

# EVOLUTION

Evolution of the eye: [http://www.pbs.org/wgbh/evolution/library/01/1/I\\_011\\_01.html](http://www.pbs.org/wgbh/evolution/library/01/1/I_011_01.html)

# Definitions

## 1. Theory

- a) an explanation of how and why a specific natural phenomenon occurs
- b) A former hypothesis that has been tested with repeated experiments and observations and found always to work

**2.Law:** a rule that describes, but doesn't explain, a pattern in nature and predicts what will happen under specific conditions

# The History of the Universe

**Vol. 1, Pg. 1:  
Big Bang**



**Vol. 21:  
Earth Forms  
(4.5 bya)**



**Vol. 23:  
Life on Earth**



**Vol. 29: Cambrian Era  
Diversity Explosion**

**Vol. 30**  
**Pg. 385: Dinos**  
**Pg. 450: Humans**

**30 Volumes  
450 pages each  
1 pg. = 1 mil. Yrs.  
(13.7 b.y. old)**

# I. Evidence from the past

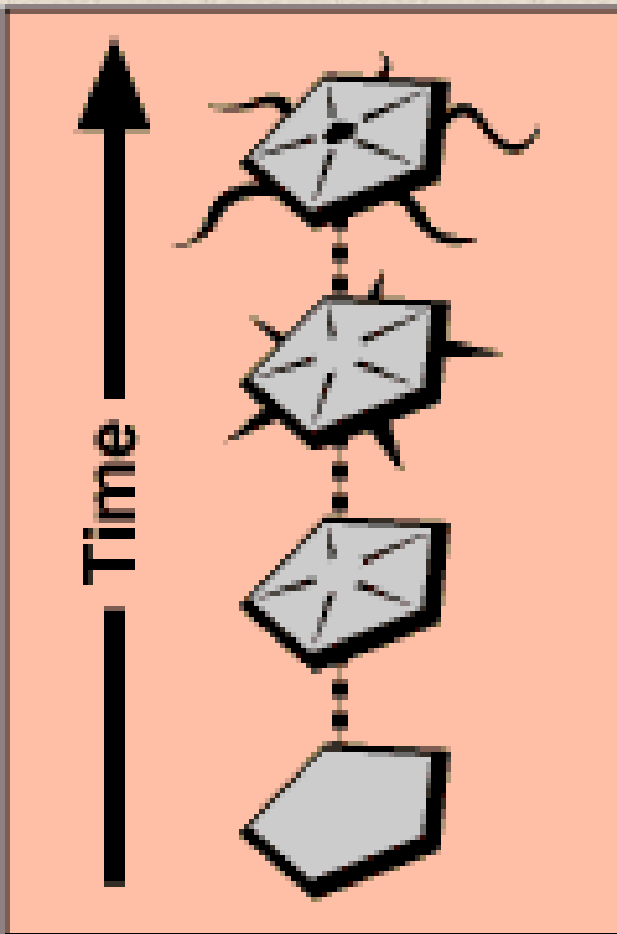
A. Fossil -- any trace or remains of an organism that has been preserved

B. fossil record - information scientists have gathered about past life

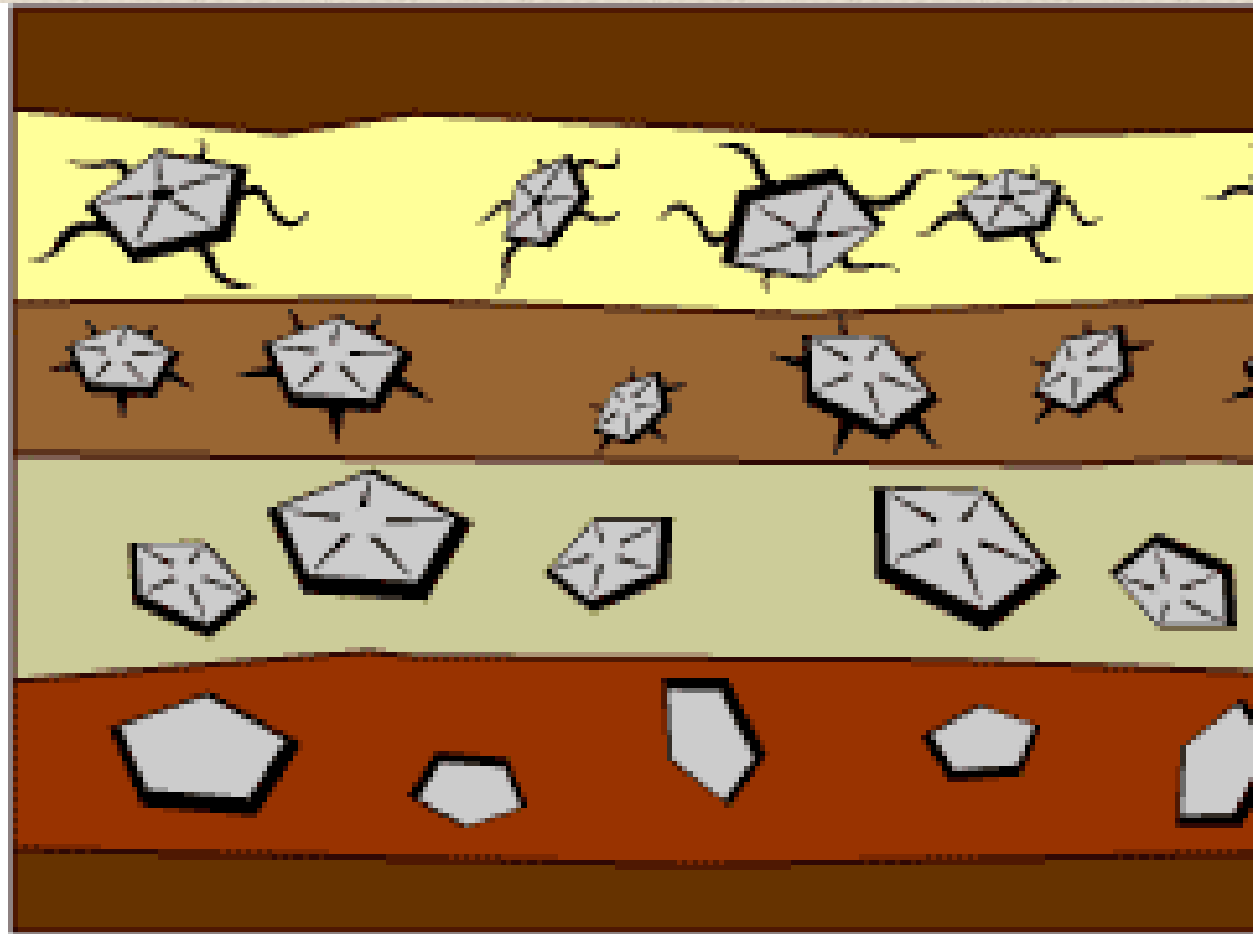
1. provides evidence about the history of life on Earth

