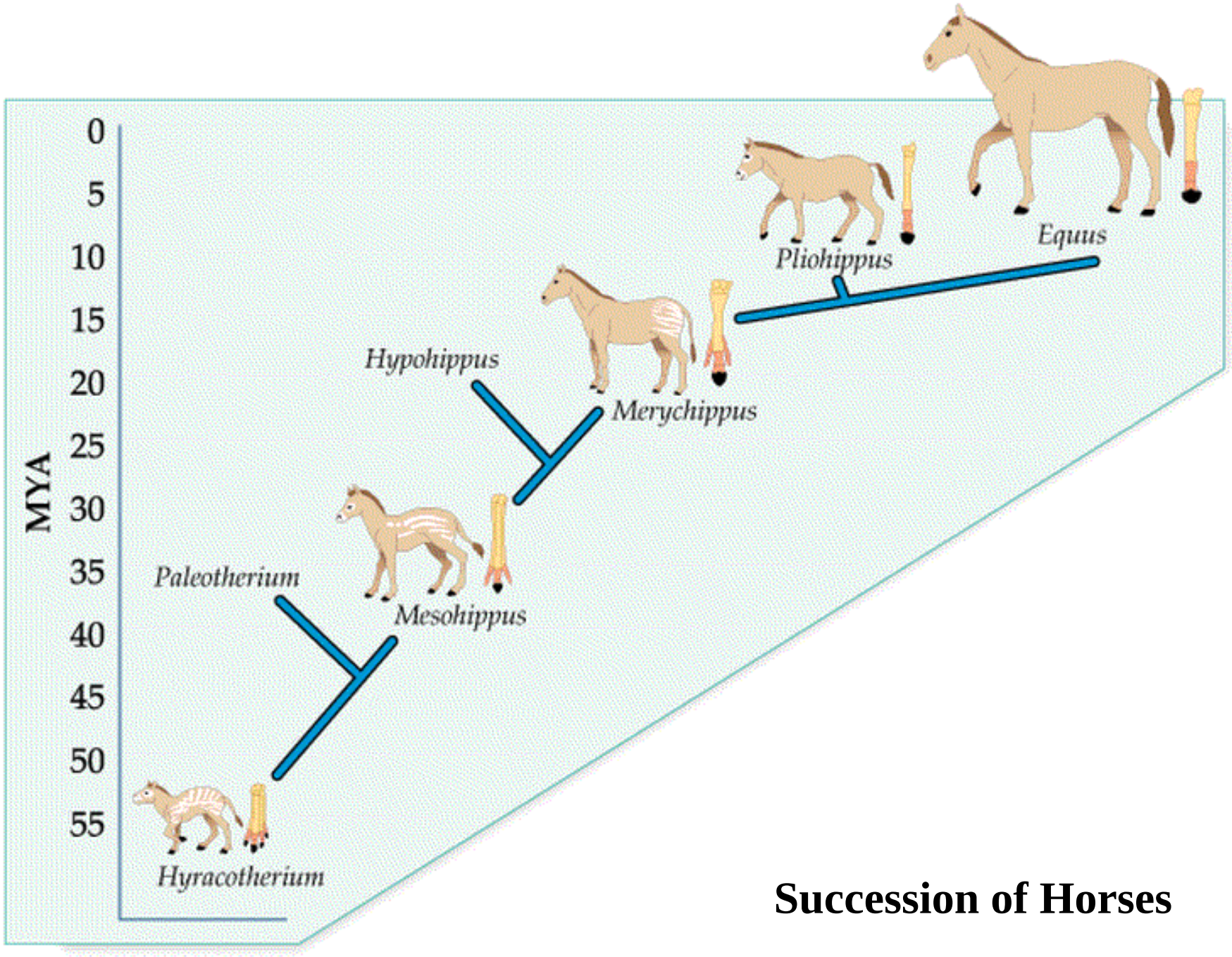
Figure 1.6 (a) Darwin's theory suggests that evolution has proceeded as a branching tree. Note that *Homo* occupies an arbitrary position in the diagram—it does not have to be the right-hand extreme. The tree should be contrasted with the popular idea (b) that evolution is a one-dimensional progressive ascent of life. In Stephen Jay Gould's words, Darwinian evolution is a bush, not a ladder. (see also Figure 1.2)



The Theoretical Side of Evolution: How Important is Natural Selection vs. Other Evolutionary Forces?

Saltationists (Early Mendelians) **Gradualists (Biometricans)**

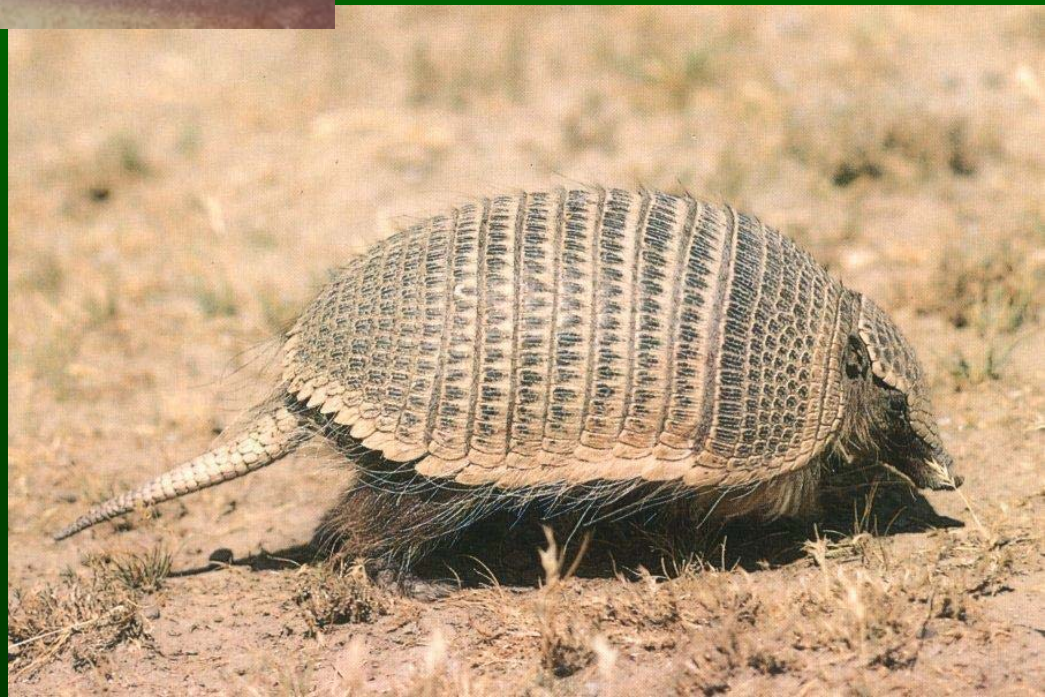




Succession of Horses

Glyptodon

Armadillo



The Logic of Darwin's Theory

- **Darwin recognized (with help from Malthus' essay) that all species have the capacity to achieve huge population sizes through reproduction, but that at some point, resources would become limiting - setting up a struggle for existence.**

The Logic of Darwin's Theory

- **Within a population, there is variation, and some of that variation is heritable.**

- **Some variants have traits that make them more likely to survive and/or reproduce than other variants, and will therefore produce more offspring than the other variants. This is natural selection.**

