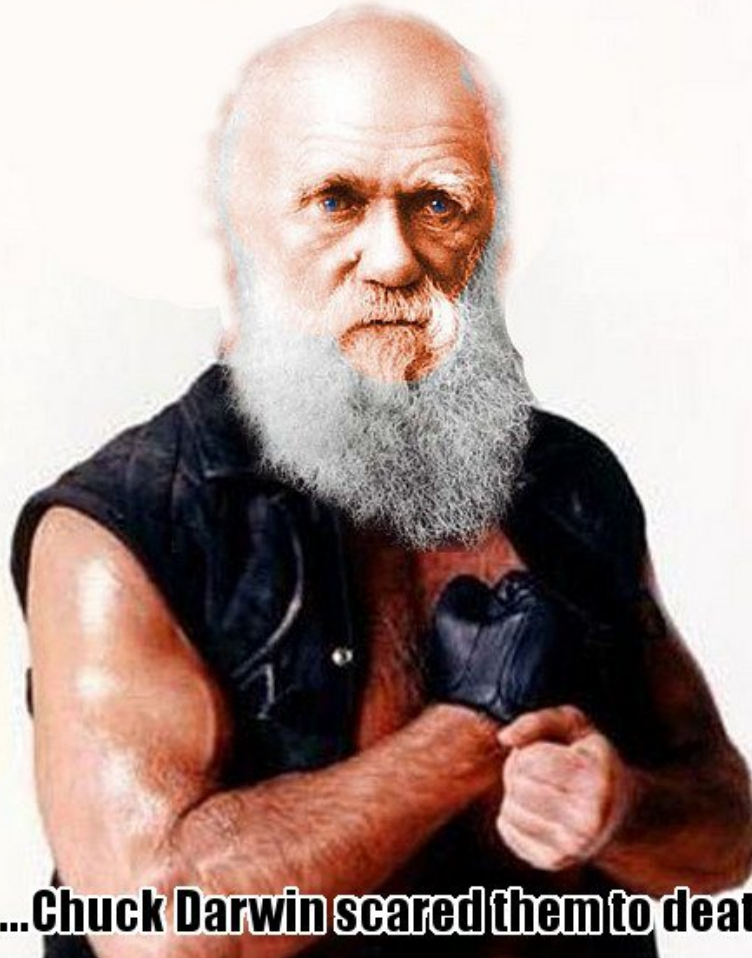


Evolution as Fact and Theory

An asteroid didn't kill the dinosaurs...



...Chuck Darwin scared them to death.

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)**

Lamarck's vs. Darwin's Theory

(a) Lamarck's view

Original, short-necked ancestor



Keeps stretching neck to reach leaves higher up on tree



And continues stretching until neck becomes progressively longer

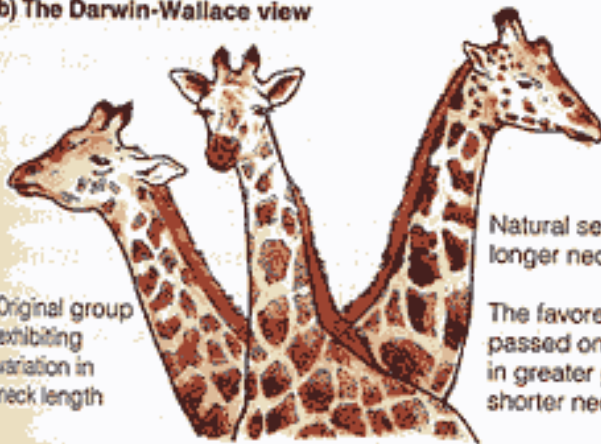


Long-necked descendant after many generations



(b) The Darwin-Wallace view

Original group exhibiting variation in neck length



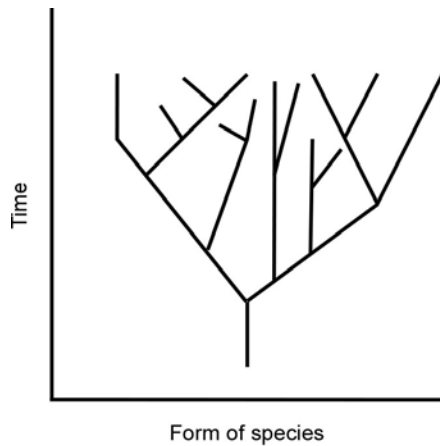
Natural selection favors longer necks

The favored characteristic is passed on to next generation in greater proportion than the shorter neck

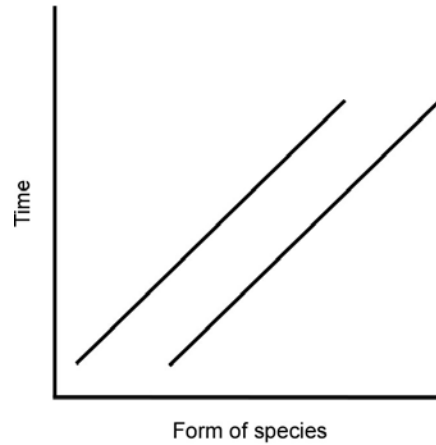


After many, many generations, group is still variable, but showing a general increase in neck length

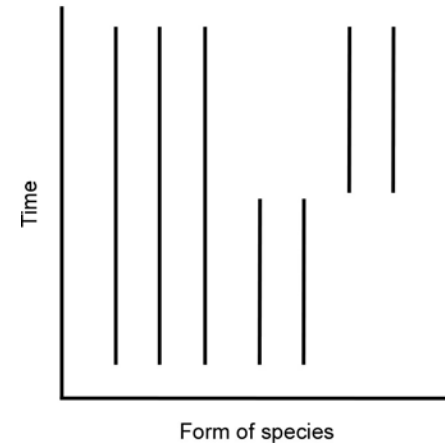
Three theories of the history of life



Evolution



Transformation

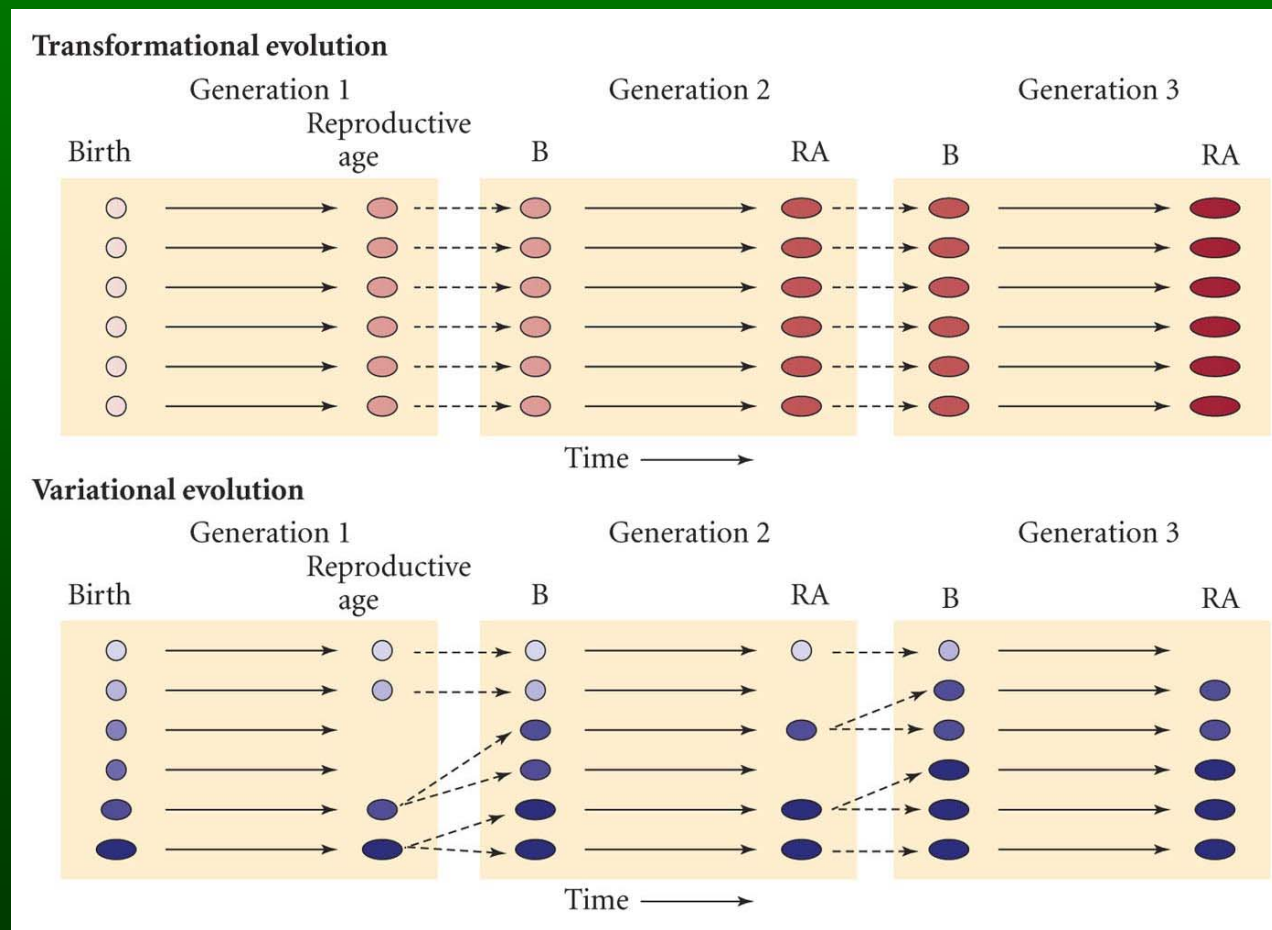


Creationism

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.