2. Shows how organisms have changed over time

# Applying the fossil record



**Gradual lineage  
evolution**

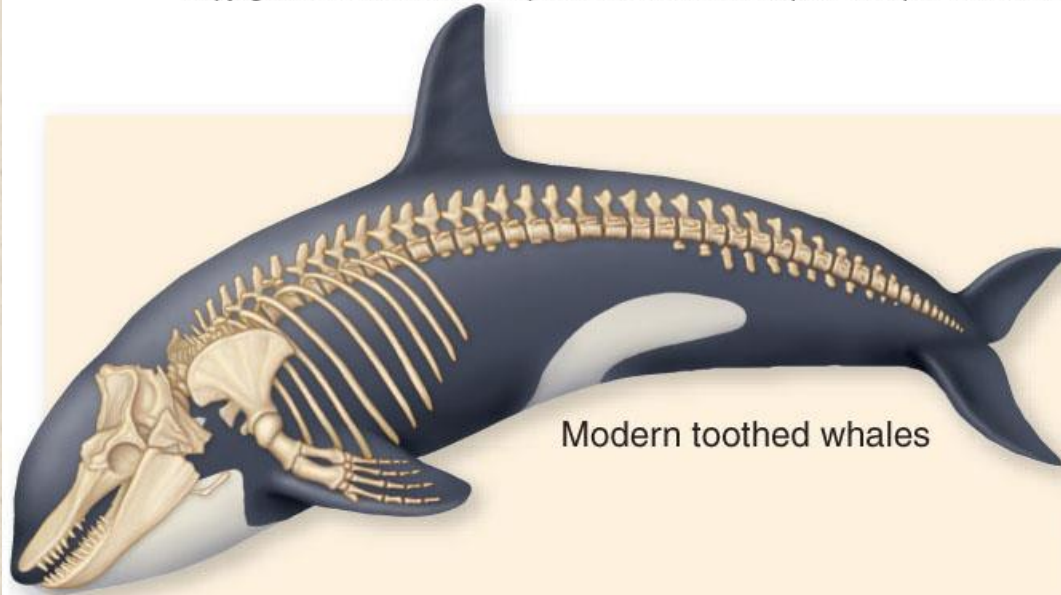


**Rock strata with fossils**



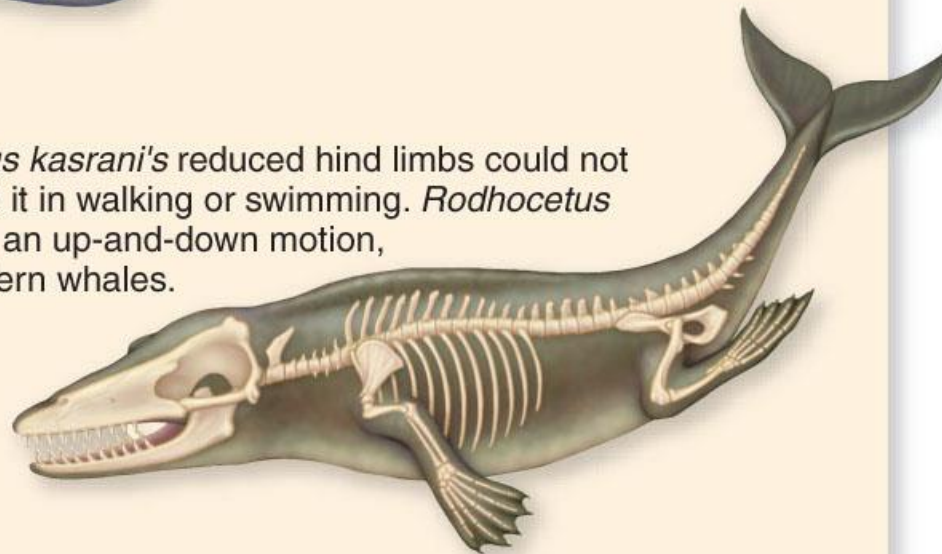
# Fossil Evidence of Evolution

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Modern toothed whales

*Rodhocetus kasrani's* reduced hind limbs could not have aided it in walking or swimming. *Rodhocetus* swam with an up-and-down motion, as do modern whales.

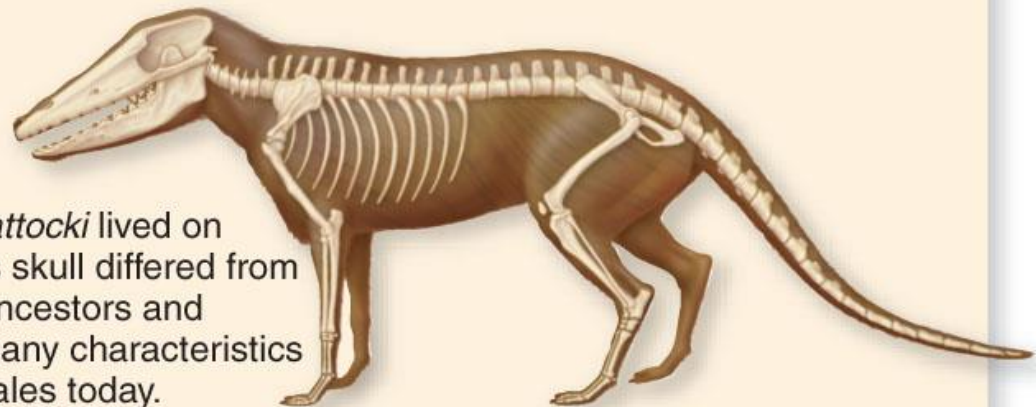


# Fossil Evidence of Evolution (Cont.)

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*Ambulocetus natans* probably walked on land (as do modern sea lions) and swam by flexing its backbone and paddling with its hind limbs (as do modern otters).

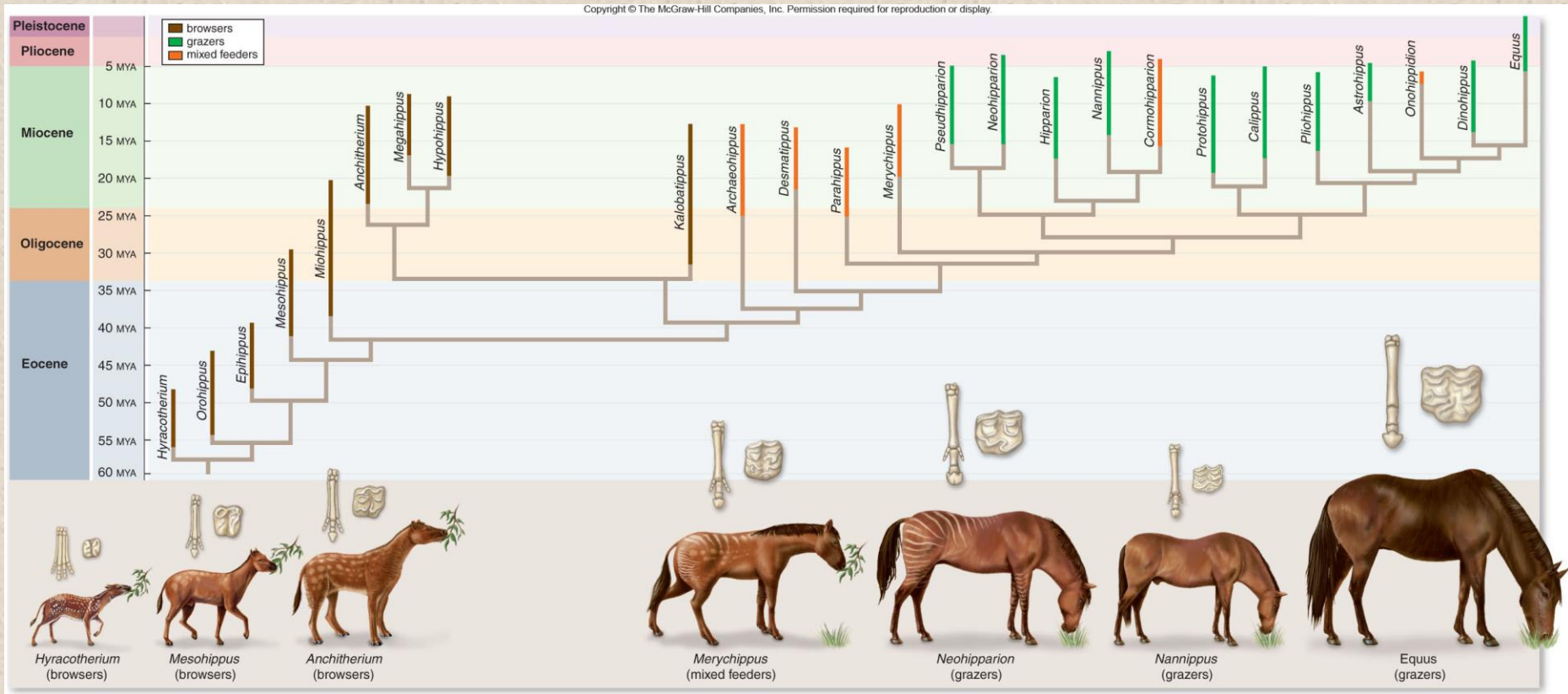


*Pakicetus attocki* lived on land, but its skull differed from that of its ancestors and exhibited many characteristics seen in whales today.

## Whale “missing links”



# Fossil Evidence of Evolution



Evolutionary change in body size and toe reduction of horses

## C.Fossil Types

1. Actual remains -- bones and shells resist decay and may be preserved (e.g. in ice, in La Brea tar pits)



*The Iceman ~5,300 yrs old*







La Brea tar pits  
~25,000 yrs old



2. Amber - hardened resin (tree sap), may contain trapped insects
3. Petrified remains - organic tissues replaced with minerals





4. Mold - the shape of an organism preserved in rock as a hollow form (like an ice cube tray)

5. Cast - when a mold fills with minerals to form a replica of the original form (like the ice cubes)



6. Imprint - a shallow impression made in mud which later hardens into rock, usually plants and feathers
7. Transformed remains - organic materials changed over time by high heat & pressure = coal, oil, etc.