The Basic Elements of Darwin's Theory

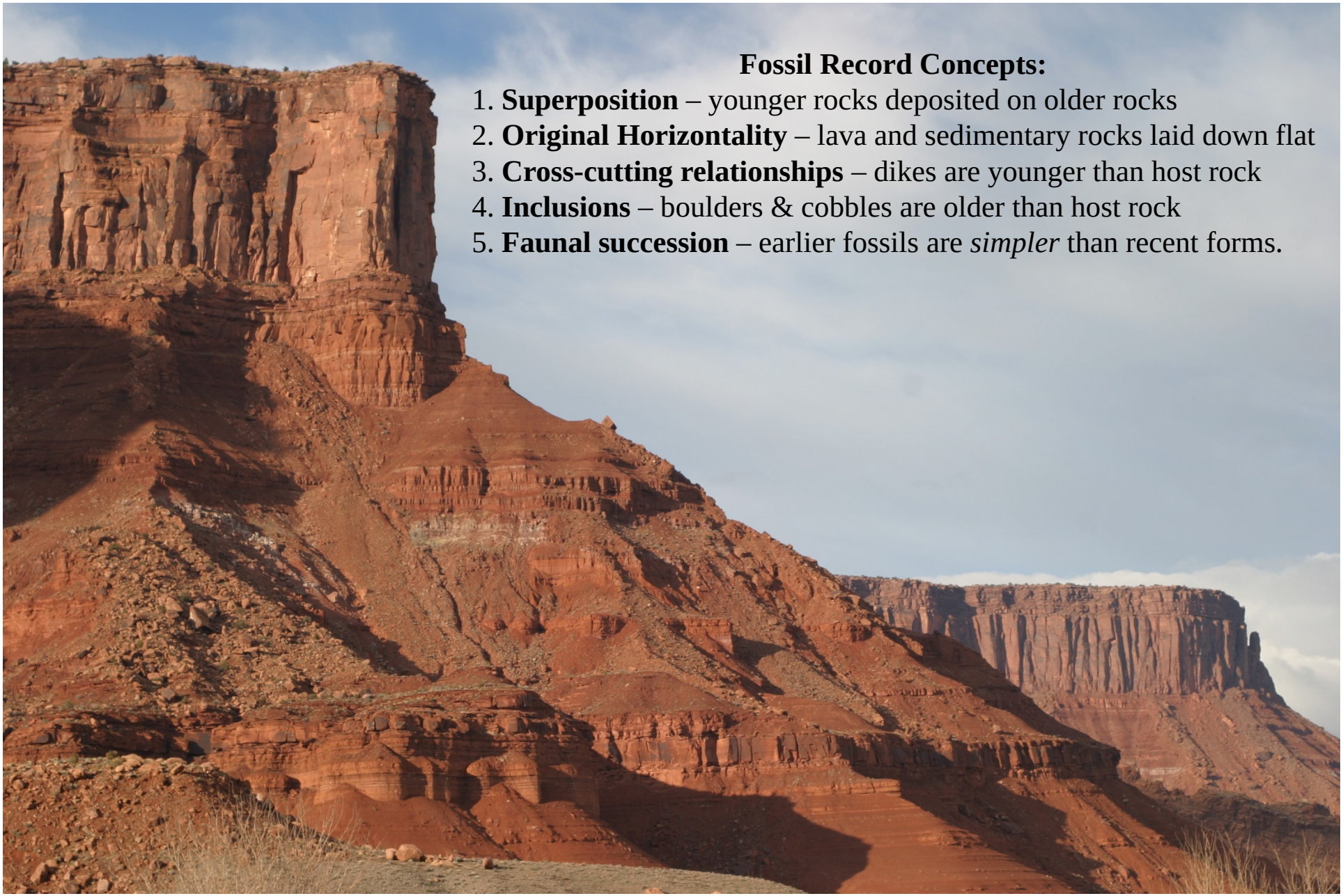
- **Life has evolved.**
- **Evolution has occurred via descent with modification from a common ancestor.**
- **The mechanism driving evolution has been natural selection.**
- **NOT a forward looking process, but fortuitous contingency.**

Evolutionary Biology since Darwin - the Modern Synthesis and beyond.

- **Discovery of the genetic basis of heredity.**
- **Development of the idea of mutation as the source of variation.**
- **Integration of microevolution and macroevolution.**
- **Addition of molecular evolution (**including the neutral theory of molecular evolution**),**
  developmental biology,
  genomics.

Evidence That Life Has Evolved

- **Fossil record**
- **Observations of evolution, including speciation.**

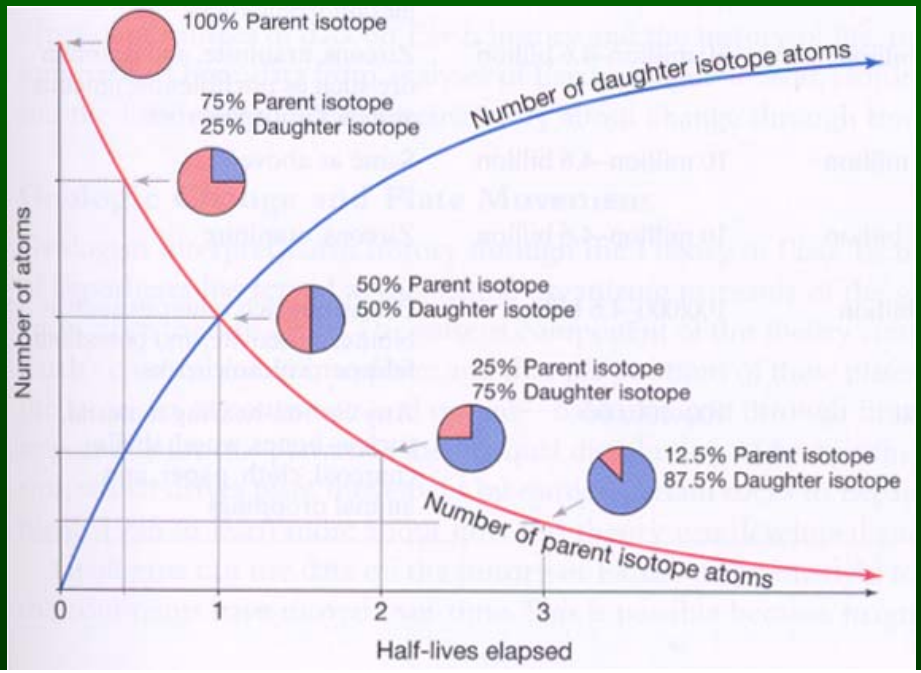


Fossil Record Concepts:

1. **Superposition** – younger rocks deposited on older rocks
2. **Original Horizontality** – lava and sedimentary rocks laid down flat
3. **Cross-cutting relationships** – dikes are younger than host rock
4. **Inclusions** – boulders & cobbles are older than host rock
5. **Faunal succession** – earlier fossils are *simpler* than recent forms.

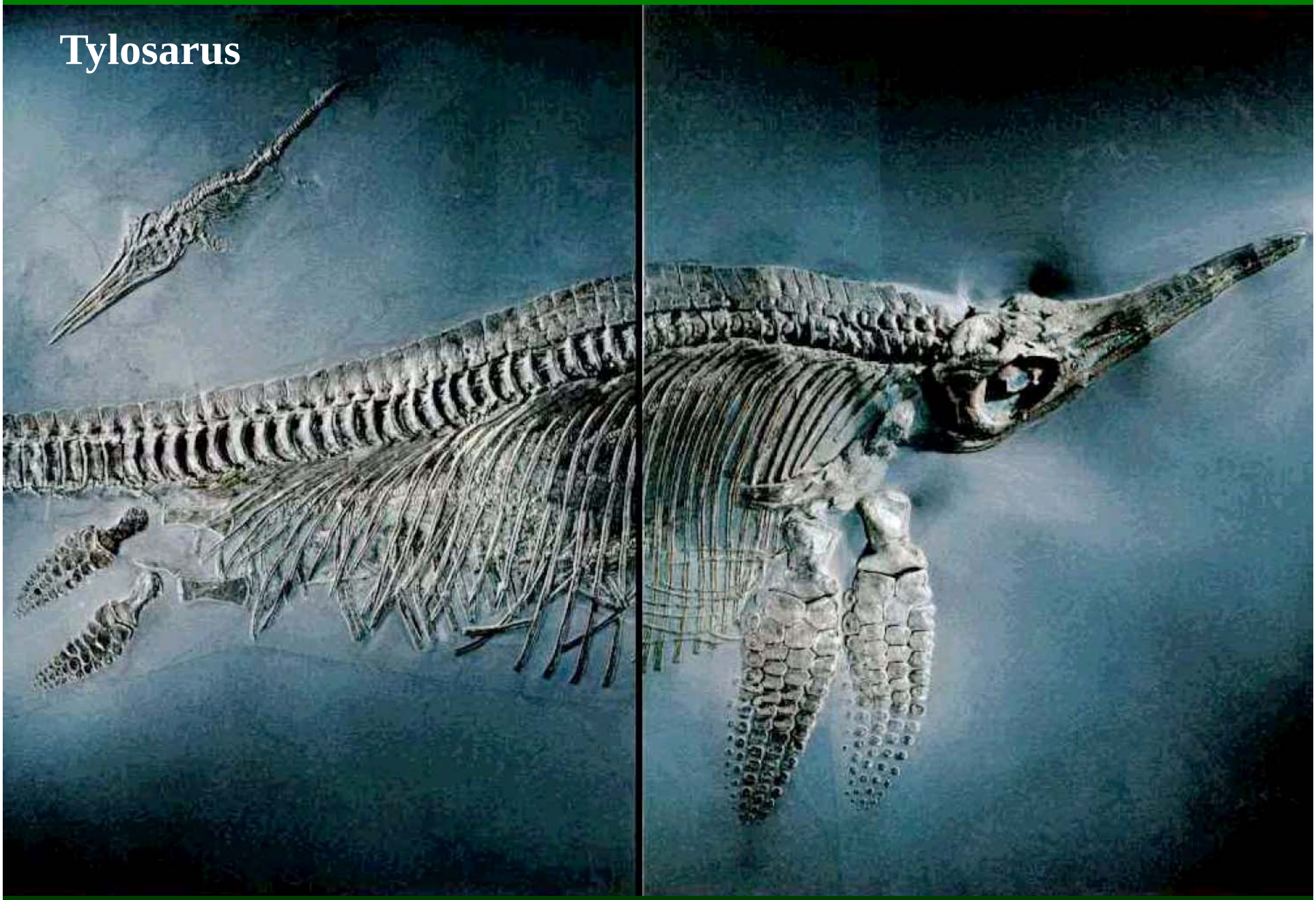
Eon	Era	Period	Epoch	Age Ma	Life Forms
Phanerozoic	Cenozoic	Quaternary	Holocene		
			Pleistocene	1.8	Earliest *Homo*
		Tertiary – Neogene	Pliocene	5.2	First daisy-family plants
			Miocene	23.8	First apes
		Tertiary – Paleogene	Oligocene	33.5	First extensive grasslands
			Eocene	55.6	First whales First horses
			Paleocene	65	Extinction of dinosaurs
	Mesozoic	Cretaceous	Late	98.9	First placental mammals
			Early	144	First flowering plants
		Jurassic	Late	160	First birds
			Middle	180	
			Early	206	First mammals
		Triassic	Late	228	First dinosaurs
			Middle		
			Scythian	251	
	Paleozoic	Permian		290	First plants with water-conducting vessels First mammal-like reptiles
		Carboniferous – Pennsylvanian			
		Carboniferous – Mississippian		353.7	First reptiles
		Devonian		408.5	First amphibians First woody plants First insects First vascular plants
		Silurian		439	First fish with jaws
		Ordovician		495	First fish (no jaws) First land plants
		Cambrian		543	
Proterozoic				2500	First multicellular organisms First eukaryotes
Archaean				3600	First bacteria
Hadean				4600	Origin of life? Oldest rocks Formation of the Earth