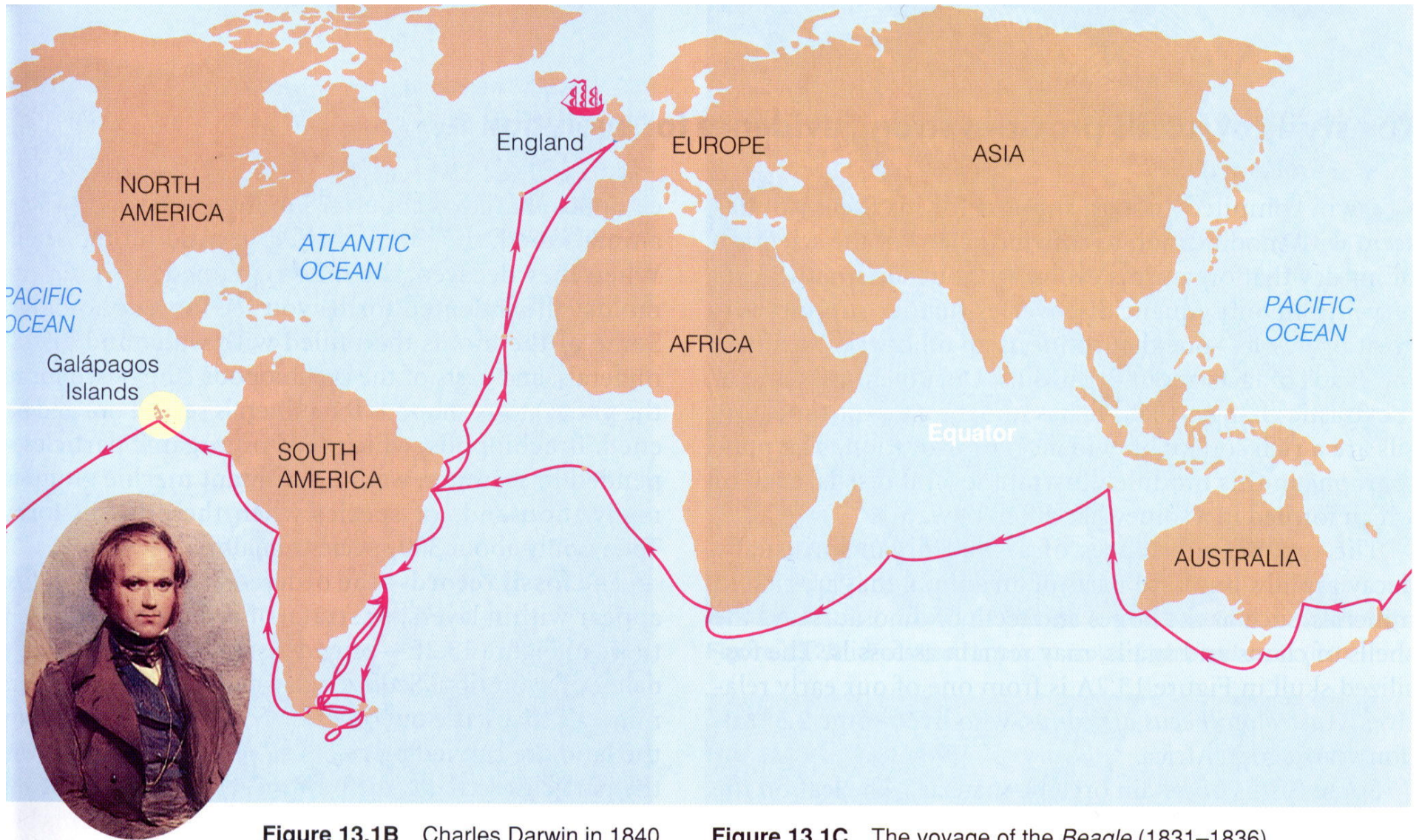
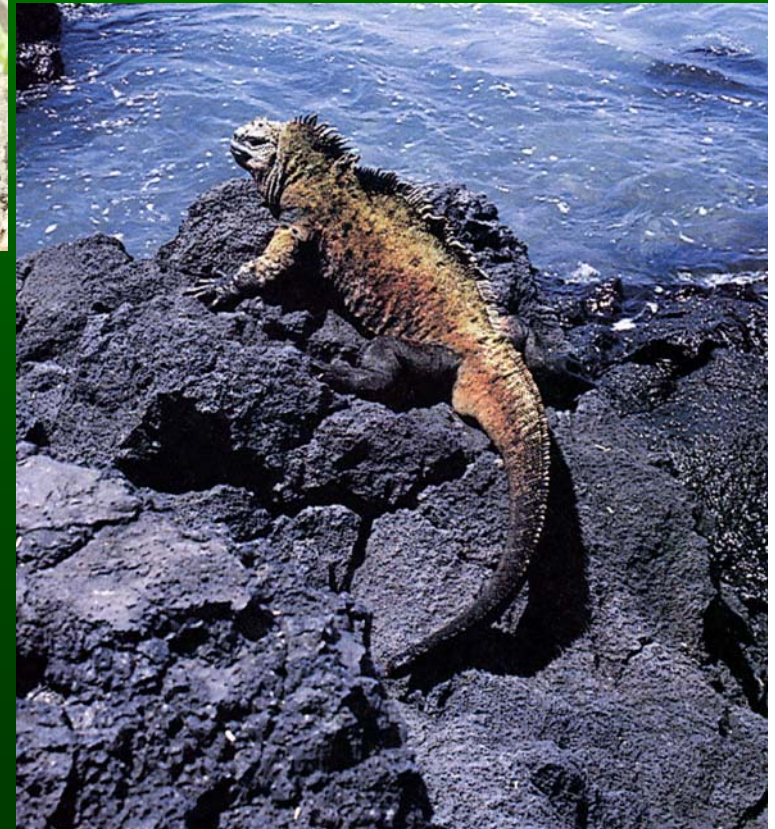


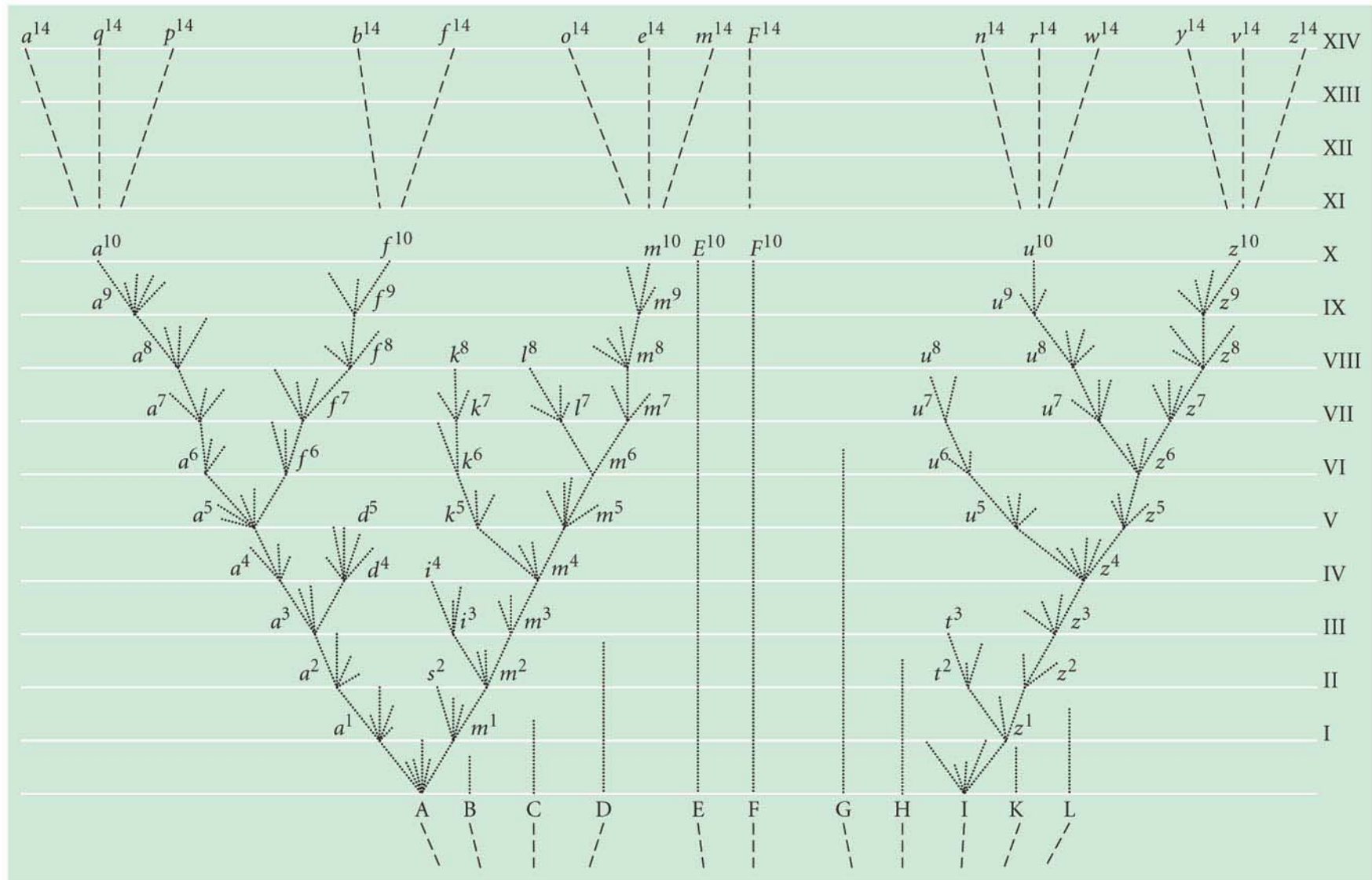
Figure 13.1B Charles Darwin in 1840

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

Galapagos Animals



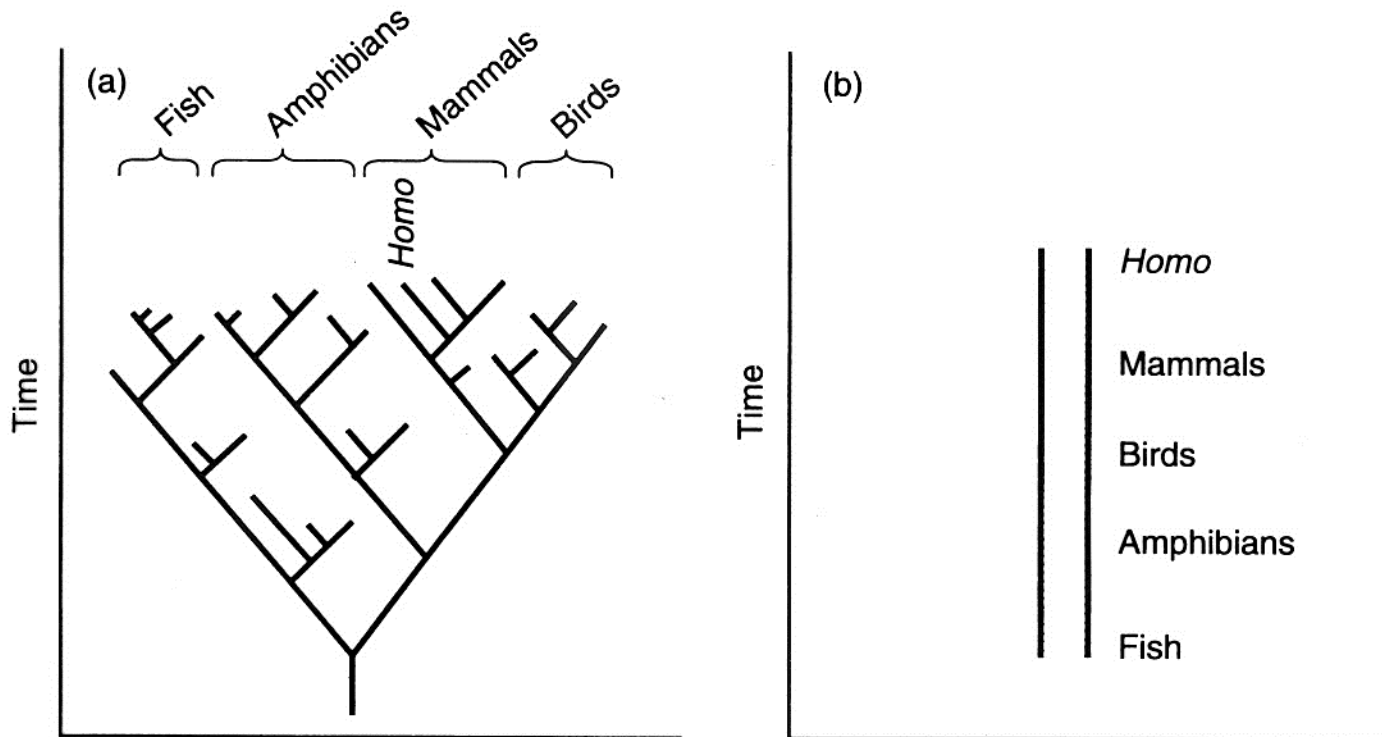
Darwin's representation of hypothetical phylogenetic relationships



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

The Cone of Complexity is NOT a linear model!