## D. Age of fossils

1. Important to determine in order to show change over time

2. Relative dating

- Examine the rock layers
- bottom = oldest, top = youngest
- Determine the order in which events occurred

3. Absolute dating

- Radioactive dating
- Determine exact age





## Relative dating

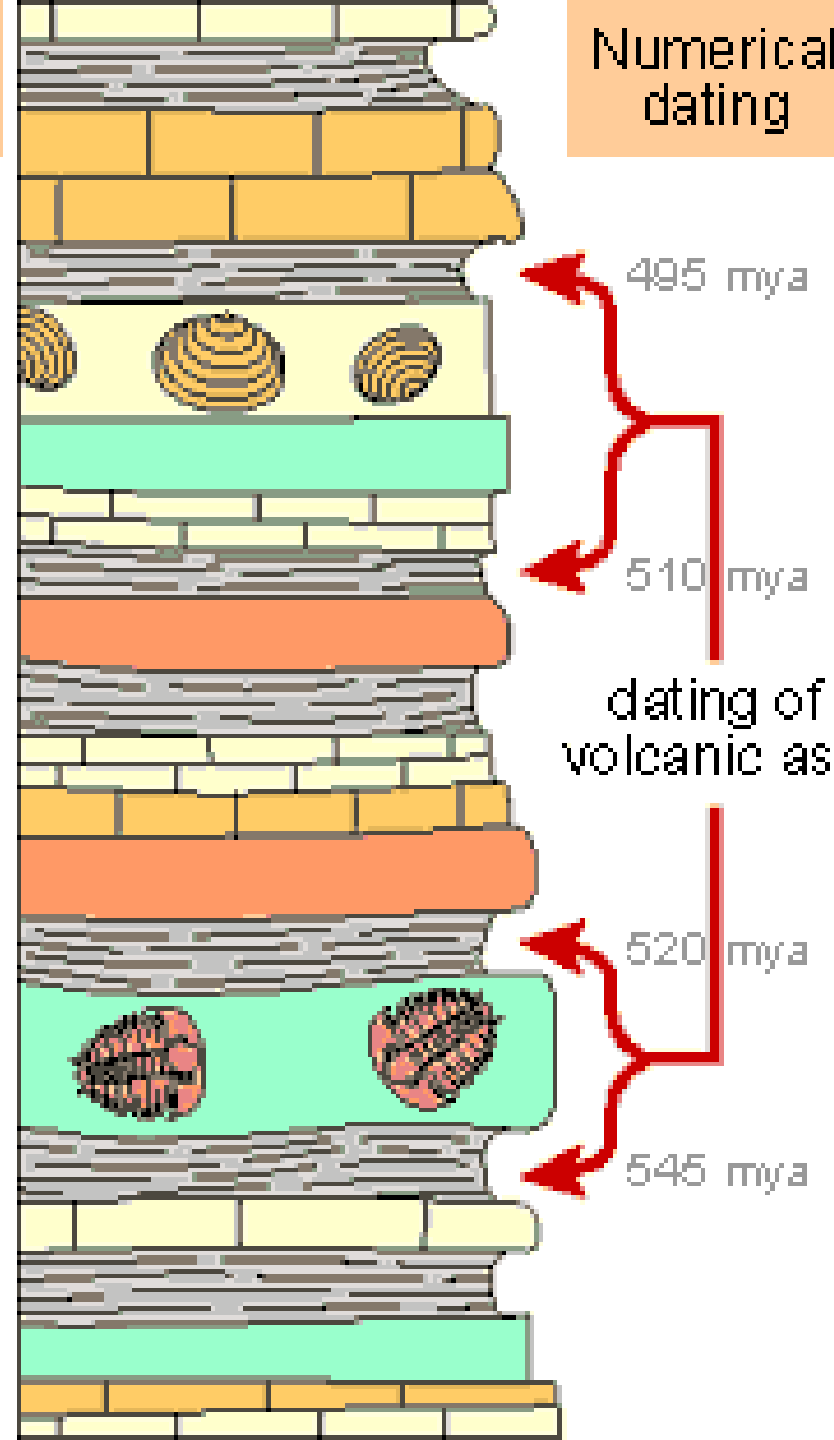
younger



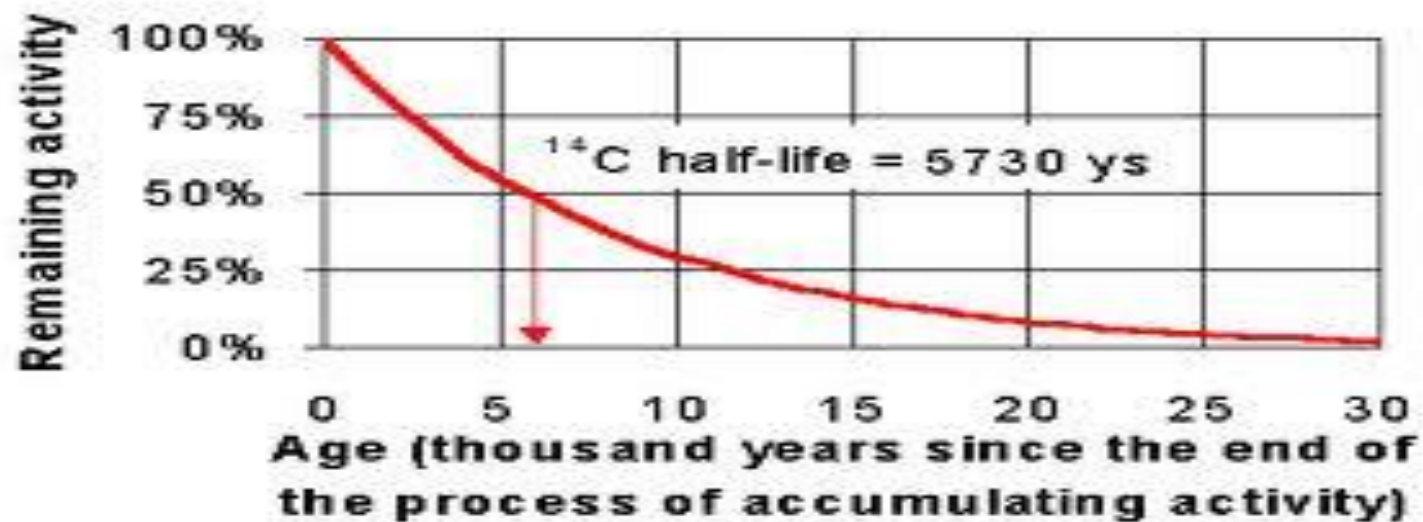
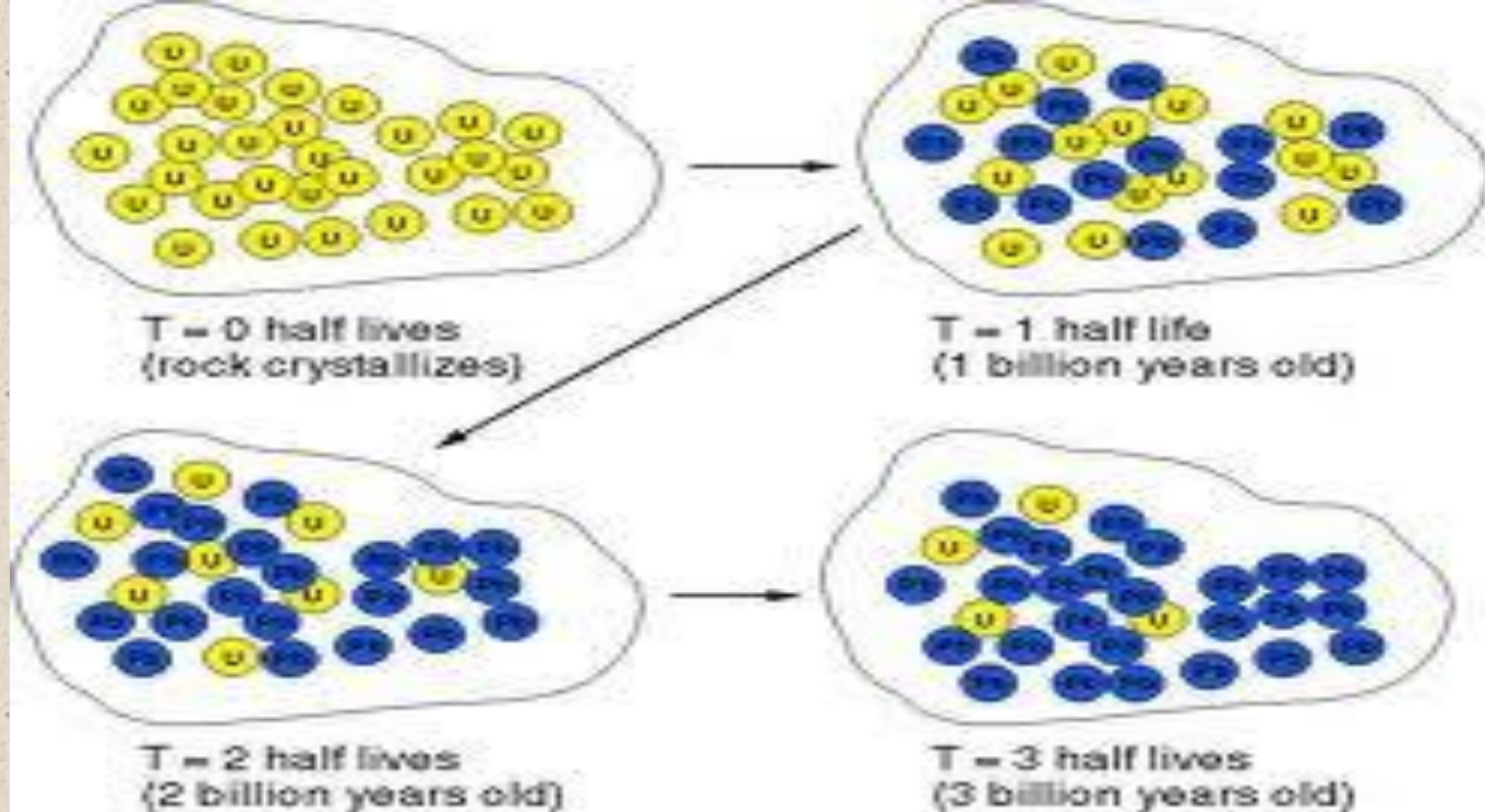
older