Geological Timeline
based on **fossil record**
and **radiometric dating.**



Trilobites

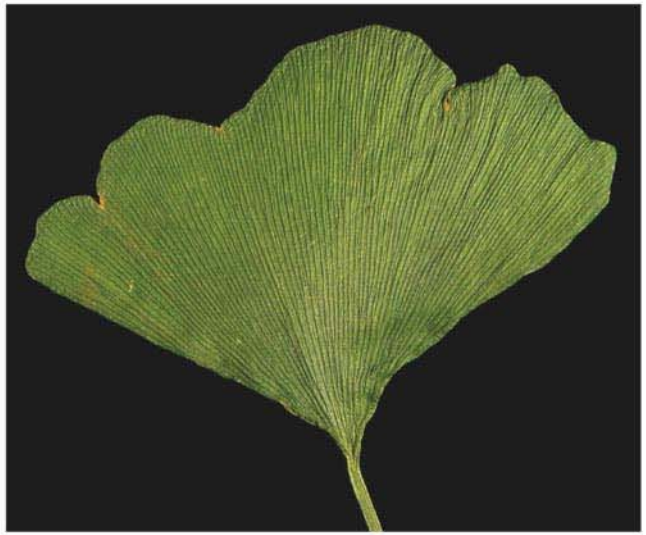
Tylosarus



Plants

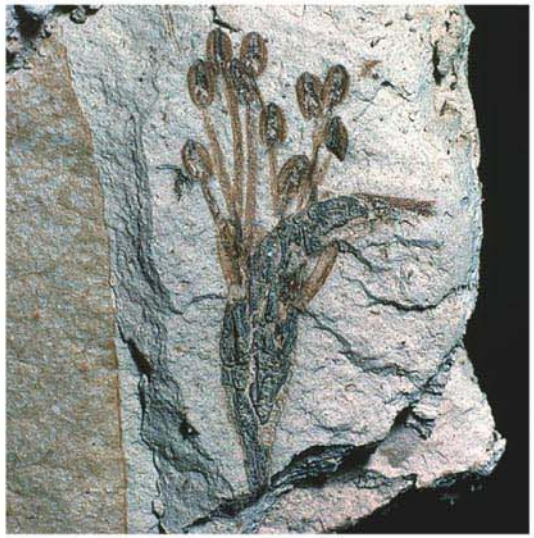
(A)

(B)



(C)

(D)



Archaeopteryx

Evidence That Life Evolves Via Descent With Modification

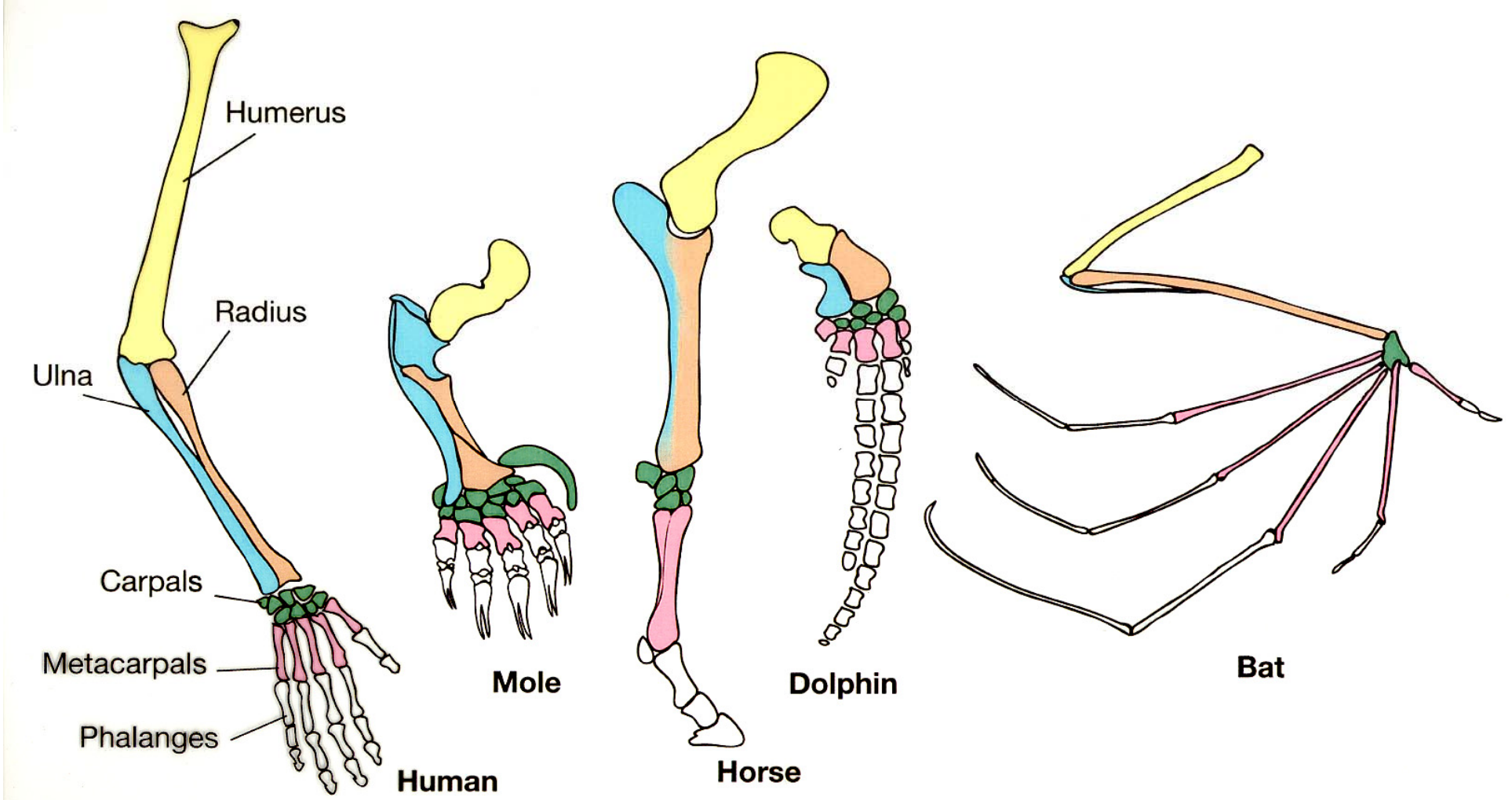
- Homology (incl. vestigial structures)
- Artificial selection
- Embryology and developmental genetics
- Imperfections
- Geographic distributions

Homology

The presence of similar features in two organisms as a result of their common ancestry.

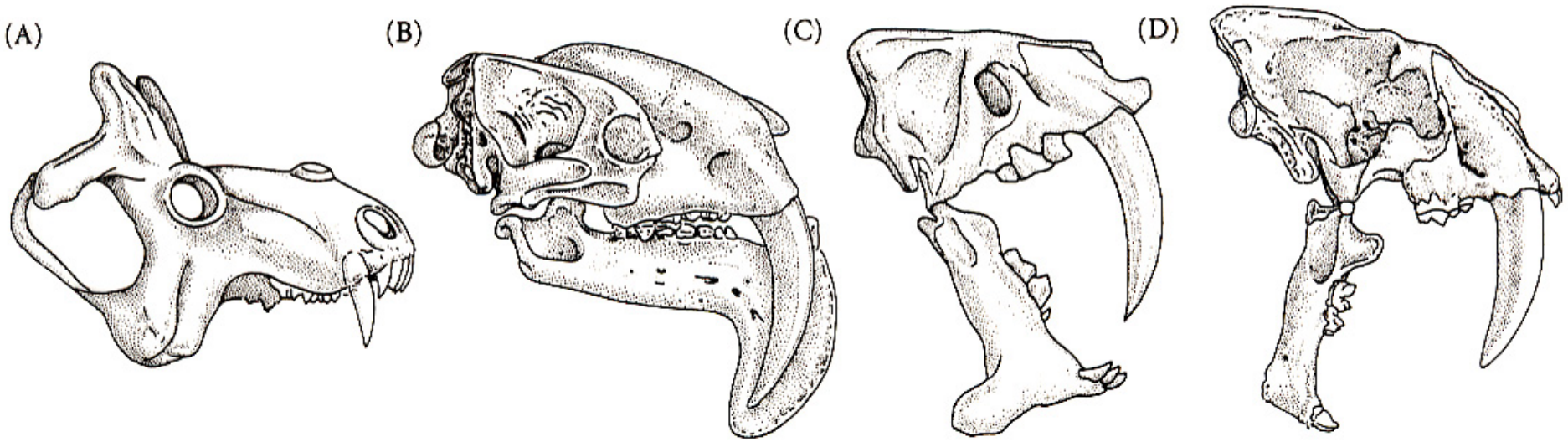
Not always easy to ascertain, might be analogous instead. Beware of similarity via coevolution.