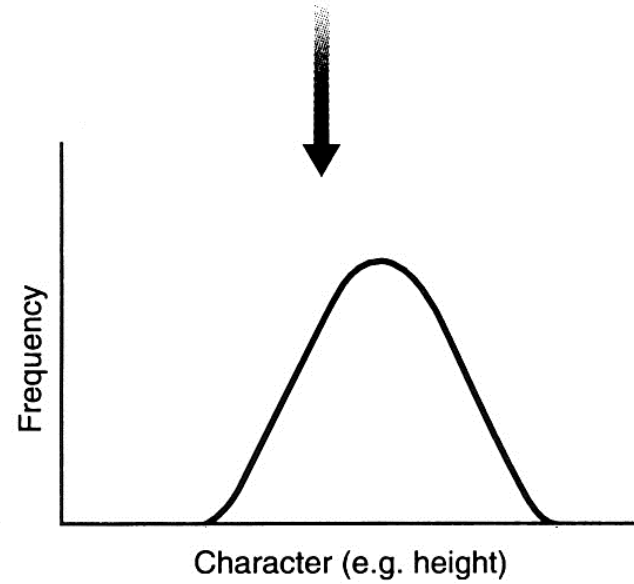
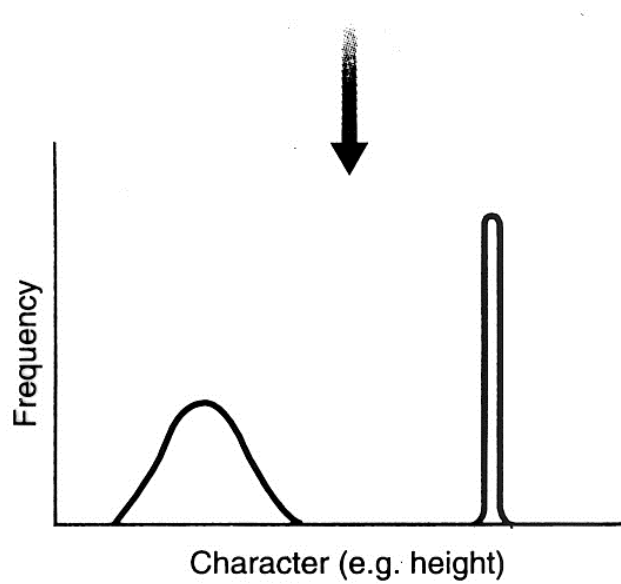
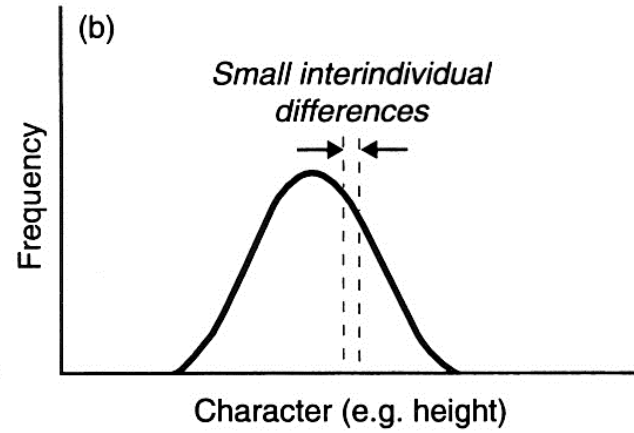
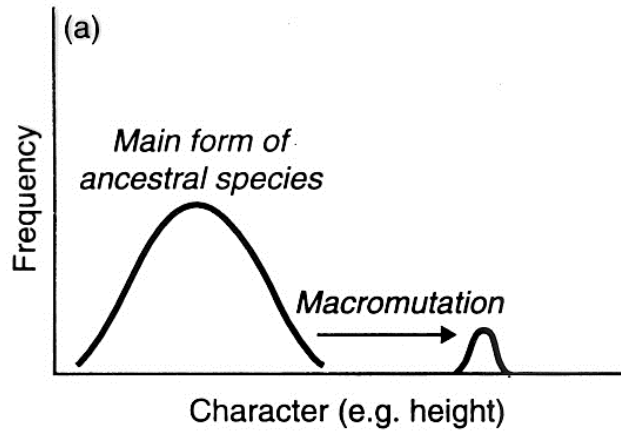
Figure 1.6 (a) Darwin's theory suggests that evolution has proceeded as a branching tree. Note that *Homo* occupies an arbitrary position in the diagram—it does not have to be the right-hand extreme. The tree should be contrasted with the popular idea (b) that evolution is a one-dimensional progressive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