## Numerical dating





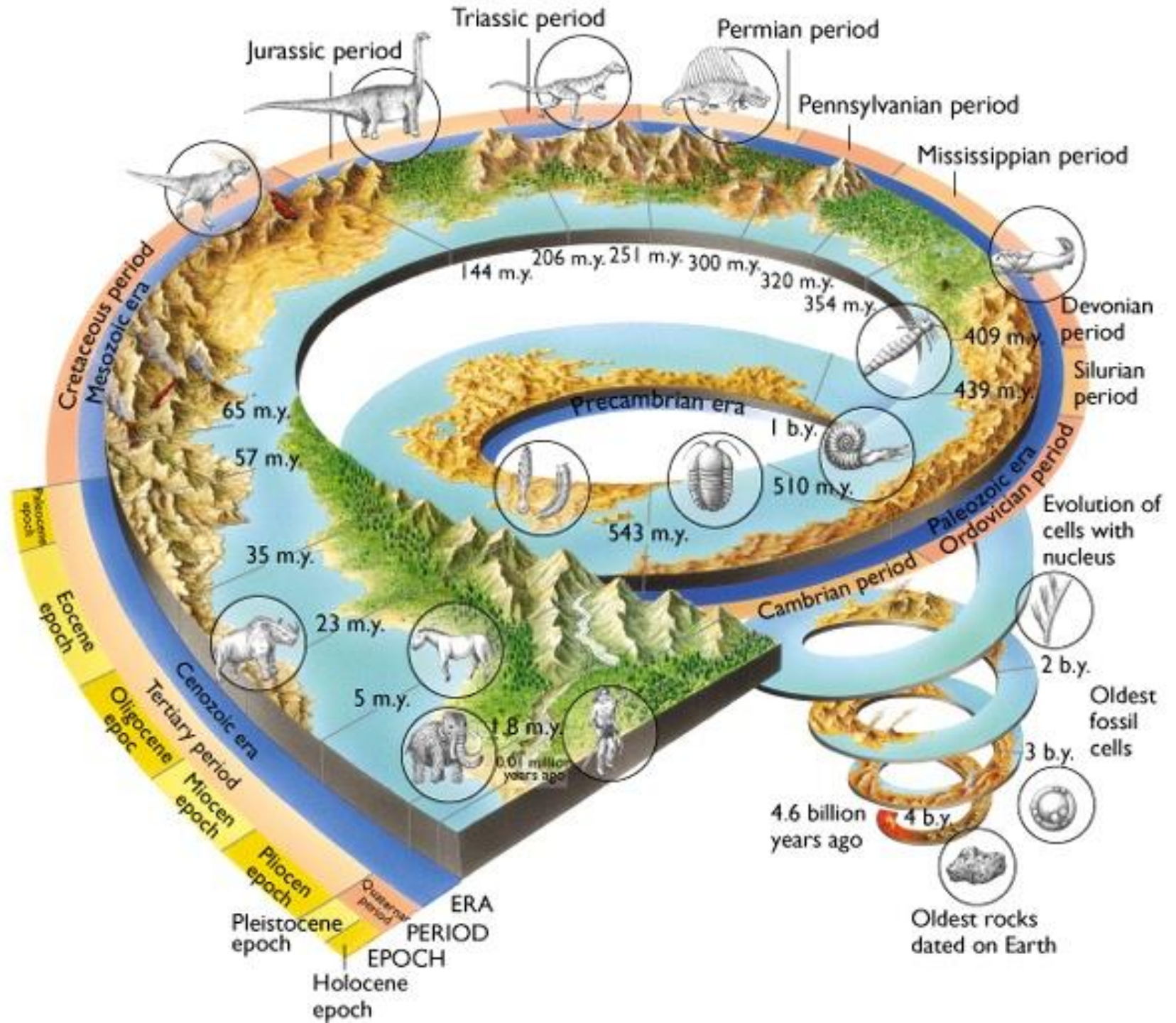


4. Index fossils - fossils that have been found only in a narrow period of time
- E.g. trilobites only lived between 500-600 million years ago