Homology of form



Sabertooth Condition

FIGURE 5.21 Convergent evolution of the "sabertooth" condition of the canine tooth in four distantly related extinct lineages. (A) A mammal-like reptile, the tapinocephalian *Estemmenosuchus*, from the Permian of Russia. This animal was probably an omnivore that used the canines for fighting, rather than for killing prey as in the other species illustrated. (B) A marsupial, *Thylacosmilus*, from the Miocene of South America. (C) A nimravid carnivore, *Barbourofelis*, from the Miocene of North America. (D) A true cat, *Smilodon*, from the Pleistocene of North America. (A after Cowen 1990; B after Riggs 1934; C after Stearn and Carroll 1989; D after Romer 1966.)



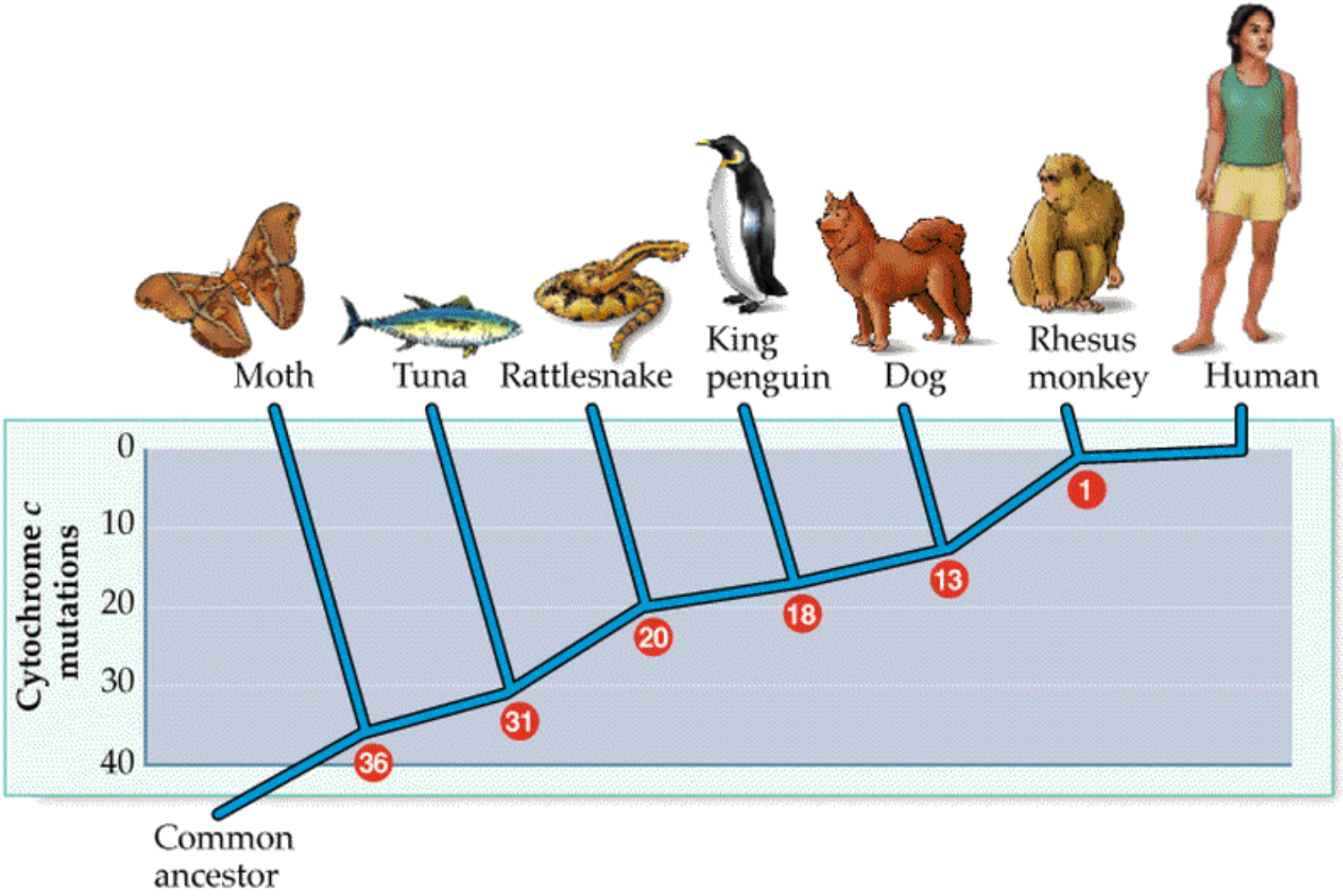
Reptile **Marsupial** **Nimravid** **True Cat**

Smilodon:
Sabertooth Tiger

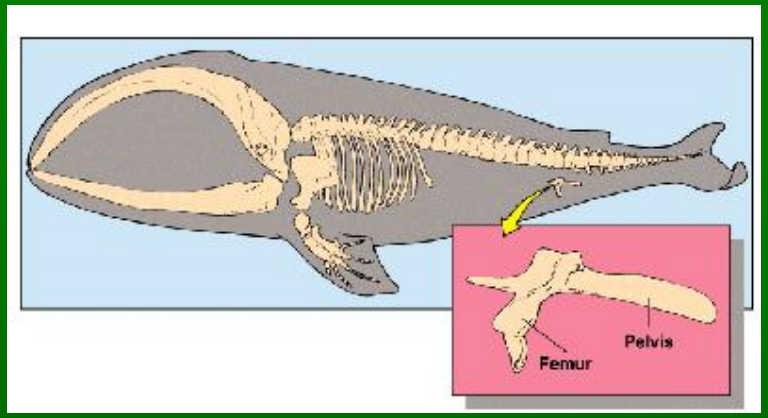
Smilodonichthys:
A Pliocene salmonid fish