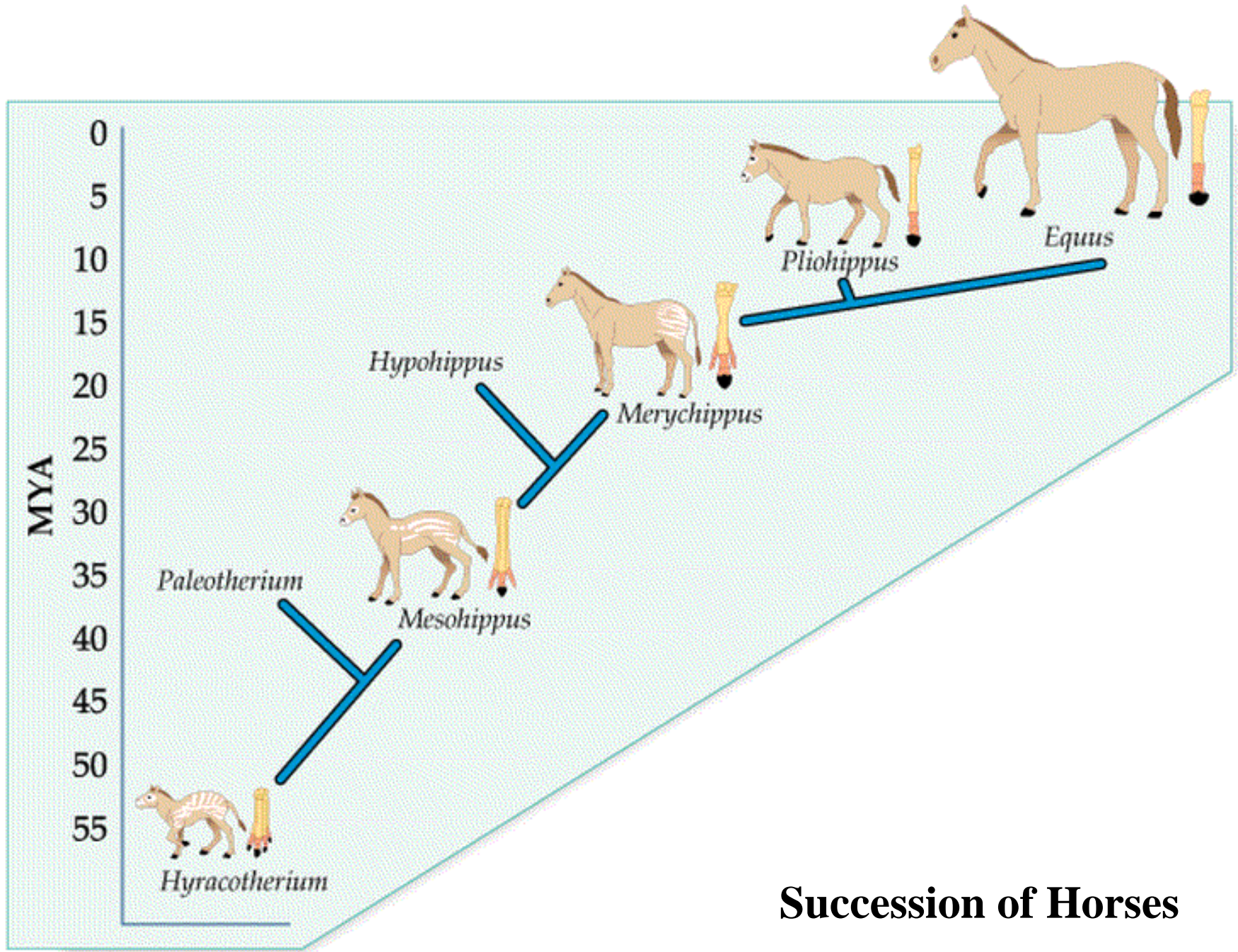


**The Theoretical Side of
Evolution: How Important is
Natural Selection vs. Other
Evolutionary Forces?**

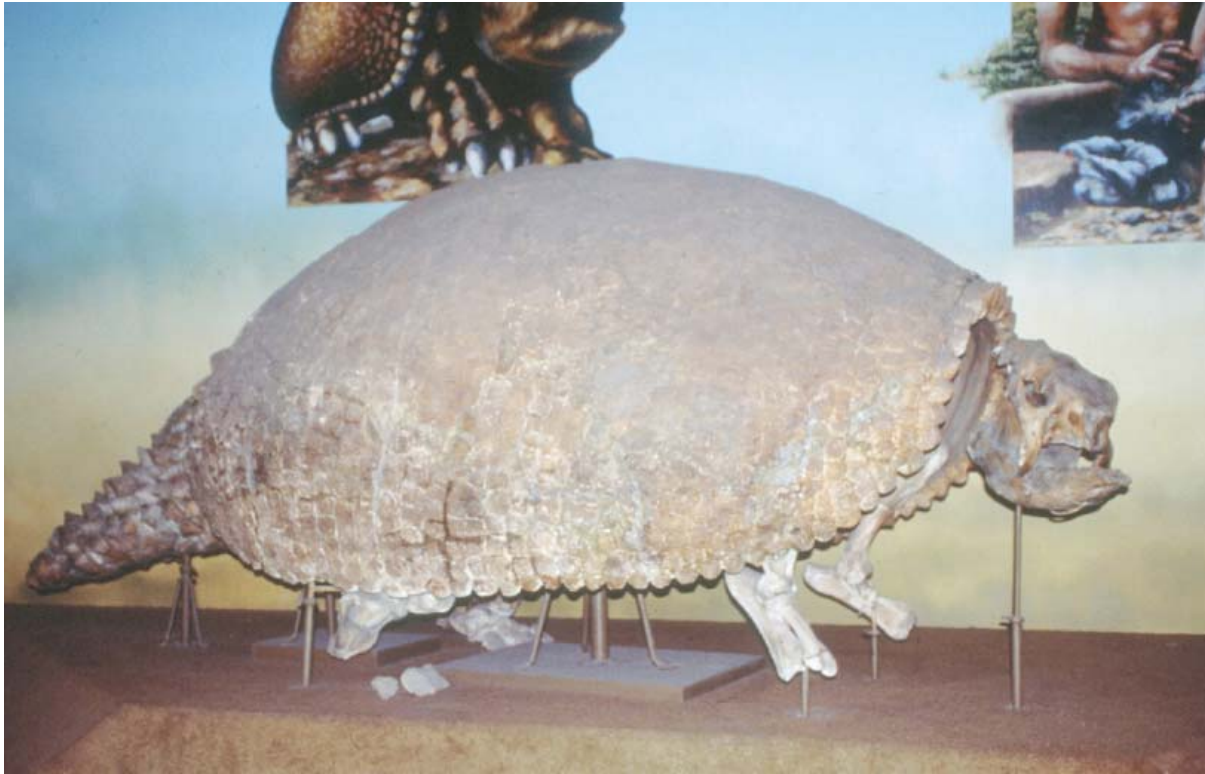
Saltationists (Early Mendelians)

Gradualists (Biometricians)





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.**

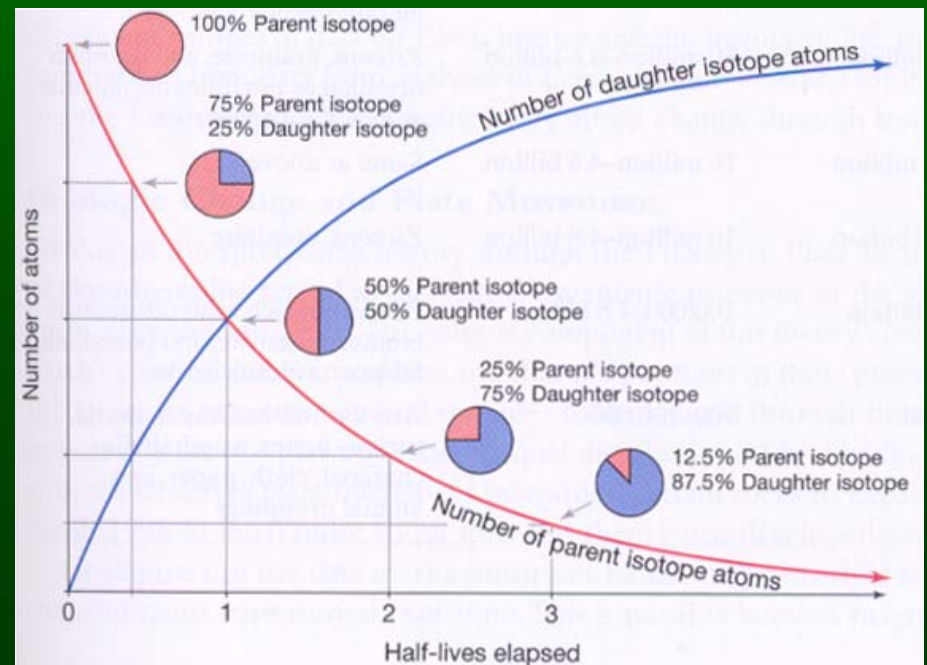


Fossil Record Concepts:

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	1.8	Earliest <i>Homo</i> First daisy-family plants First apes First extensive grasslands First whales First horses Extinction of dinosaurs First placental mammals First flowering plants First birds First mammals First dinosaurs First plants with water-conducting vessels First mammal-like reptiles First reptiles First amphibians First woody plants First insects First vascular plants First fish with jaws First fish (no jaws) First land plants First multicellular organisms First eukaryotes	
			Pleistocene			
		Tertiary	Neogene	Pliocene		5.2
				Miocene		23.8
				Oligocene		33.5
			Paleogene	Eocene		55.6
				Paleocene		65
				Mesozoic		Cretaceous
		Early	144			
		Jurassic	Late			160
	Middle		180			
	Early		206			
	Triassic	Late	228			
		Middle	251			
		Scythian	290			
		Permian	Carboniferous		Pennsylvanian	353.7
					Mississippian	408.5
	Devonian	439				
	Silurian	495				
	Ordovician	543				
	Paleozoic	Cambrian		2500		
				3600		
	Proterozoic			4600		
	Archaean					
	Hadean					

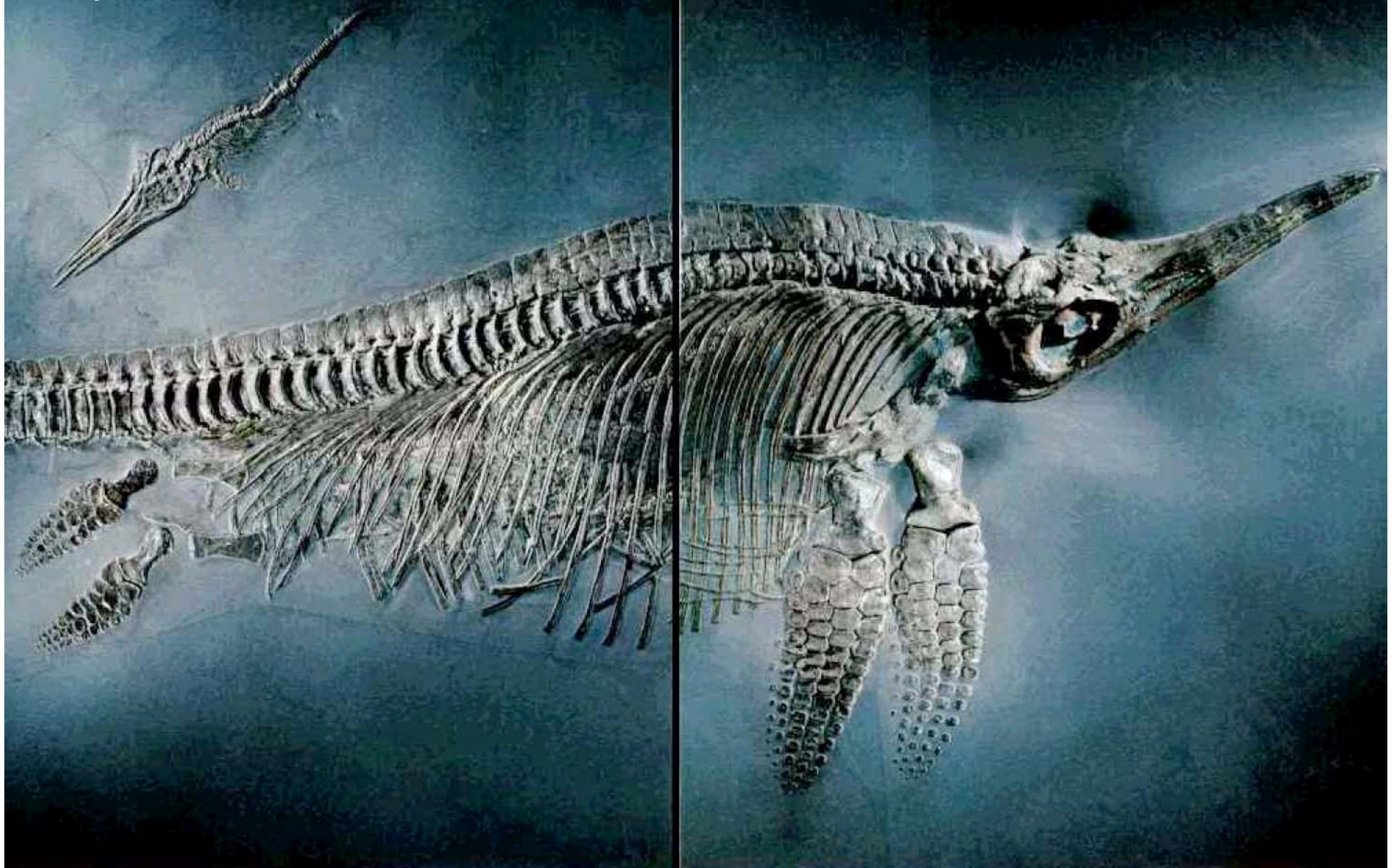
Geological Timeline based on fossil record and radiometric dating.



Trilobites



Tylosarus

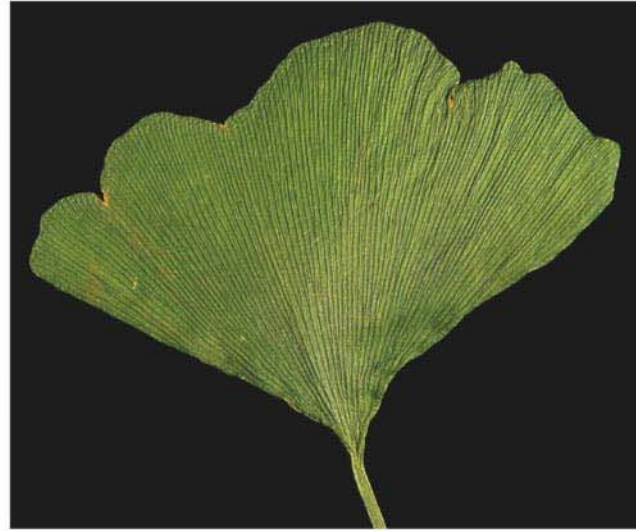


Plants

(A)



(B)



(C)



(D)