5. Geologic time scale - a timetable that divides Earth's history into eras
- Based on organisms living through time







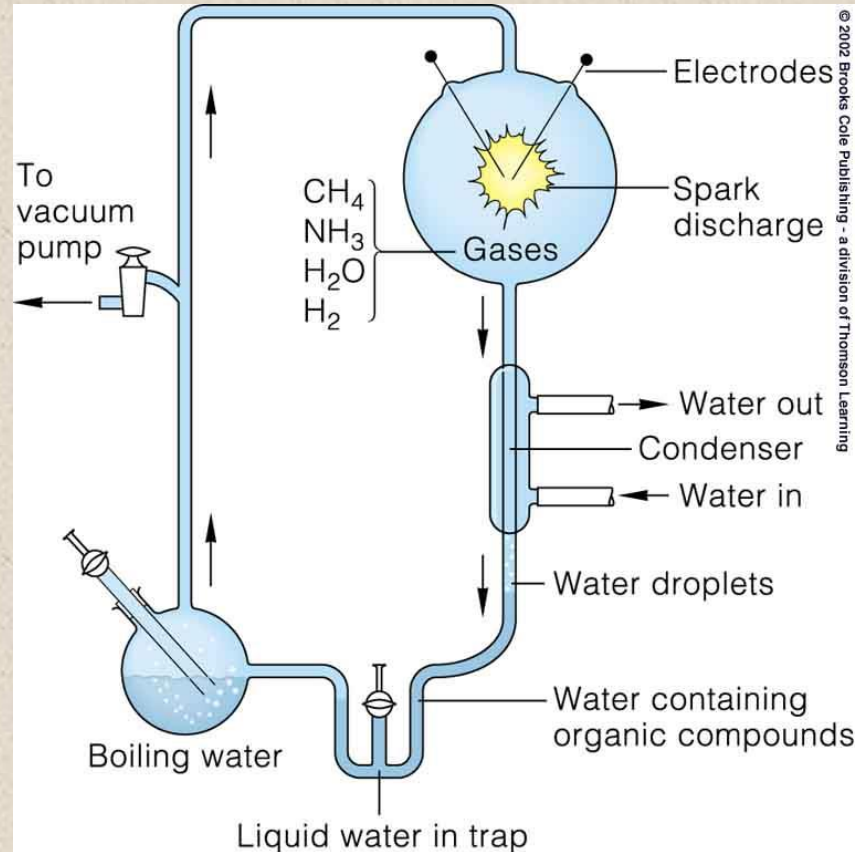
## II. Origins of Life

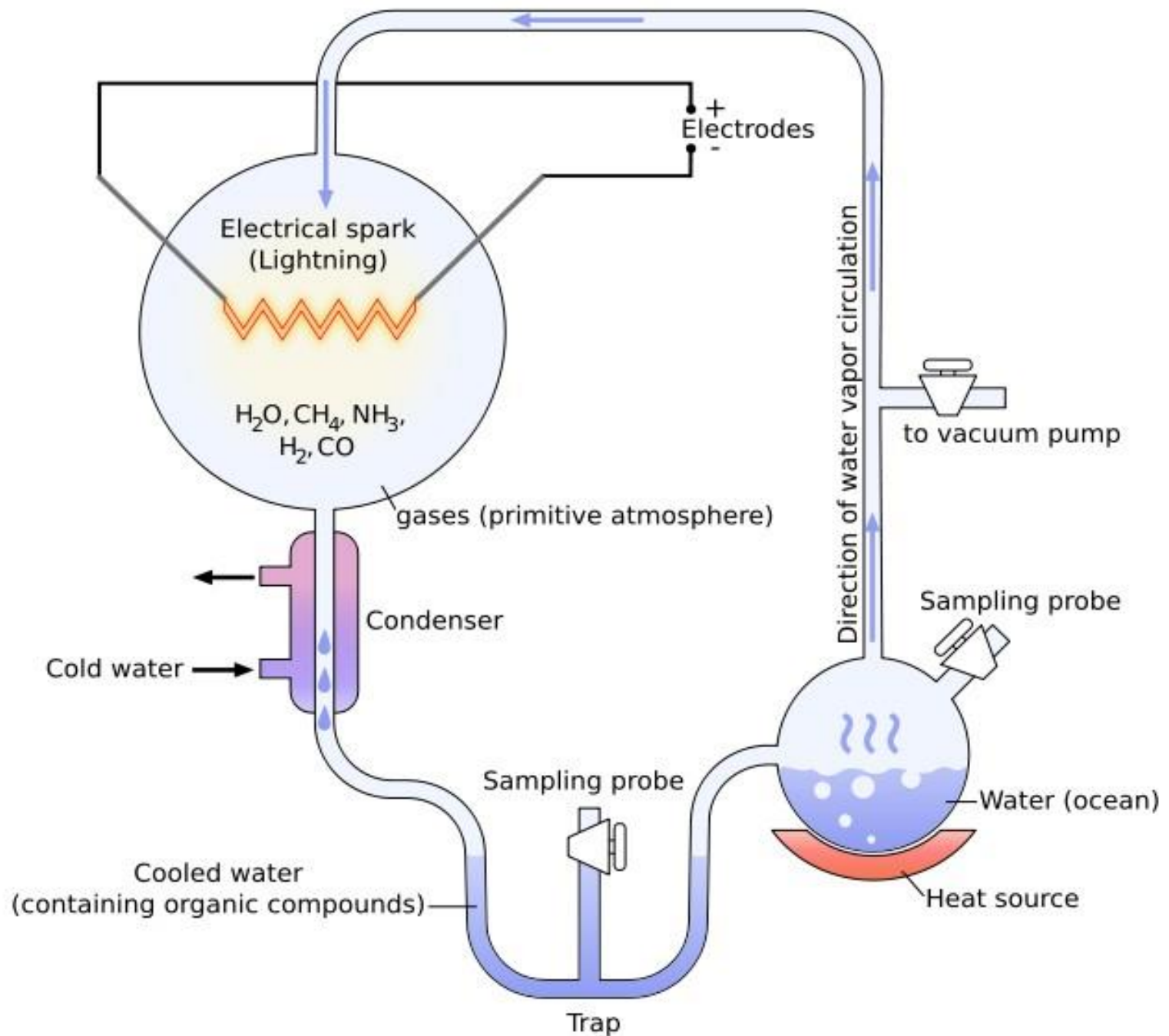
A. Biogenesis -- living things can only come from other living things

B. Where did the first living things come from?



# 1. Miller & Urey: experimental evidence that organic compounds can form from simpler compounds present in Earth's early atmosphere







## 2. First cells:

- a) fossil evidence of prokaryotes from 3.5 billion years ago
- b) These photosynthetic cells produced enough oxygen to create an atmosphere that heterotrophic eukaryotes could survive in

Stromatolite



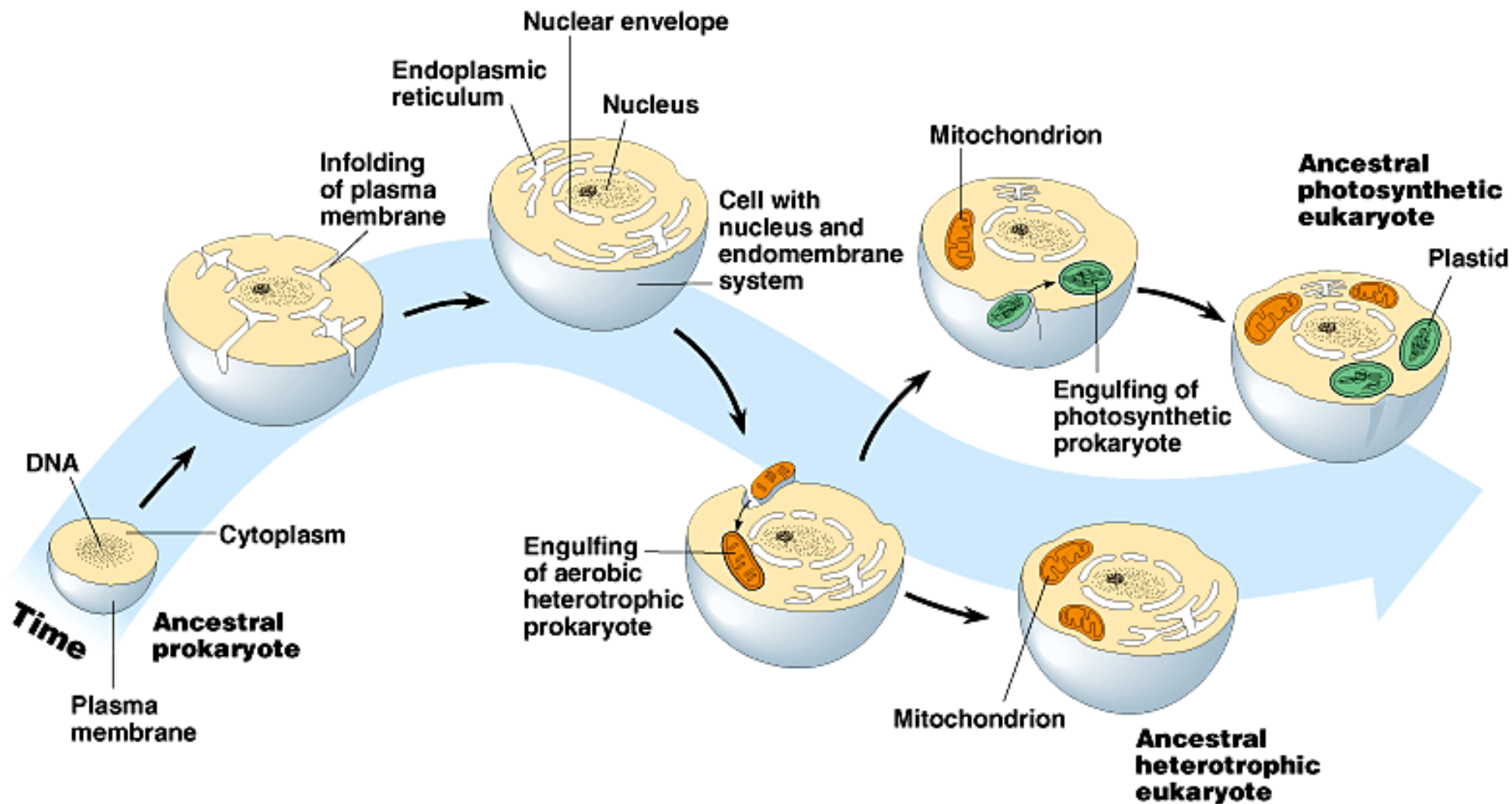






### 3. Endosymbiont theory

- a) Eukaryotic & prokaryotic cells shared a mutualistic relationship
- b) Over time, prokaryotic cells became organelles instead of distinct cells
- c) Mitochondria and chloroplasts share many characteristics with prokaryotes, and are thought to have formed by endosymbiosis

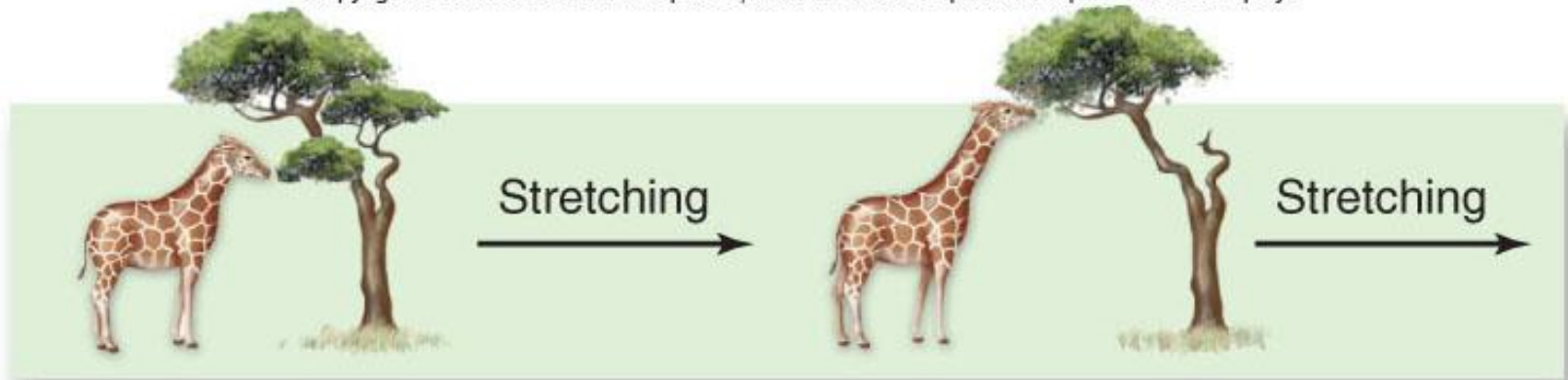


### III. Leading up to Darwin

- A. Lamarck - first attempt to explain how organisms change over time
  - 1. change is made by what organisms want or need
  - 2. acquired traits = inheritable