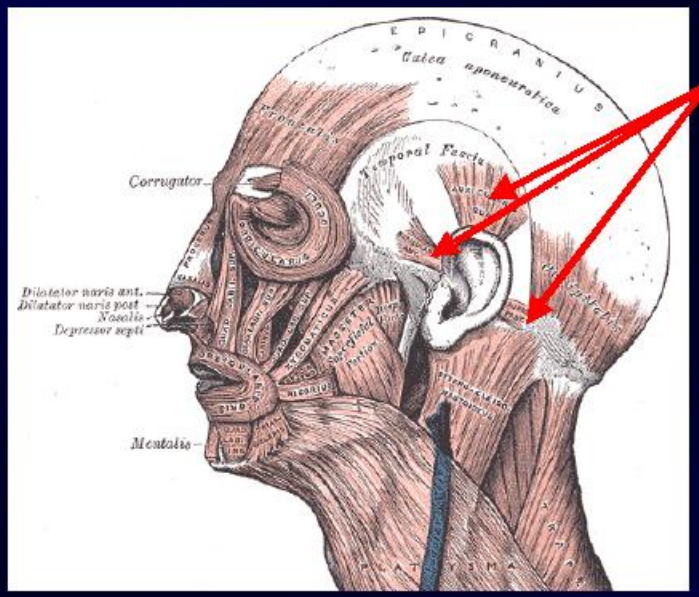
Analogous Structures

Homology of molecules



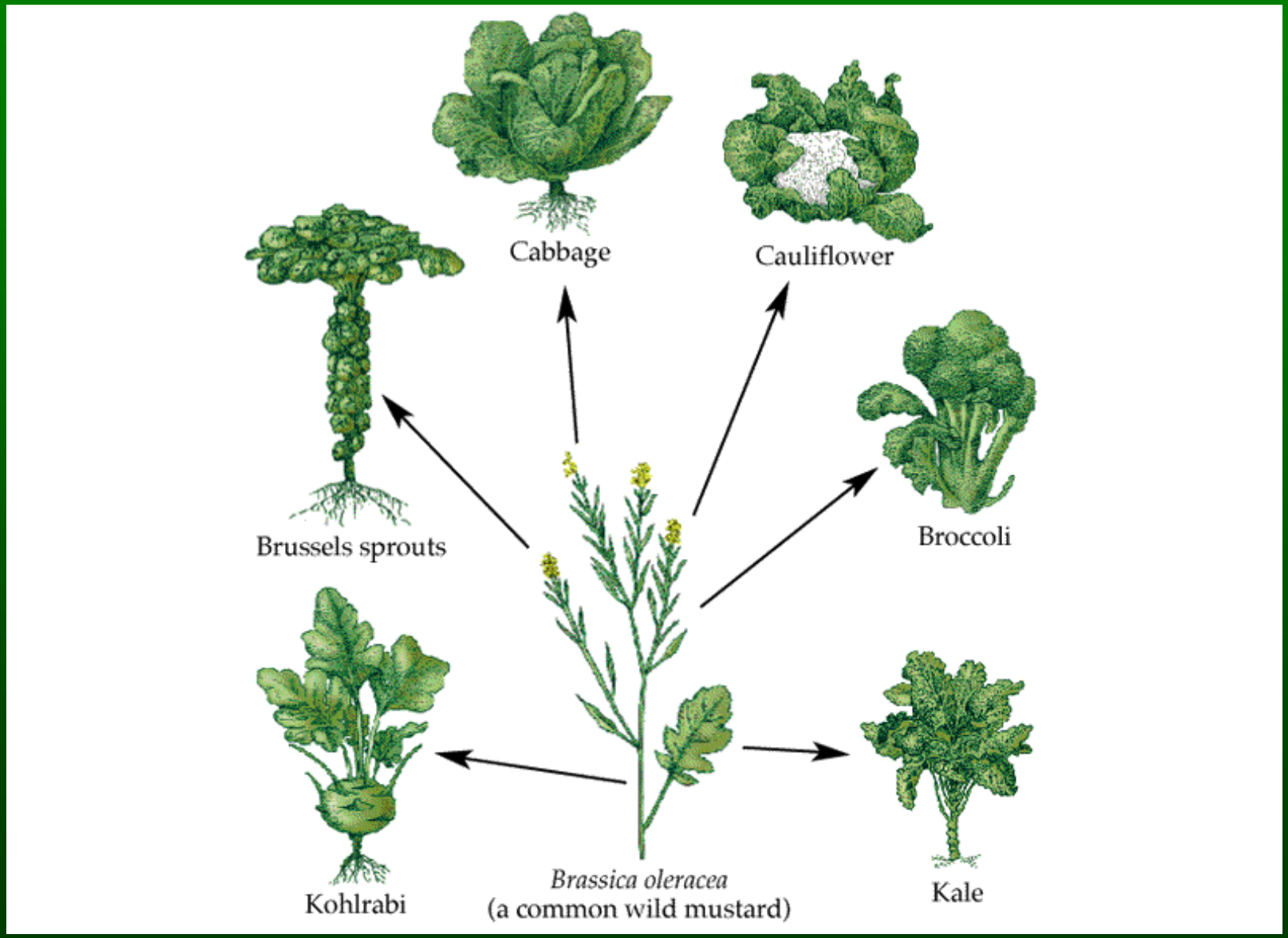
Vestigial Structures: Exhibited by loss of function.



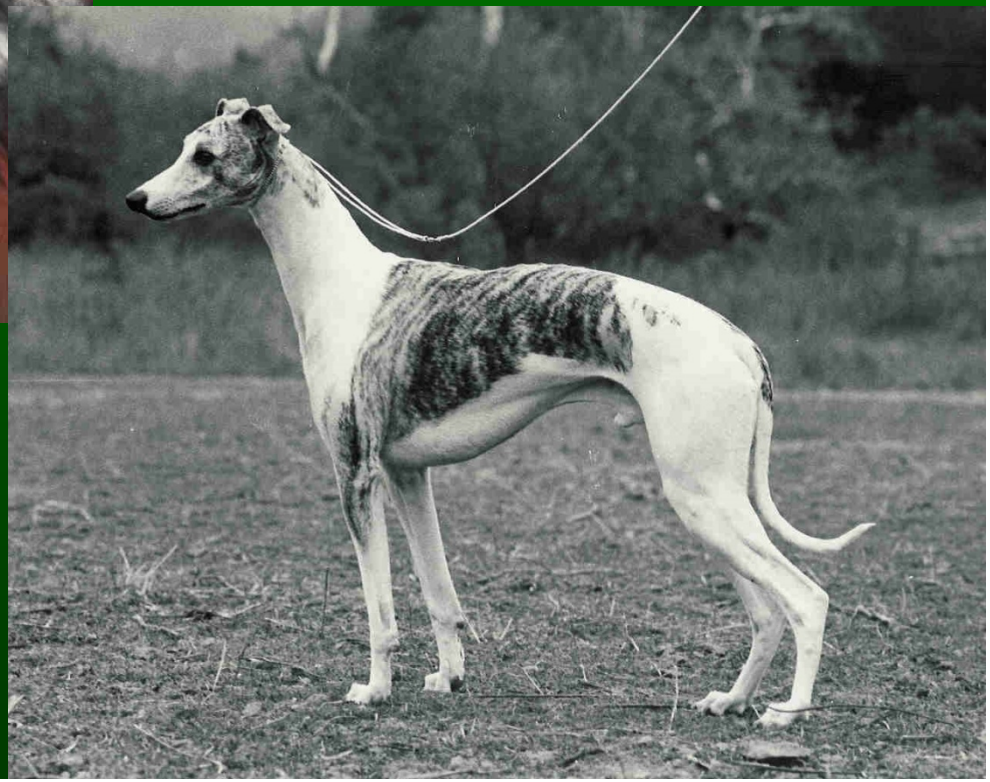


Mammals have muscles that move their external ears. You do, too, but most people never learn to use them, and ear-wiggling doesn't make any difference to your survival. . . so what are the muscles doing there?

Artificial selection has produced dramatic change in plants...