Archaeopteryx

Evidence That Life Evolves Via Descent With Modification

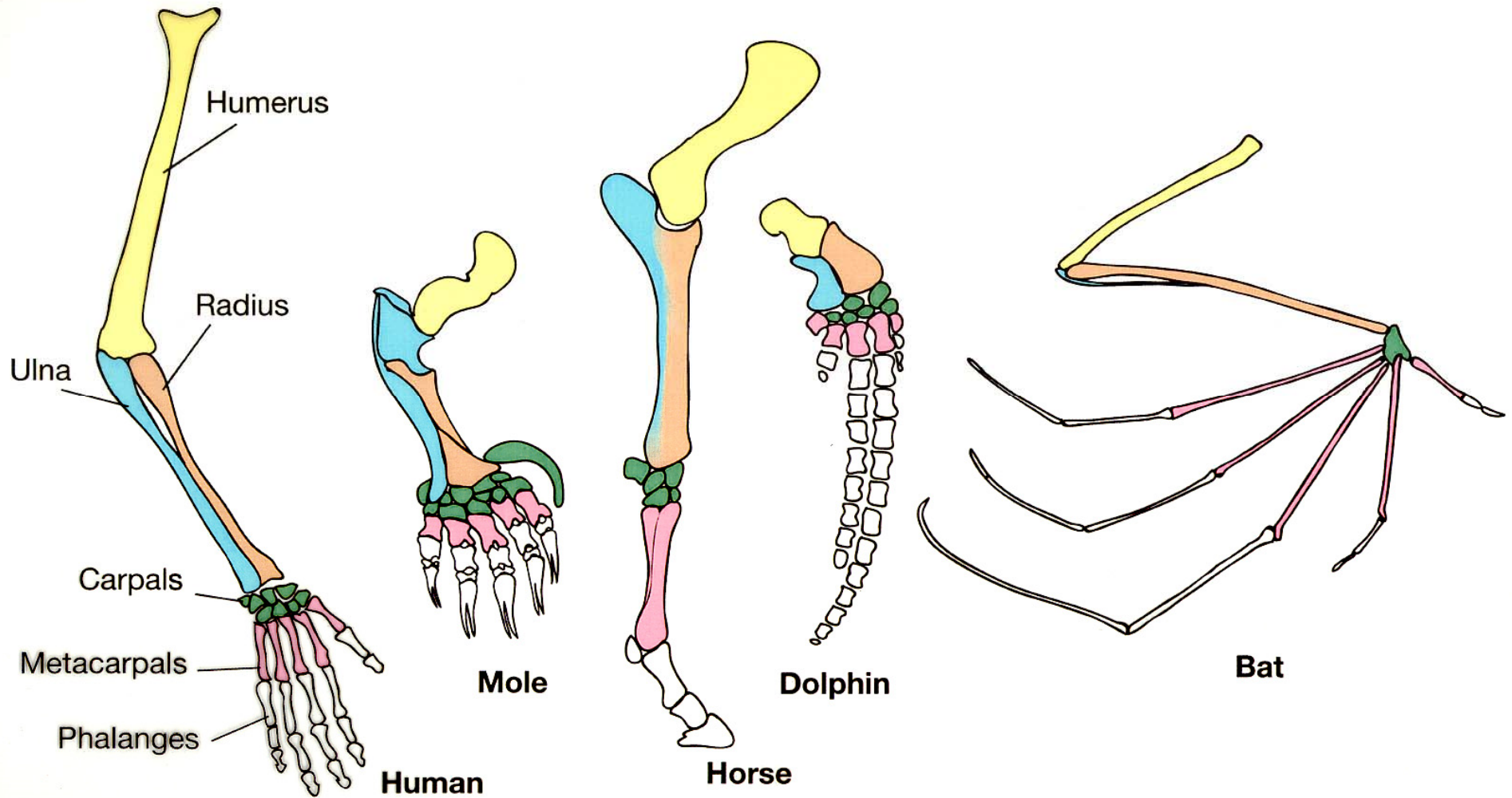
- **Homology (incl. vestigial structures)**
- **Artificial selection**
- **Embryology and developmental genetics**
- **Imperfections**
- **Geographic distributions**

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.

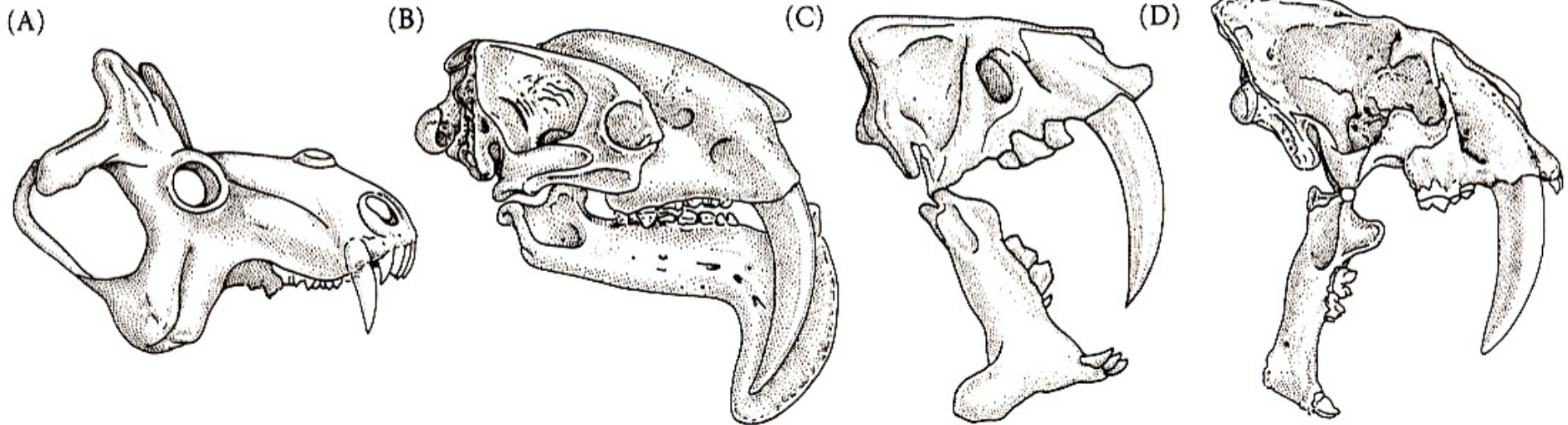
Homology of form



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

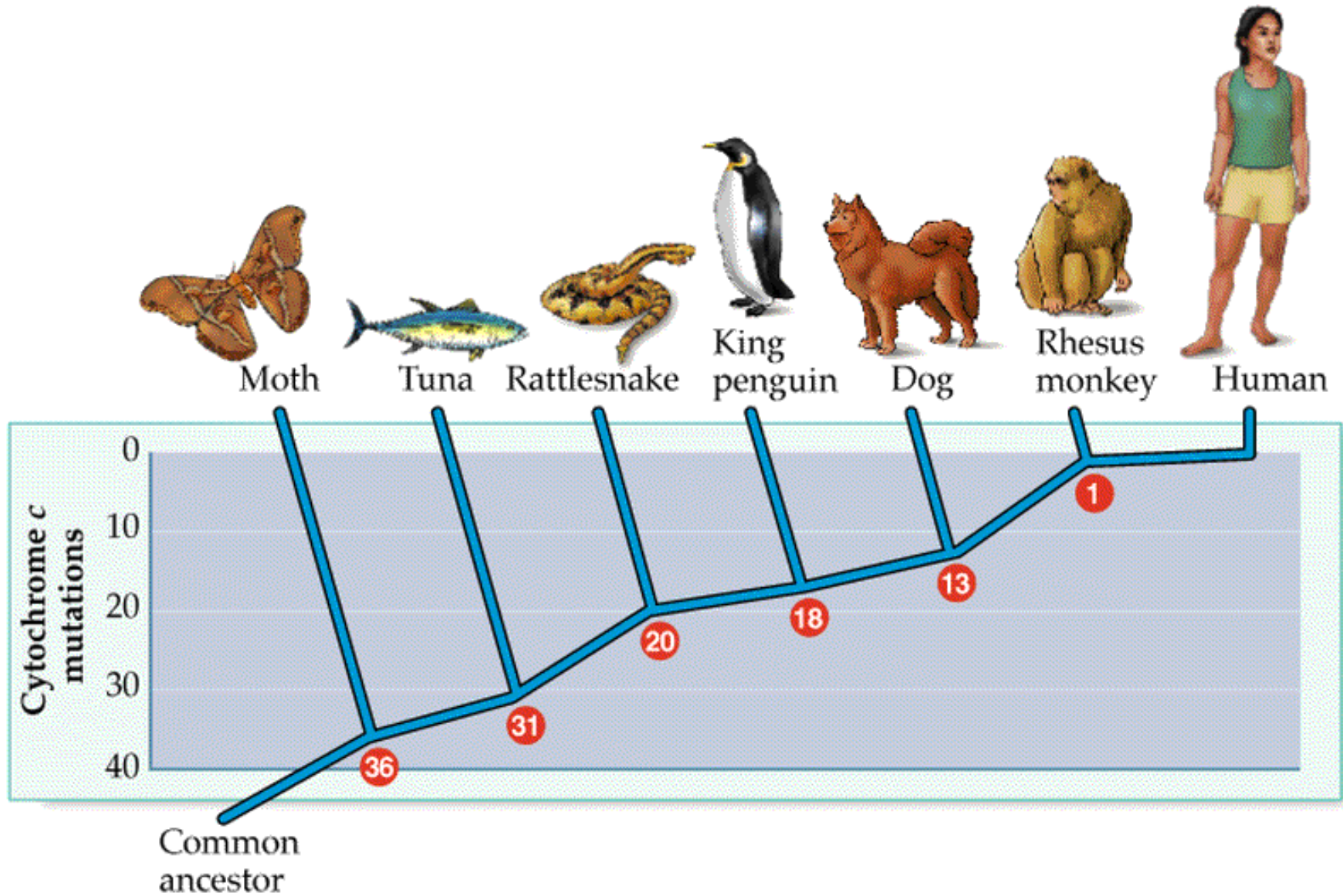
**Smilodon:
Sabertooth Tiger**



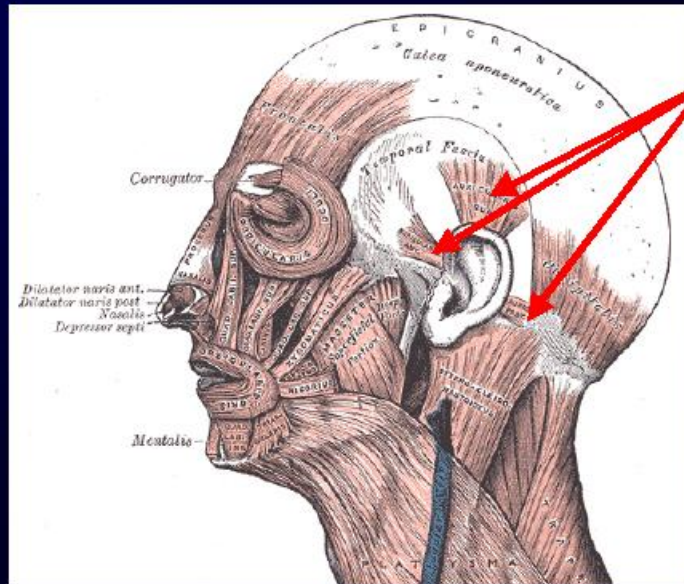
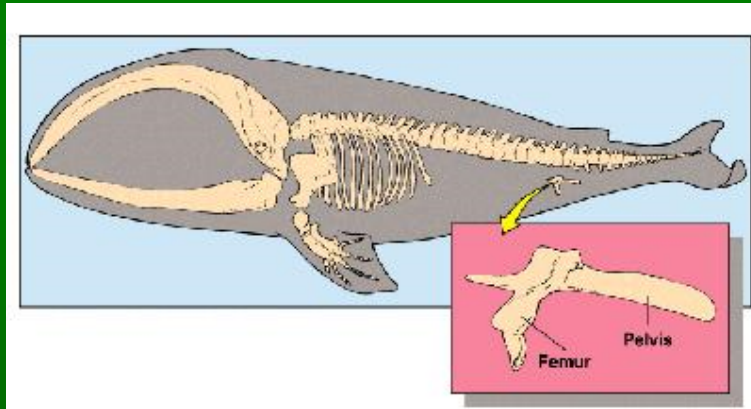
**Smilodonichthys:
A Pliocene salmonid fish**