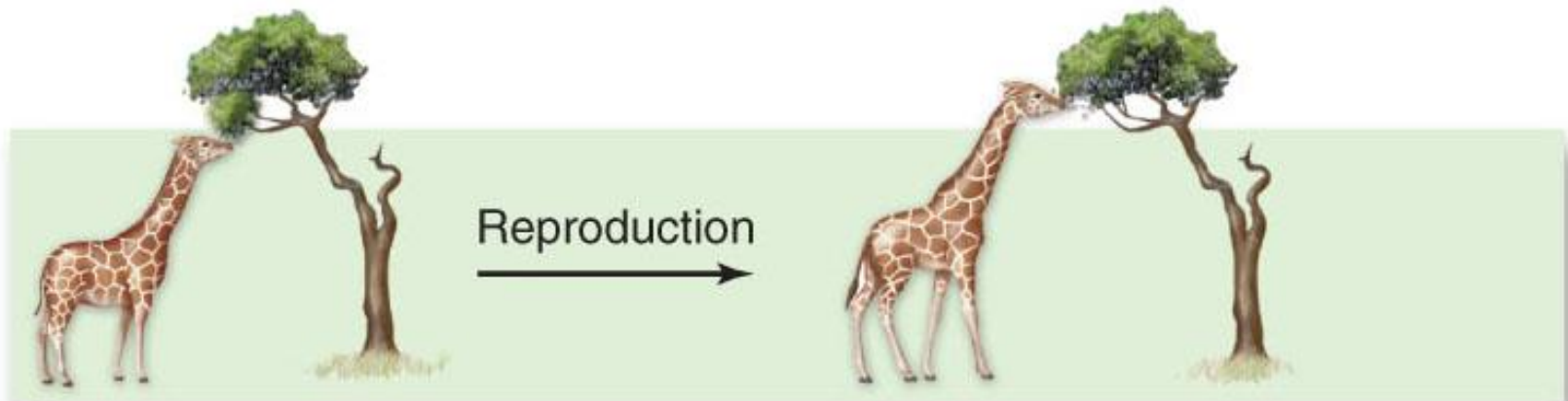
**(HE WAS WRONG!)**





Proposed ancestor of giraffes has characteristics of modern-day okapi.

The giraffe ancestor lengthened its neck by stretching to reach tree leaves, then passed the change to offspring.



**a.** Lamarck's theory: acquired variation is passed on to descendants.

# Lamarck's theory of how giraffes' long necks evolved

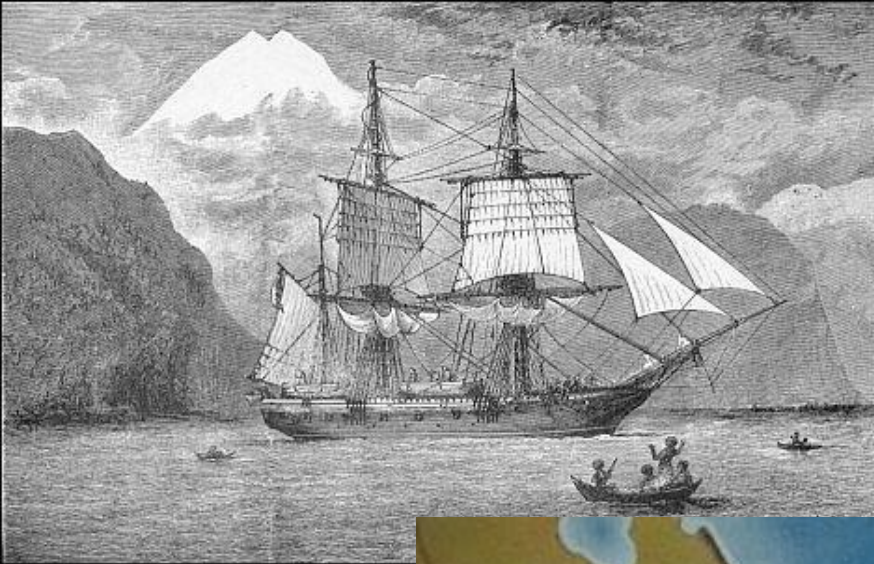
## IV. Darwin's Theory of Evolution

A. Traveled on the Beagle for 5 years  
as the ship's naturalist

1. Observed land & organisms  
everywhere they went

2. Began to notice connections  
between species





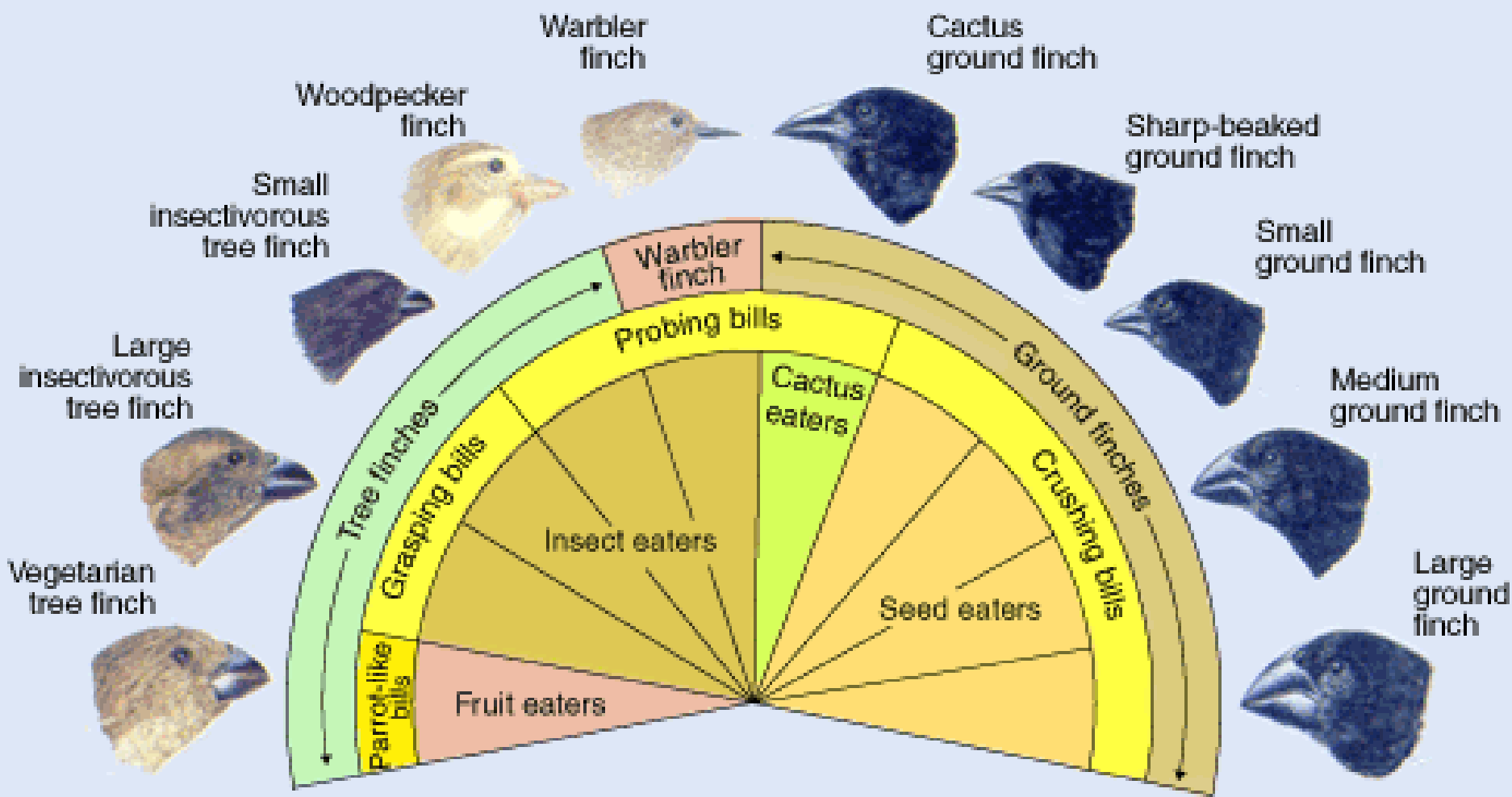
H.M.S. *Beagle* in Straits of Magellan



<http://etext.library.adelaide.edu.au/d/darwin/charles/>



3. Most famous for his observations of Galapagos finches
  - a) Some islands much drier than others
  - b) Different islands had their own, slightly different varieties of animals
  - c) Long after returning from his journey, Darwin hypothesized that new species could gradually appear much like animal breeders can artificially develop new species through selective breeding



Similar for tortoises on  
different islands...