… and animals

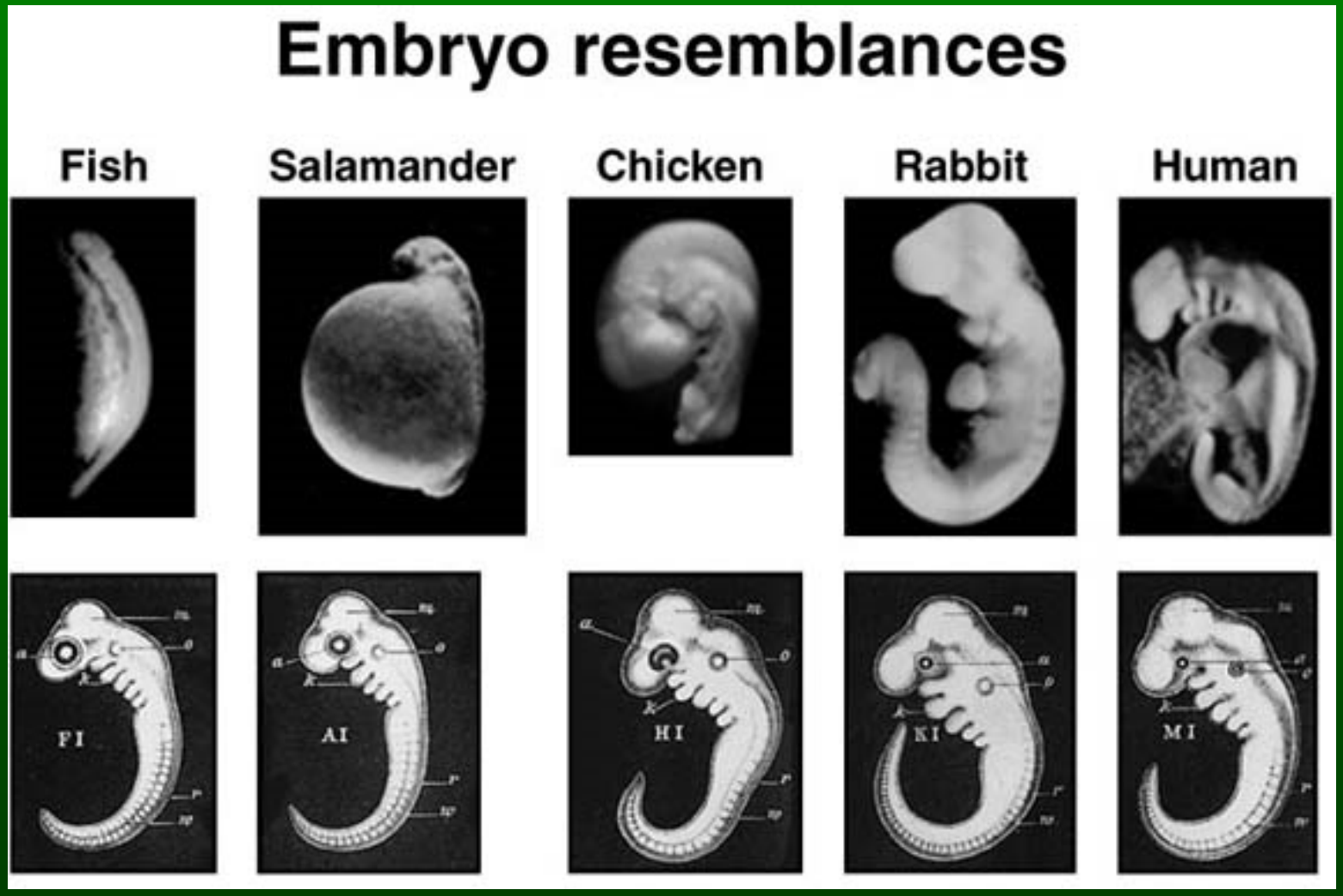


… and animals

Myostatin mutation =

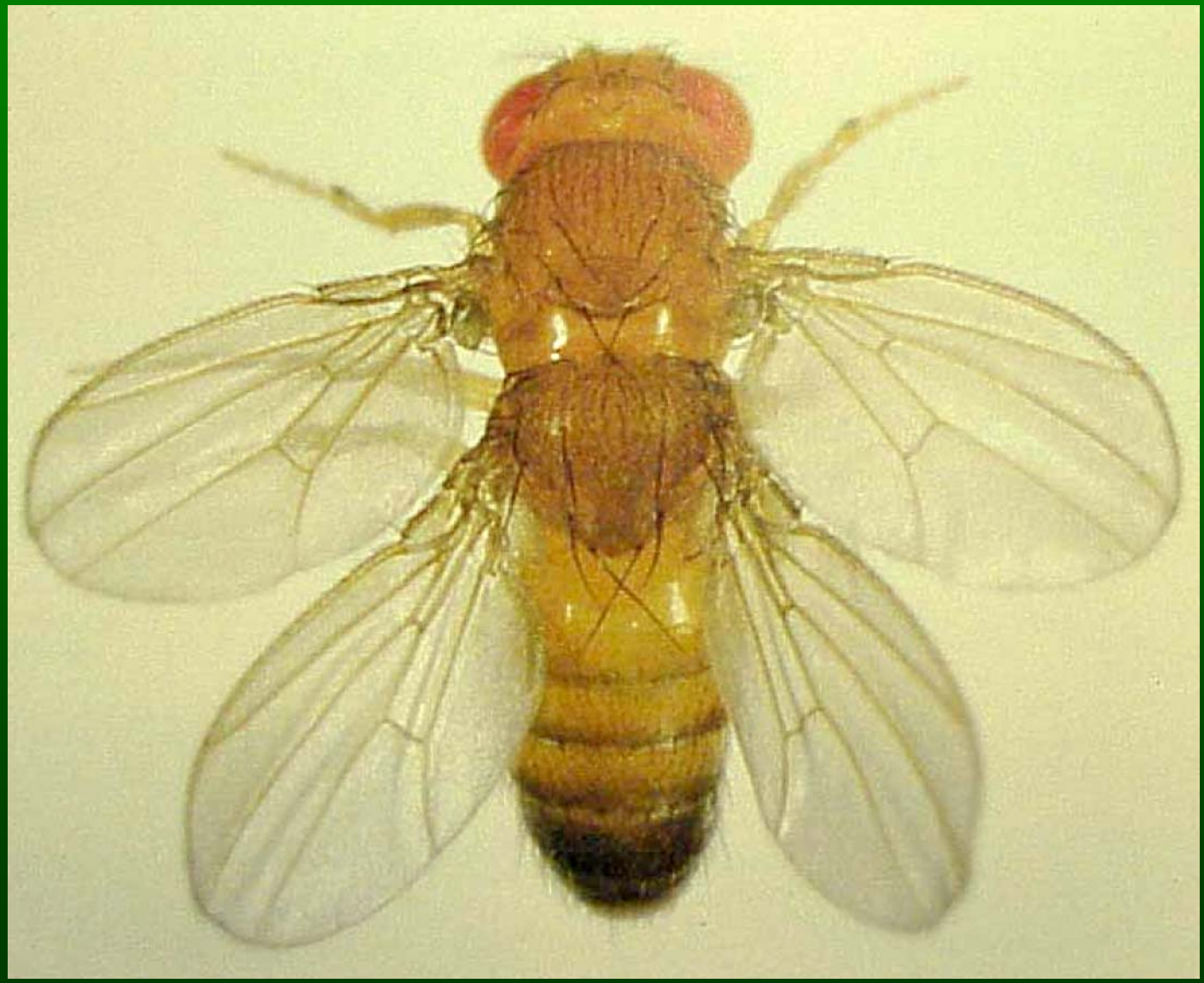
Bully Whippet

Similarities in early development indicate organisms are derived from a similar plan.

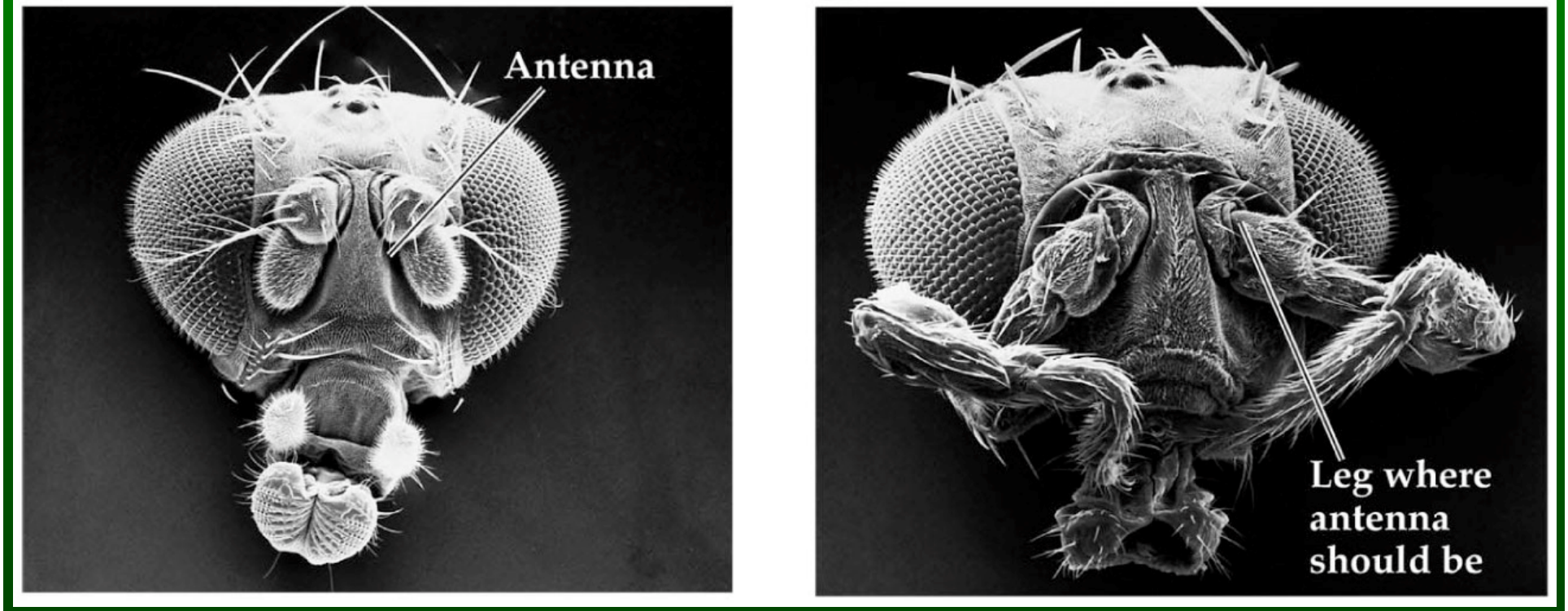


Ontogeny recapitulates Phylogeny?

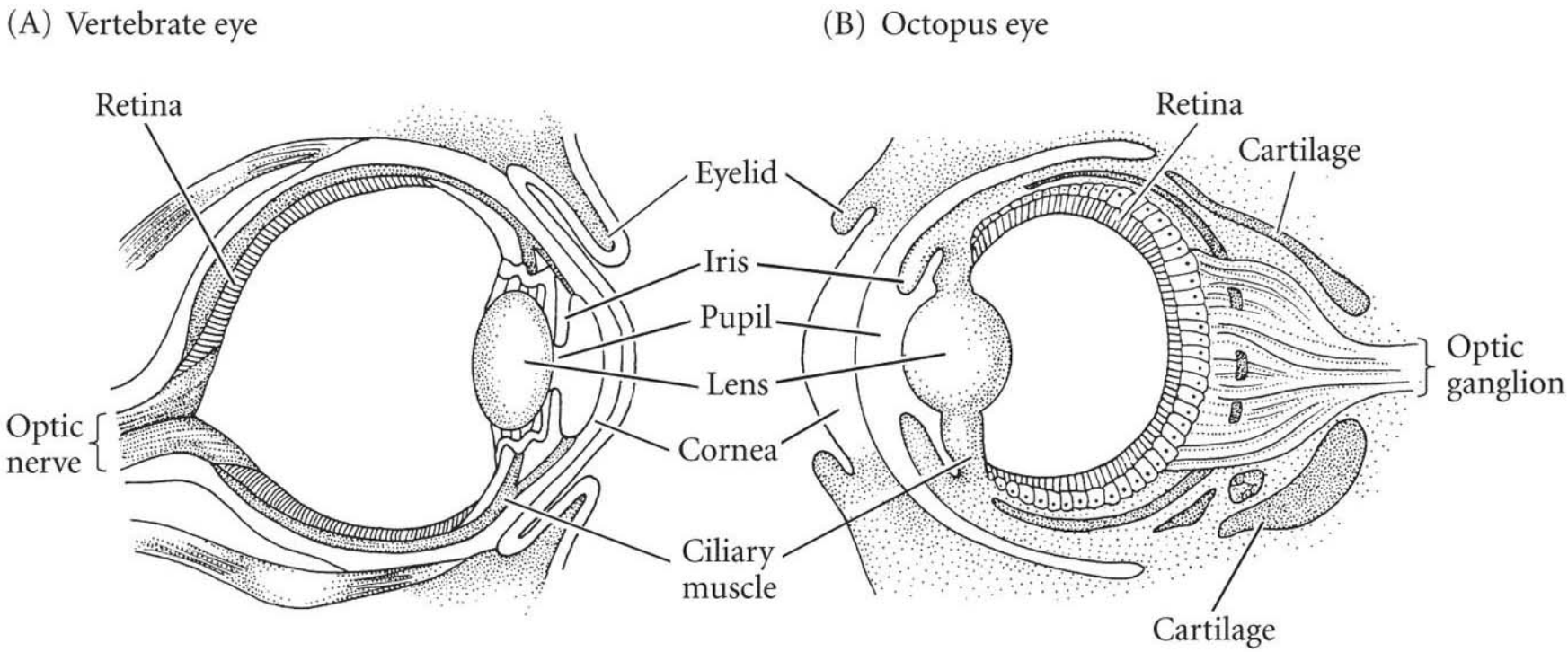
Developmental genes reveal the basis for alterations of the common plan.