Analogous Structures

Homology of molecules



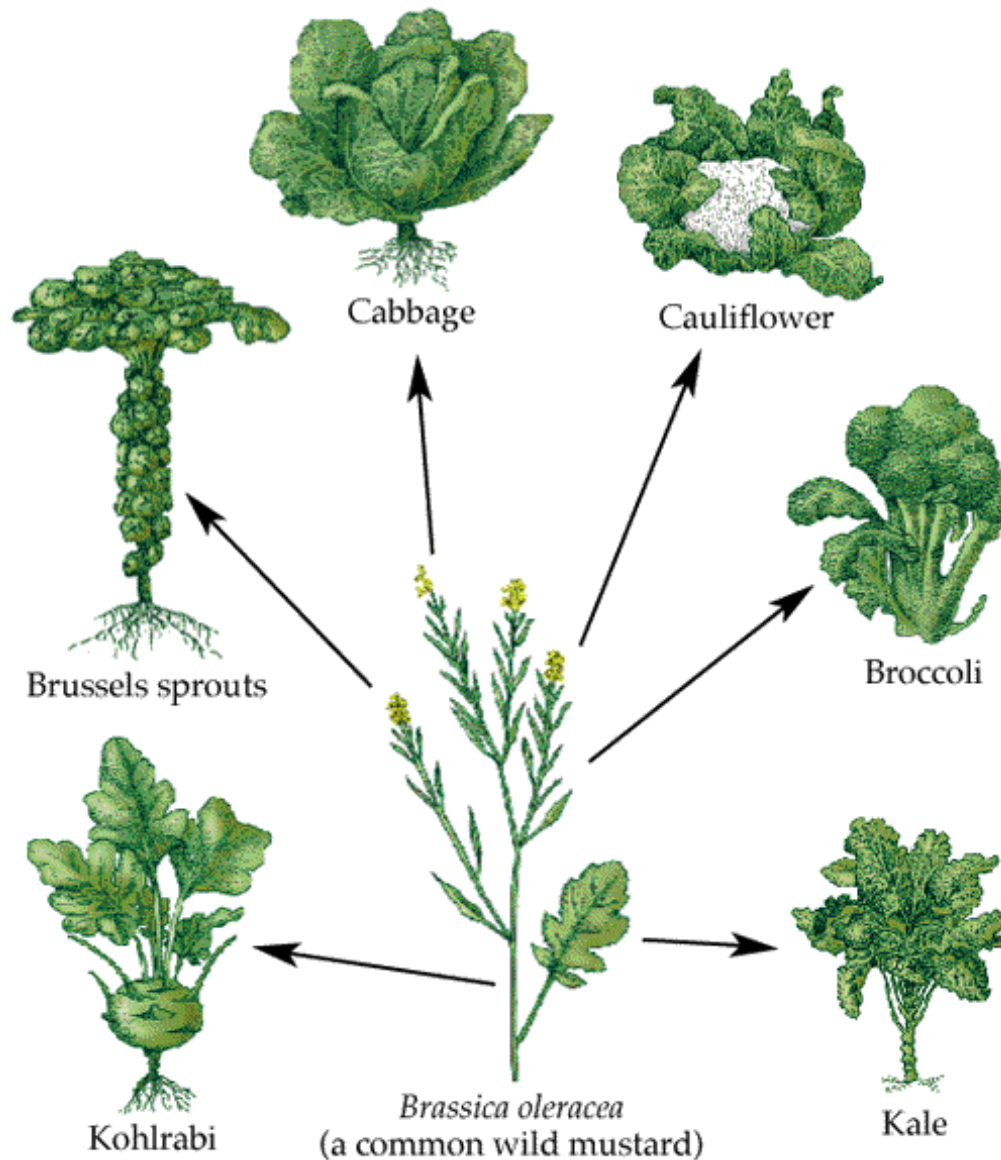
Vestigial Structures: Exhibited by loss of function.



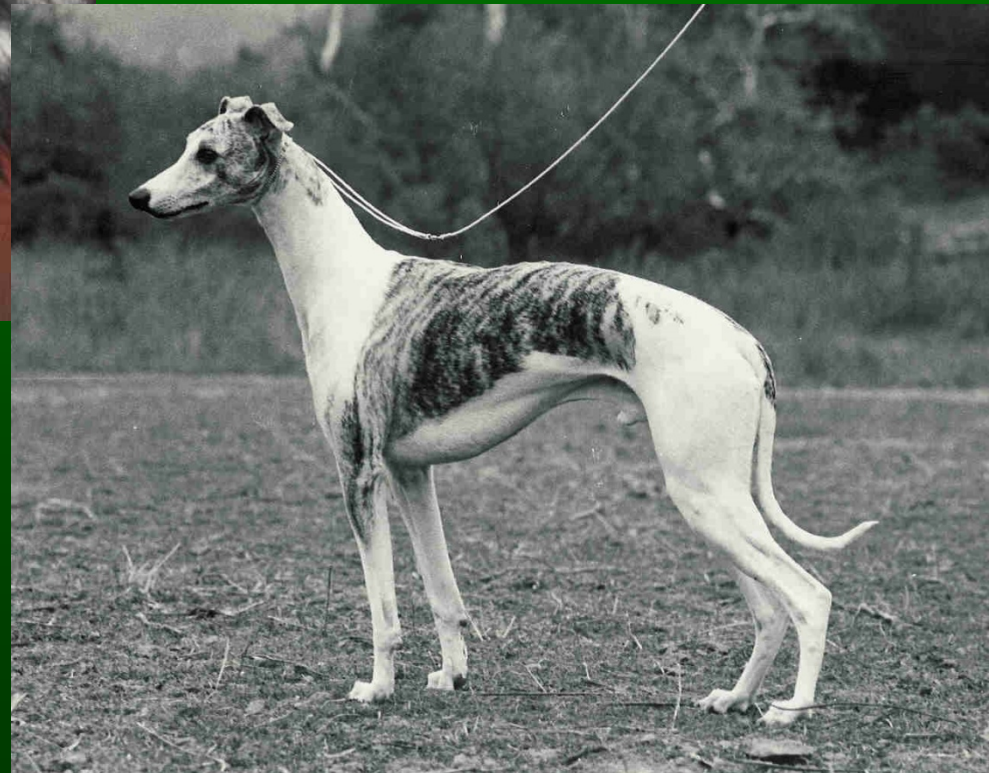
Mammals have muscles that move their external ears. You do, too, but most people never learn to use them, and ear-wiggling doesn't make any difference to your survival. . . so what are the muscles doing there?



Artificial selection has produced dramatic change in plants...