“normal” tortoise

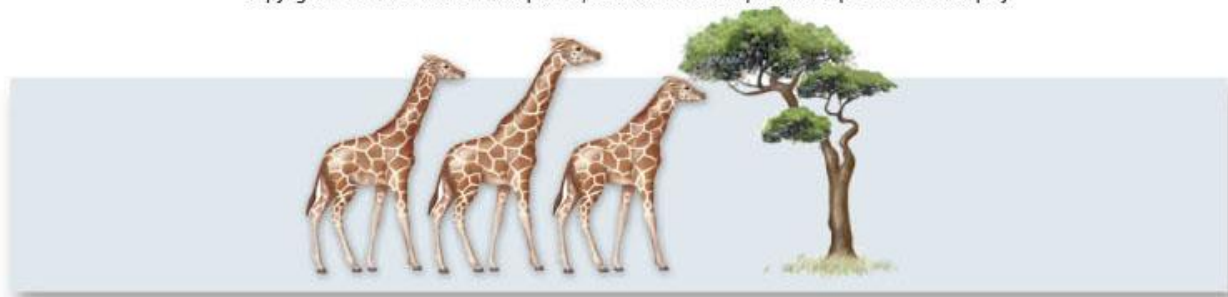
Saddleback allows tortoise to reach  
higher leaves on drier islands



B. Explaining his observations: *natural selection*

1. Variation: individuals in a population differ from one another
2. Heritability: variations are inherited from parents
3. Overproduction: organisms produce more offspring than can survive (survival of the fittest)
4. Reproductive advantage: some variations allow the organism that possesses them to have more offspring – those variations become more common and the population changes over time

# Darwin's theory for how long necks evolved in giraffes



Some individuals born happen to have longer necks due to genetic differences.



Individuals pass on their traits to next generation.



Over many generations, longer-necked individuals are more successful, perhaps because they can feed on taller trees, and pass the long-neck trait on to their offspring.

**b.** Darwin's theory: natural selection or genetically-based variation leads to evolutionary change.





Why are albinos rare?  
Why does a peacock have a large tail?



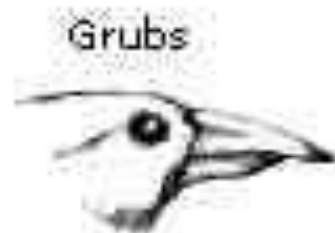
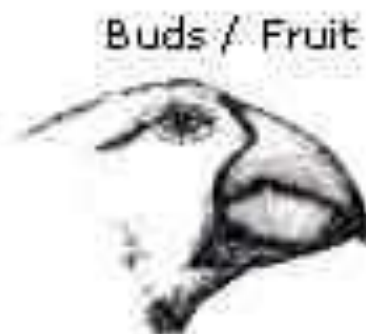
## V. Evidence from the living things

### A. Homologous structures

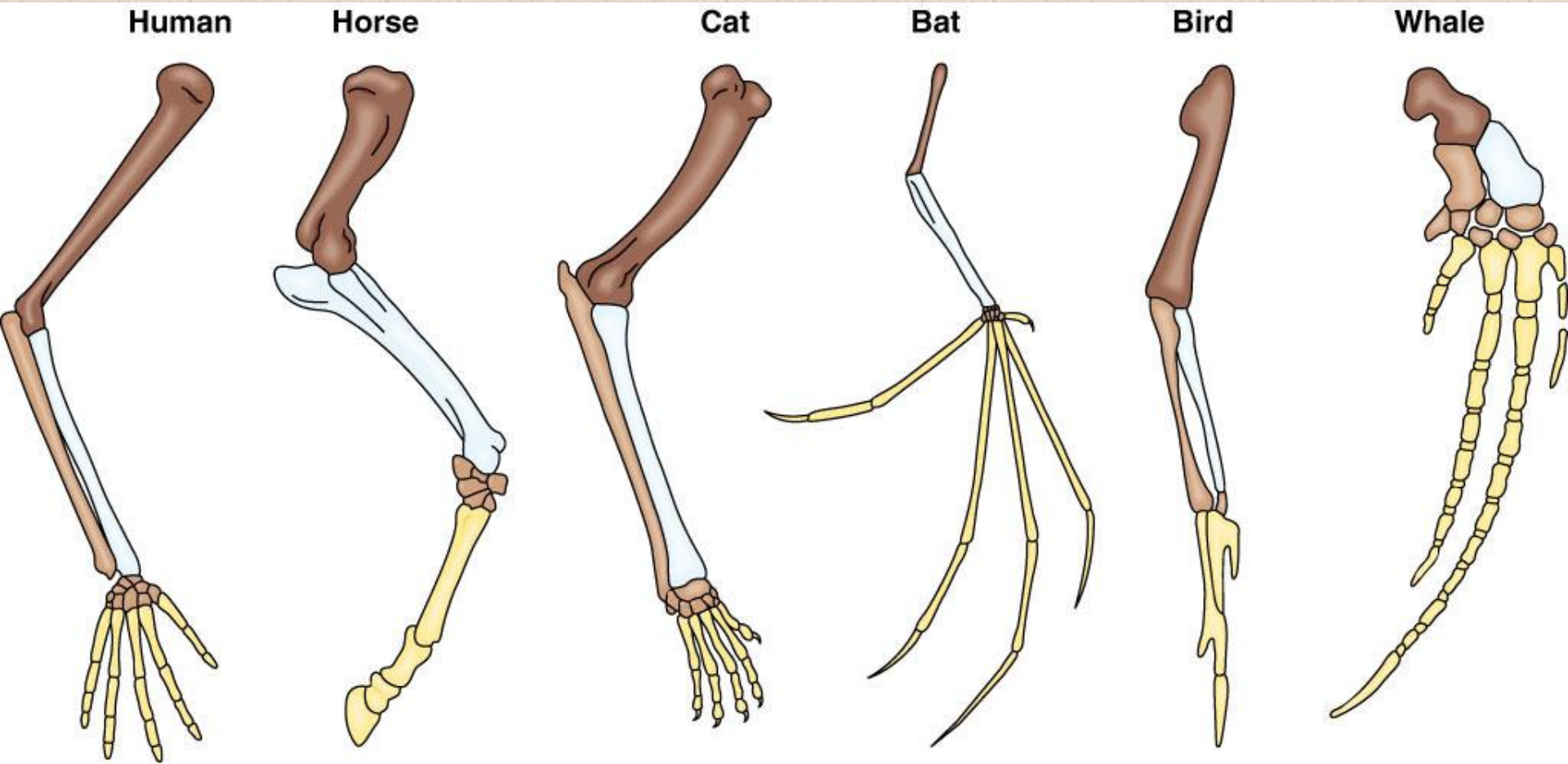
1. Similar elements derived from a common ancestor **(Same Structure- Different Function)**
2. e.g. wings, fins & arms
3. divergent evolution: when a single species evolves into several different forms that live in different ways