Developmental genes reveal the basis for alterations of the common plan.

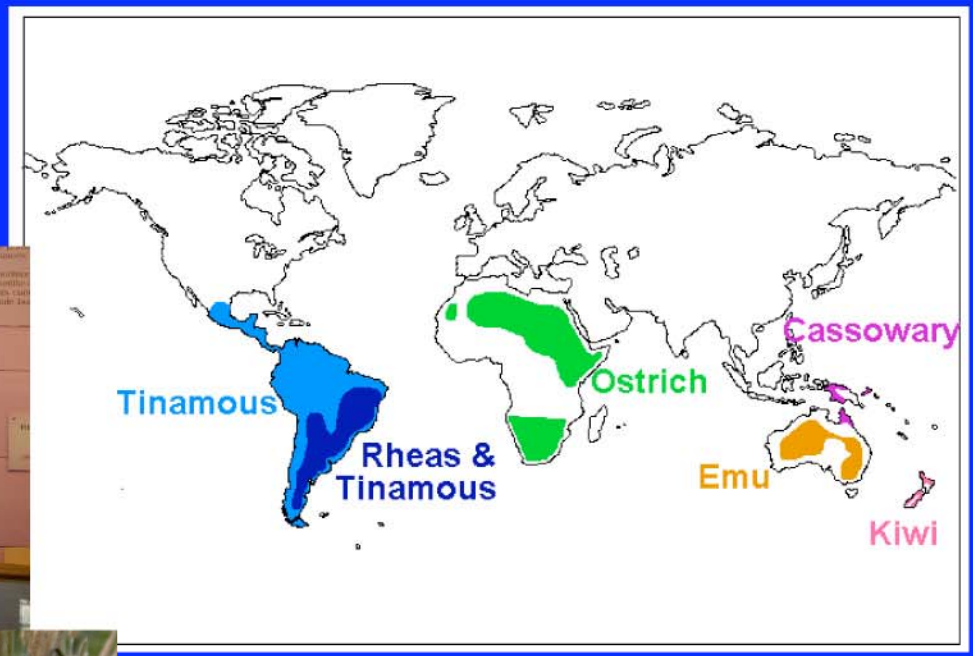


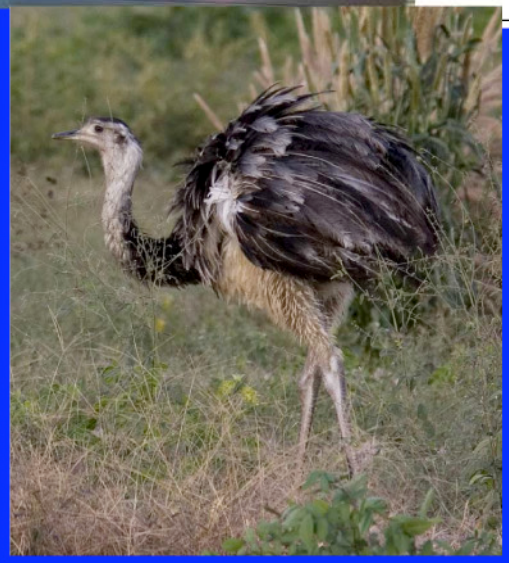
Imperfections of Design

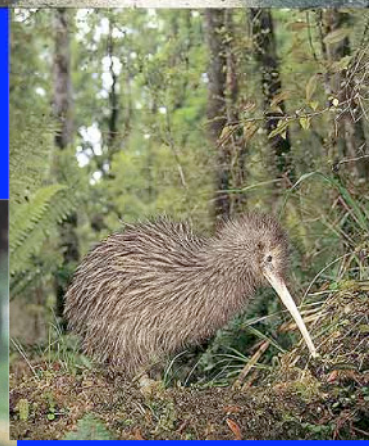


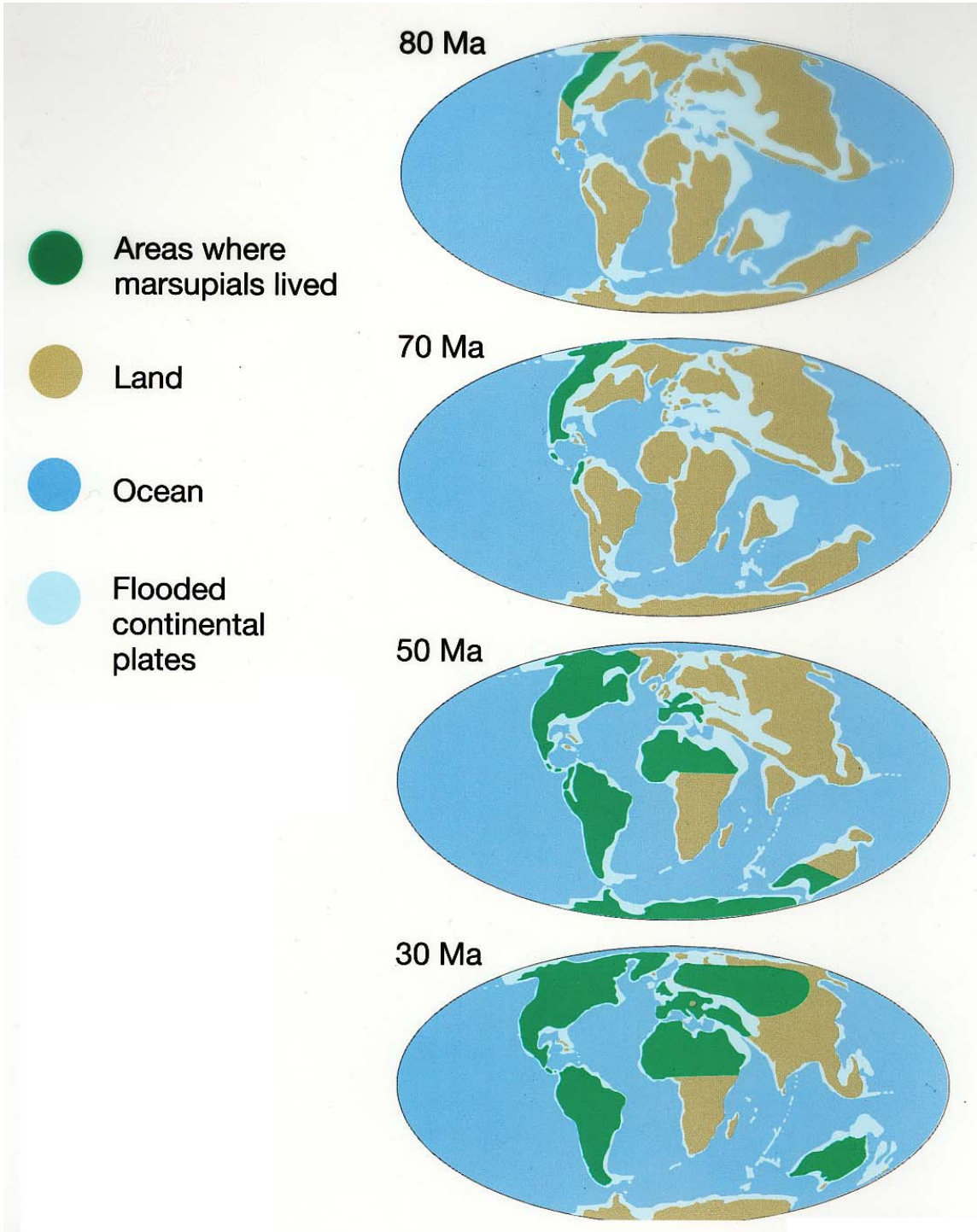
Analogous Structures too!