... and animals



... and animals

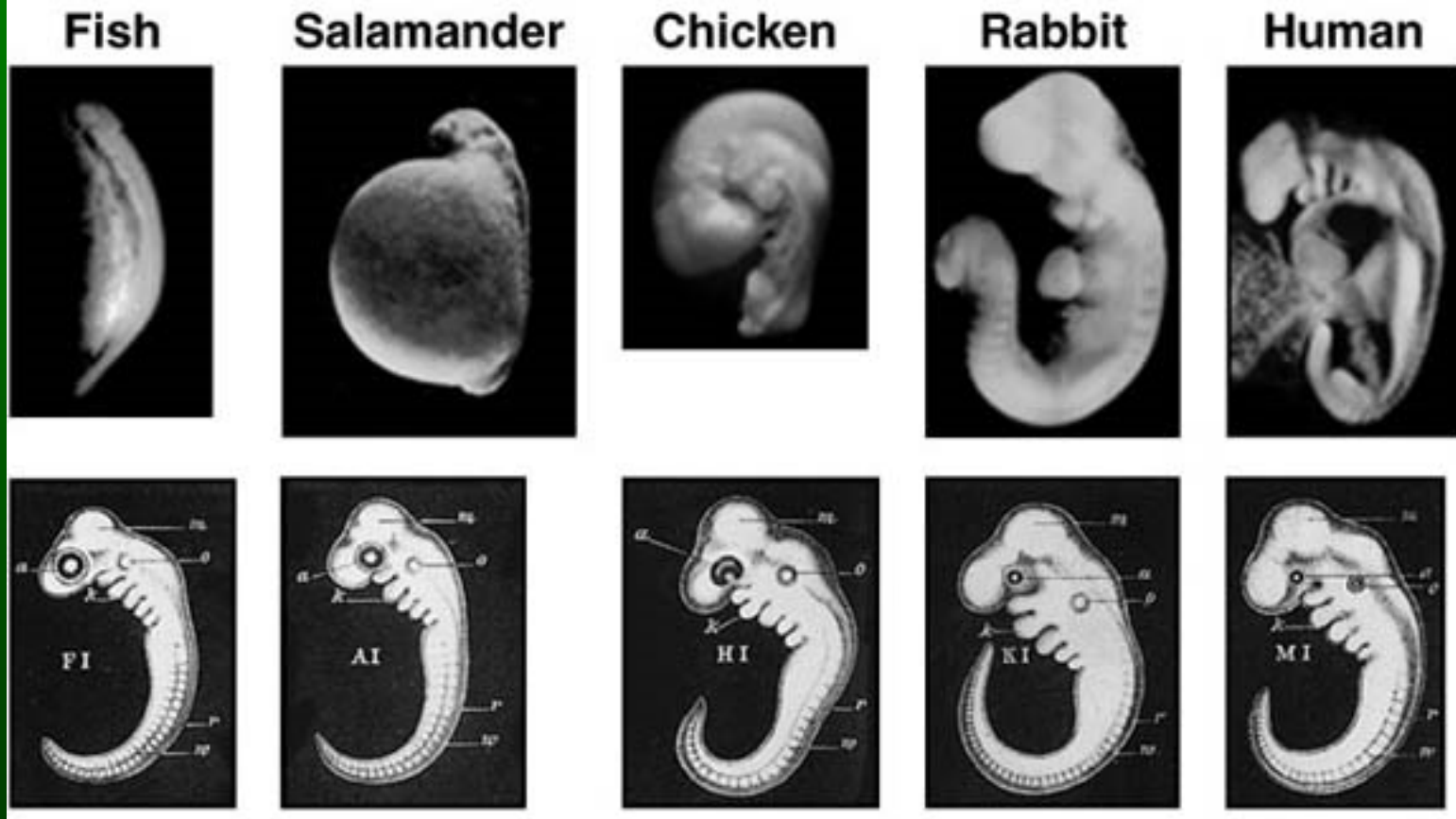


Myostatin mutation =
Bully Whippet



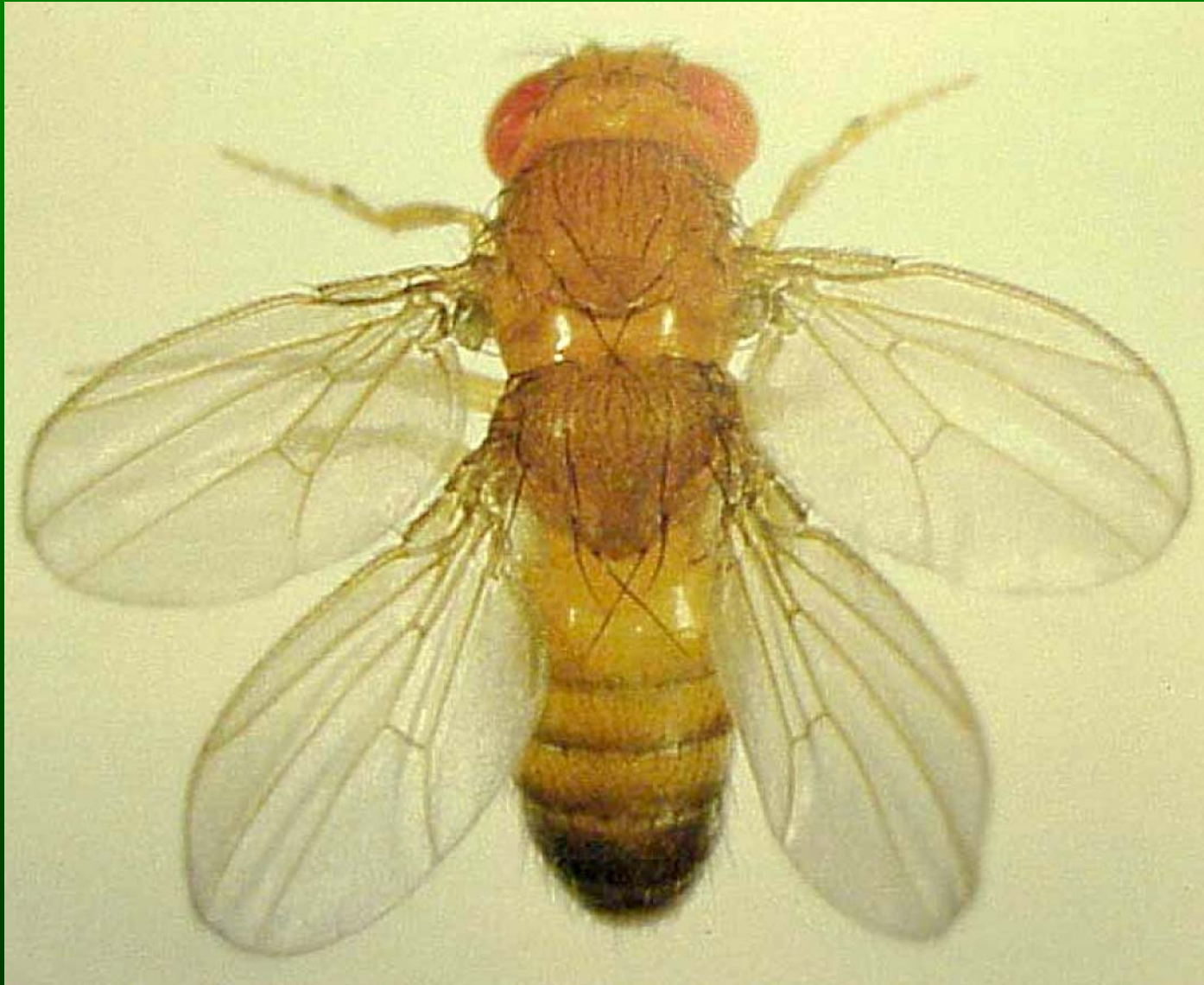
Similarities in early development indicate organisms are derived from a similar plan.

Embryo resemblances

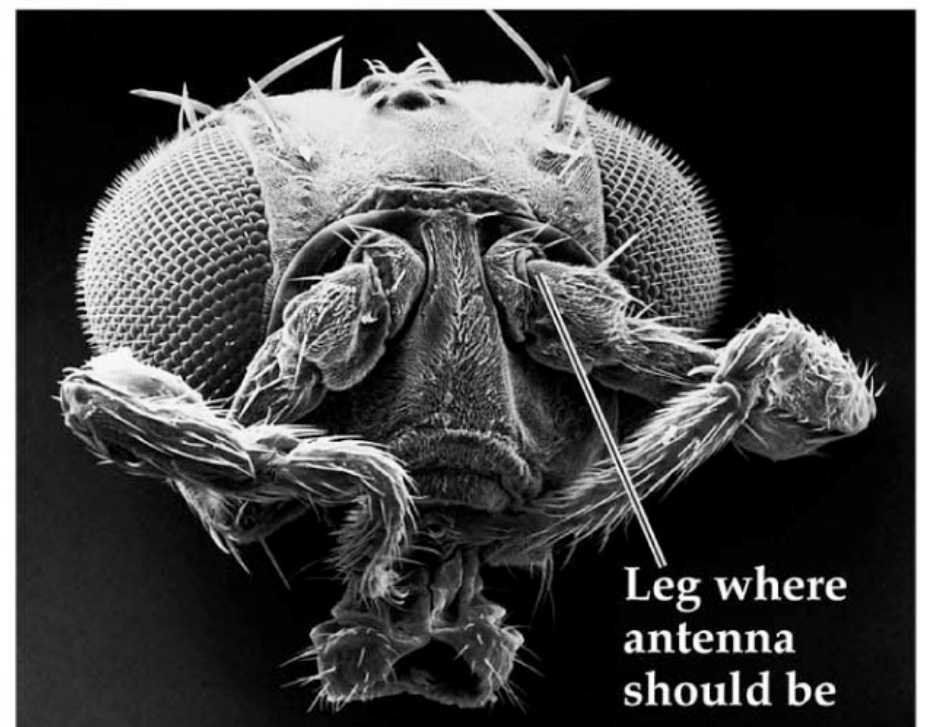
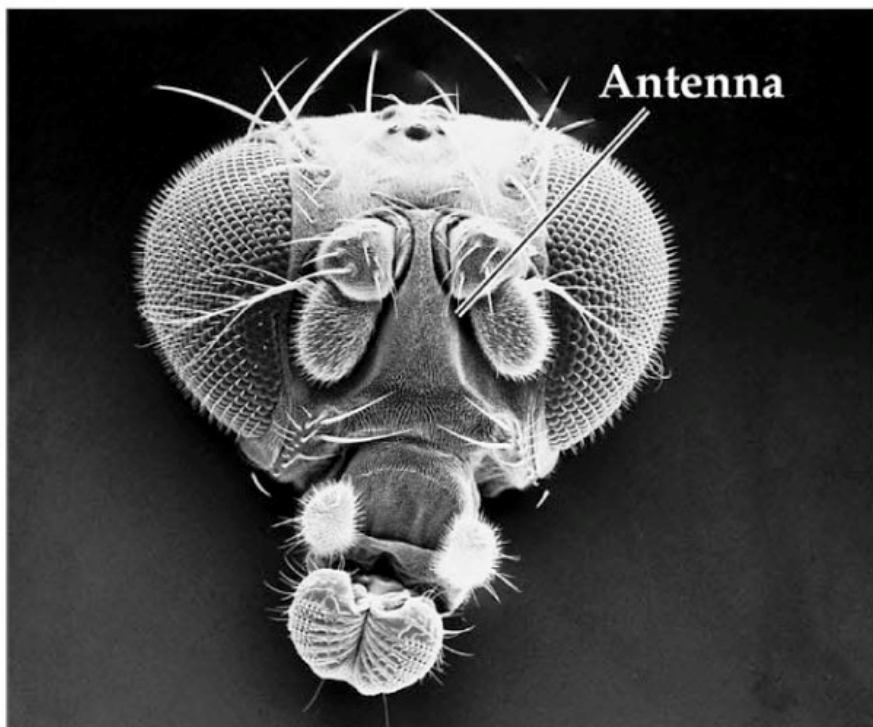


Ontogeny recapitulates Phylogeny?

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



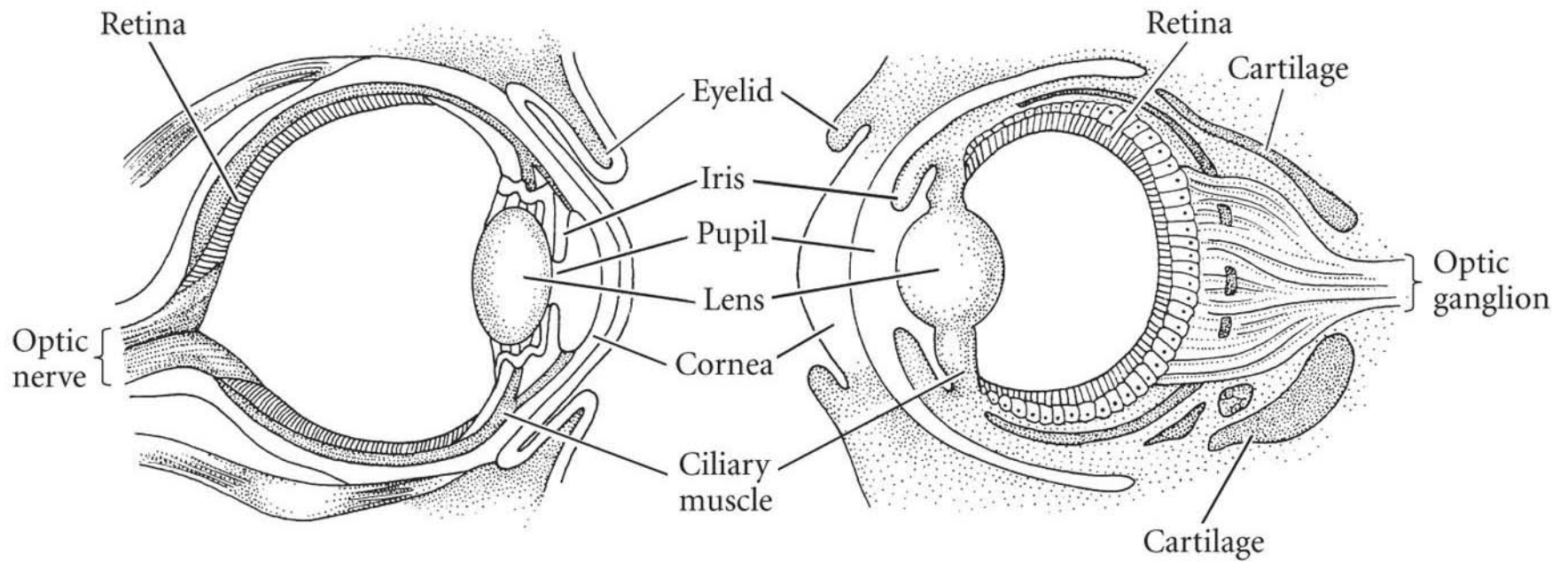
Developmental genes reveal the basis for alterations of the common plan.