Geographic Distributions









The Evolutionary History of Marsupial Mammals

Requires Integration of:
Plate Tectonics
Fossil Record
Radioisotope Dating

Biogeography

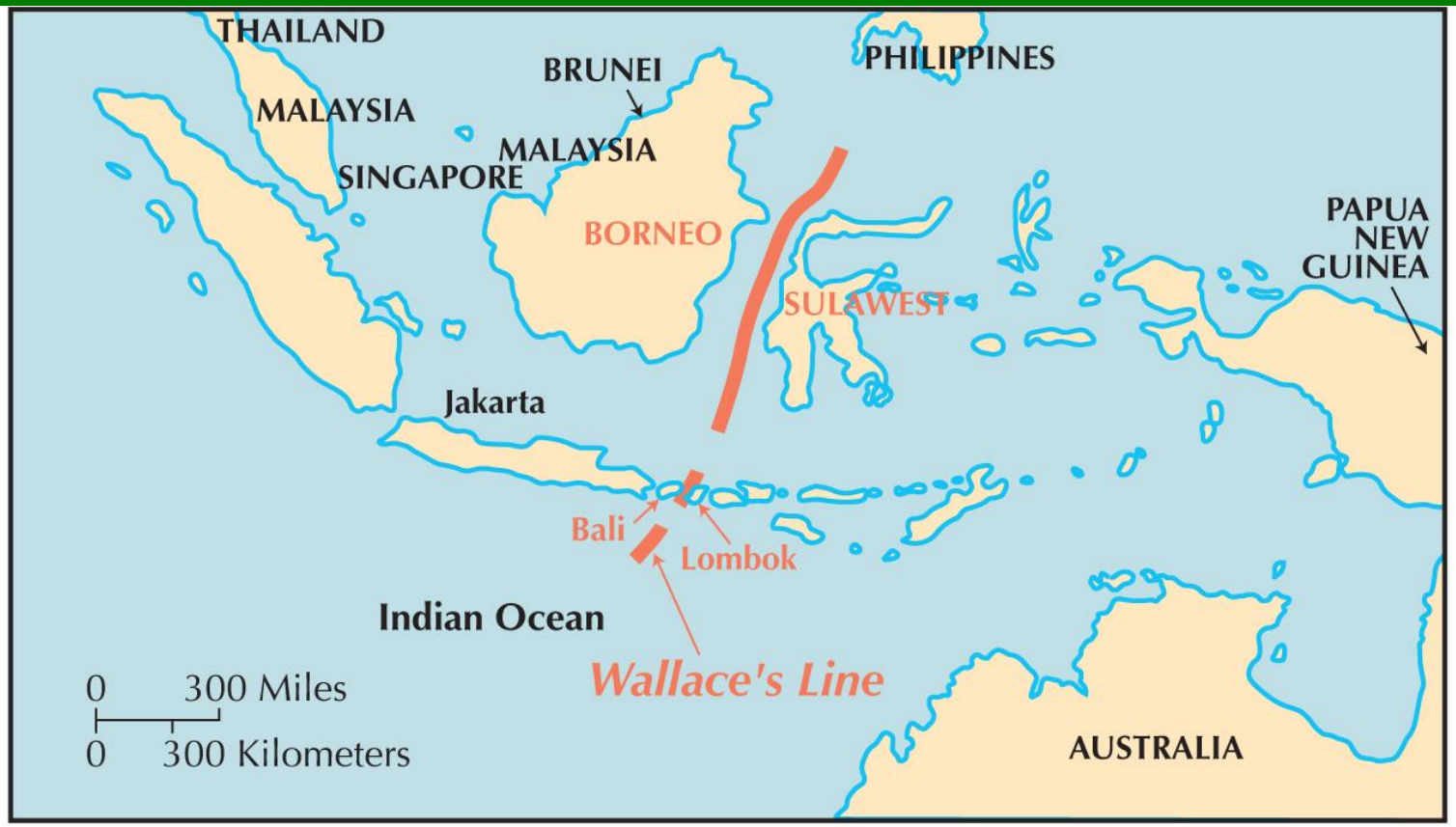
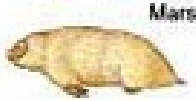
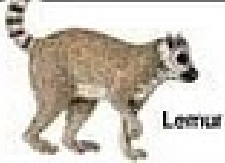
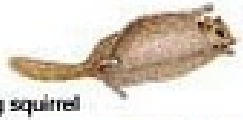
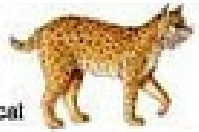
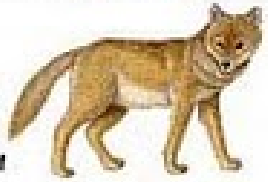
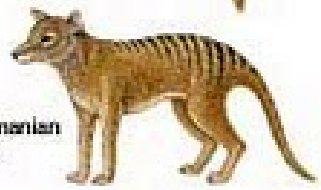
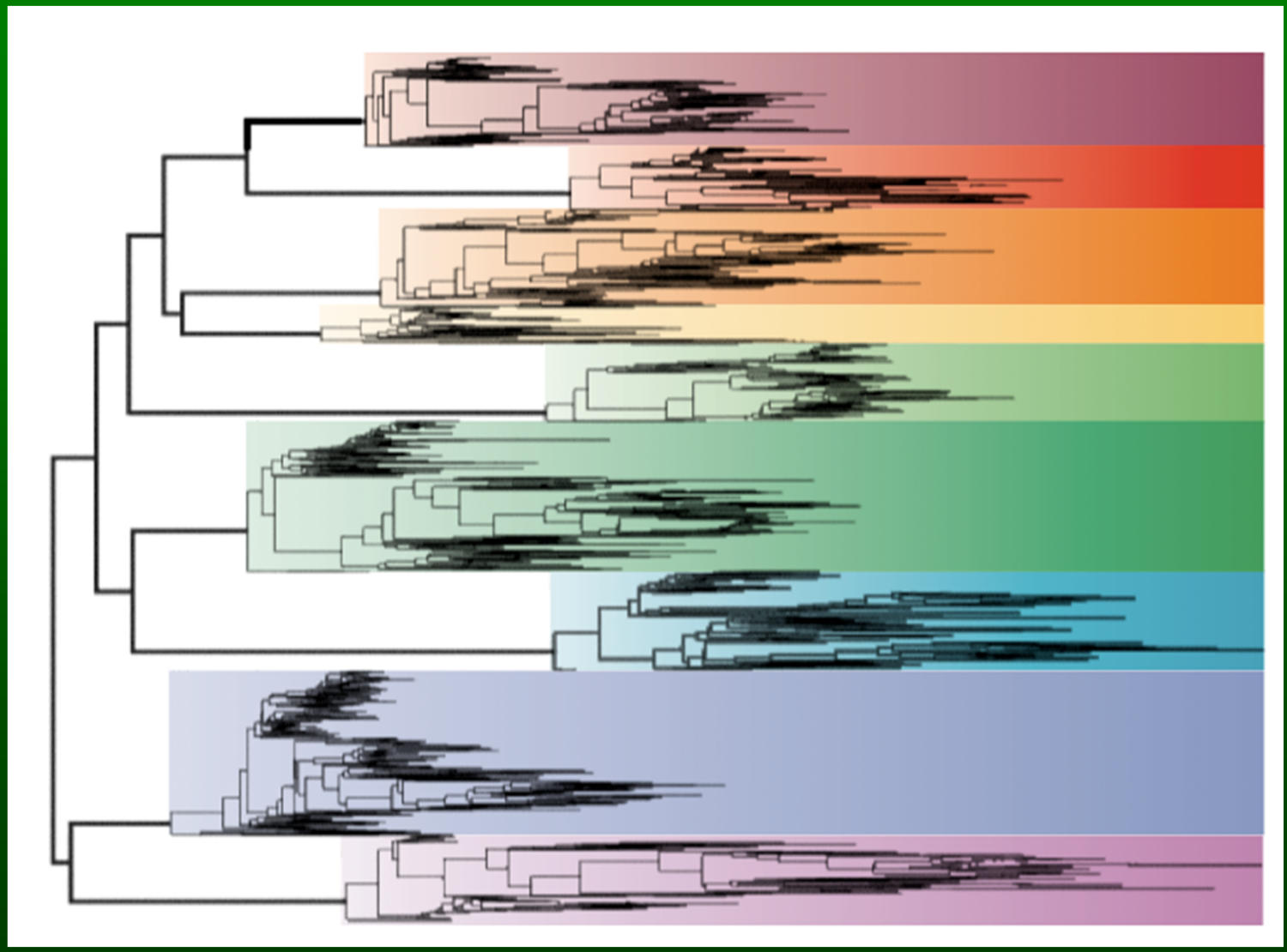


FIGURE 3.6. Wallace's Line (*thick red line*) separates two distinct present-day land faunas.

Convergence

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

Divergence



HIV viruses from 9 different patients from successive time intervals

The Basic Elements of Darwin's Theory

- **All life has evolved.**
- **Evolution has occurred via descent with modification from a common ancestor.**
- **The mechanism driving evolution has been natural selection.**

- **Neodarwinian theory is supported by as much scientific evidence as any theory in science.**
- **Thus, as much as is scientifically possible, evolution via descent with modification is a fact.**