Imperfections of Design

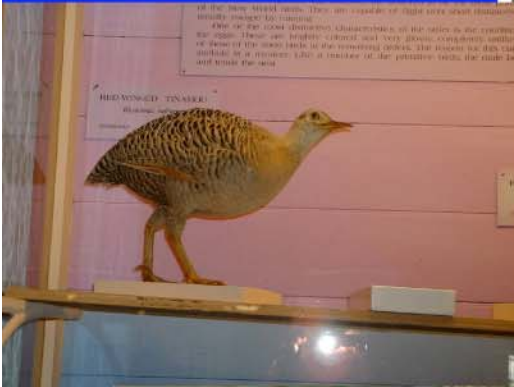
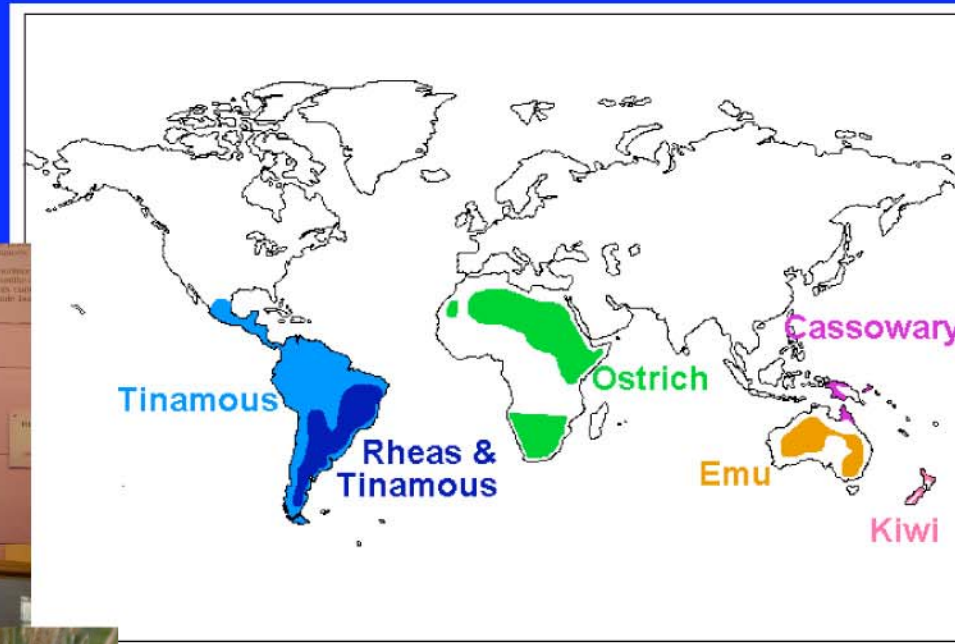
(A) Vertebrate eye

(B) Octopus eye



Analogous Structures too!

Geographic Distributions



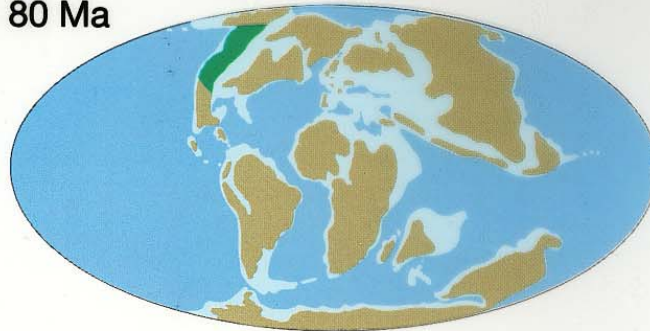
● Areas where marsupials lived

● Land

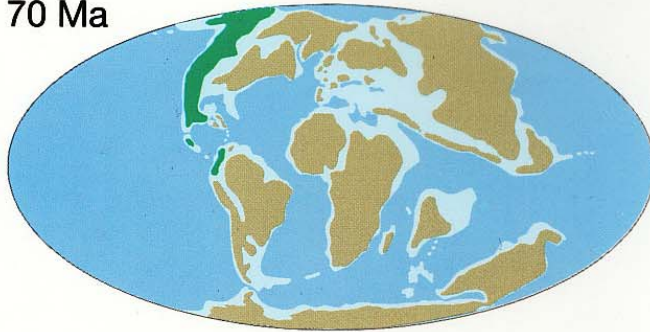
● Ocean

● Flooded continental plates

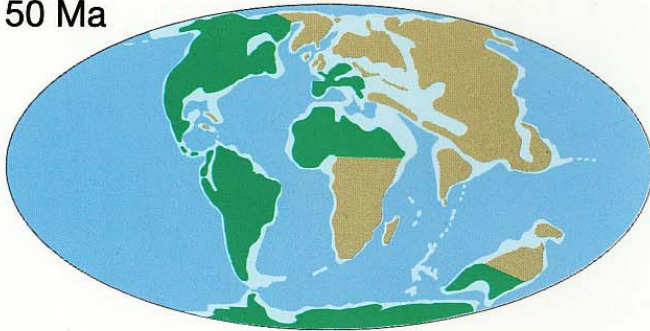
80 Ma



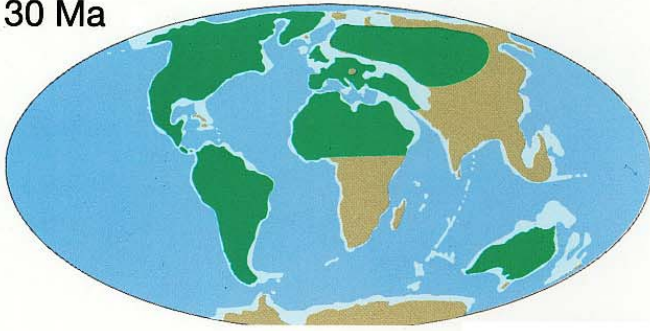
70 Ma



50 Ma



30 Ma



The Evolutionary History of Marsupial Mammals











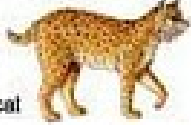


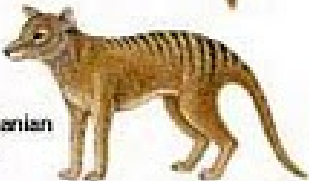
Requires Integration of:
Plate Tectonics
Fossil Record
Radioisotope Dating

Biogeography

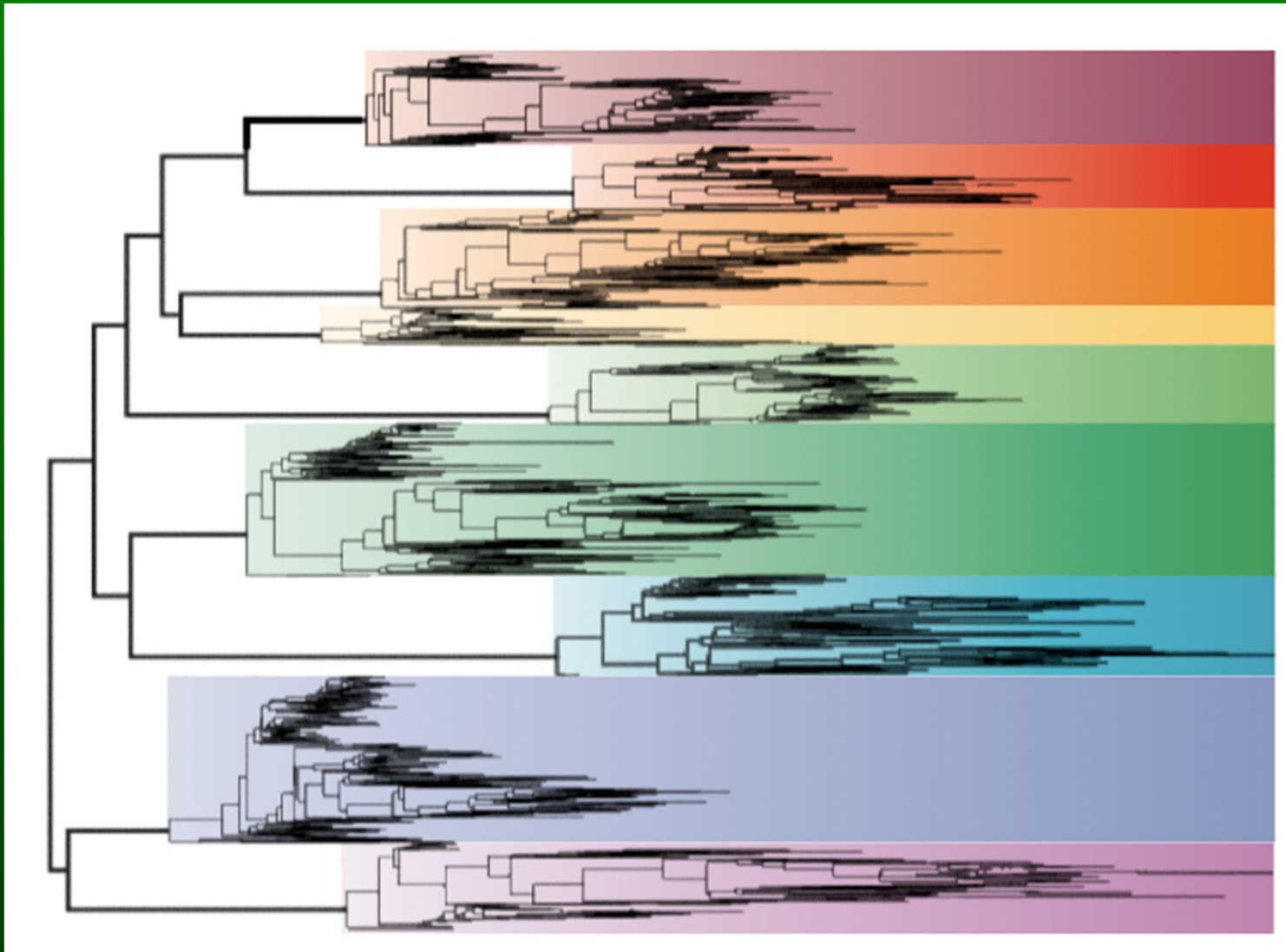


FIGURE 3.6. Wallace's Line (*thick red line*) separates two distinct present-day land faunas.

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.**