# Darwin's Finches

## ADAPTIVE RADIATION

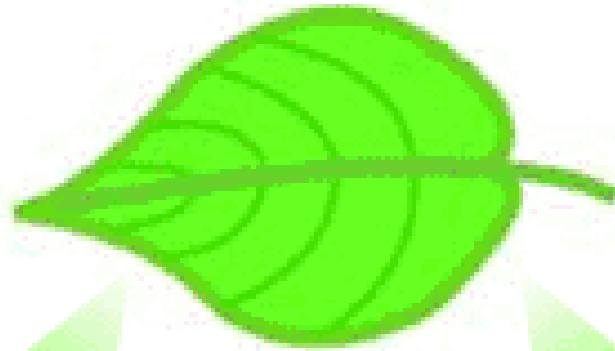


# Homologous Structures in Animals

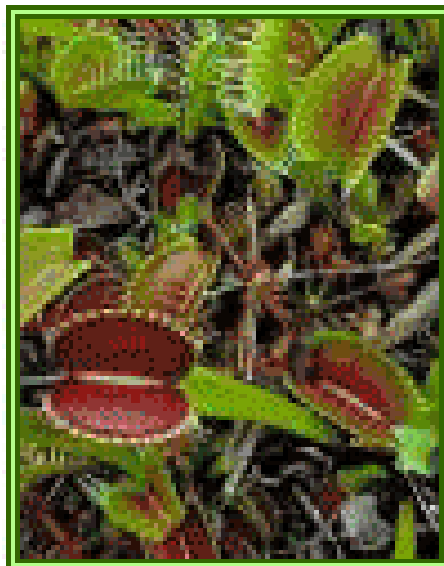




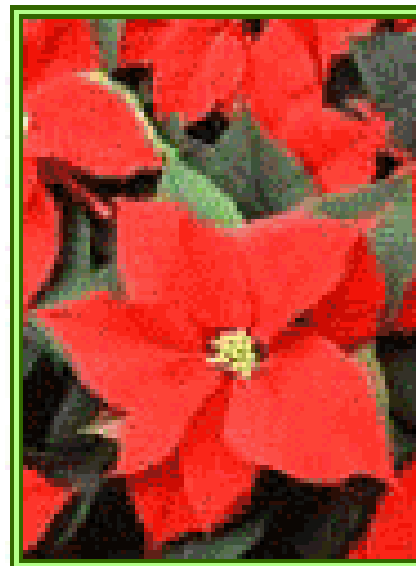
# Homologous Structures in Plants



**Pitcher Plant**  
leaves modified  
into pitchers to  
catch insects



**Venus' Flytrap**  
leaves modified  
into jaws to catch  
insects

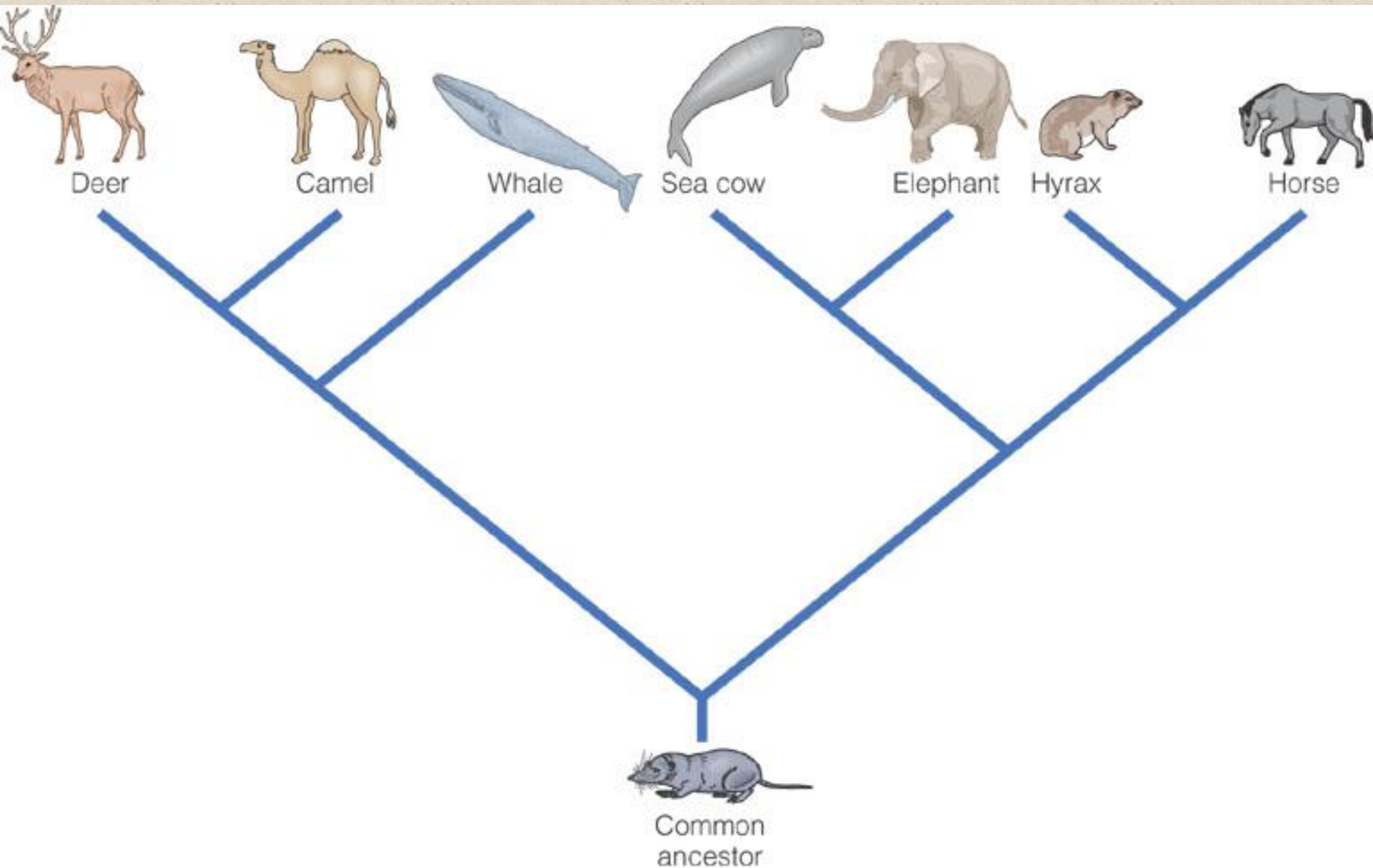


**Poinsettia**  
bright red leaves  
resemble flower  
petals



**Cactus**  
leaves have  
become spines

# Divergent evolution



## B. Analogous structures

1. Structures that serve the same function but differ in development & structure ancestor **(Same Function- Different Structure)**

e.g. wings of bats, insects, & birds

2. Convergent evolution: organisms living in similar environments, subject to similar selection pressure, end up evolving common features



# Analogous Structures

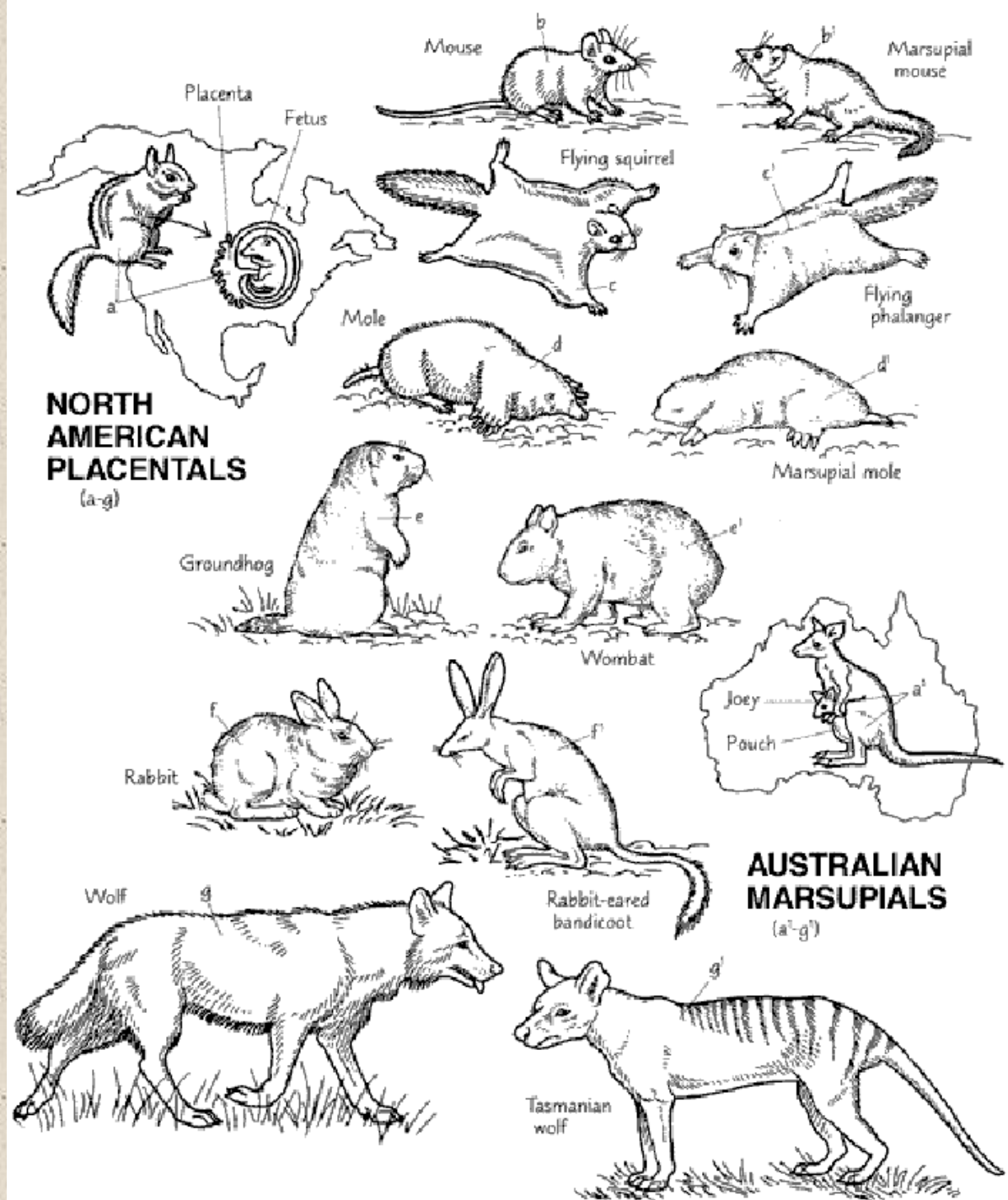


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# Shark vs Dolphin



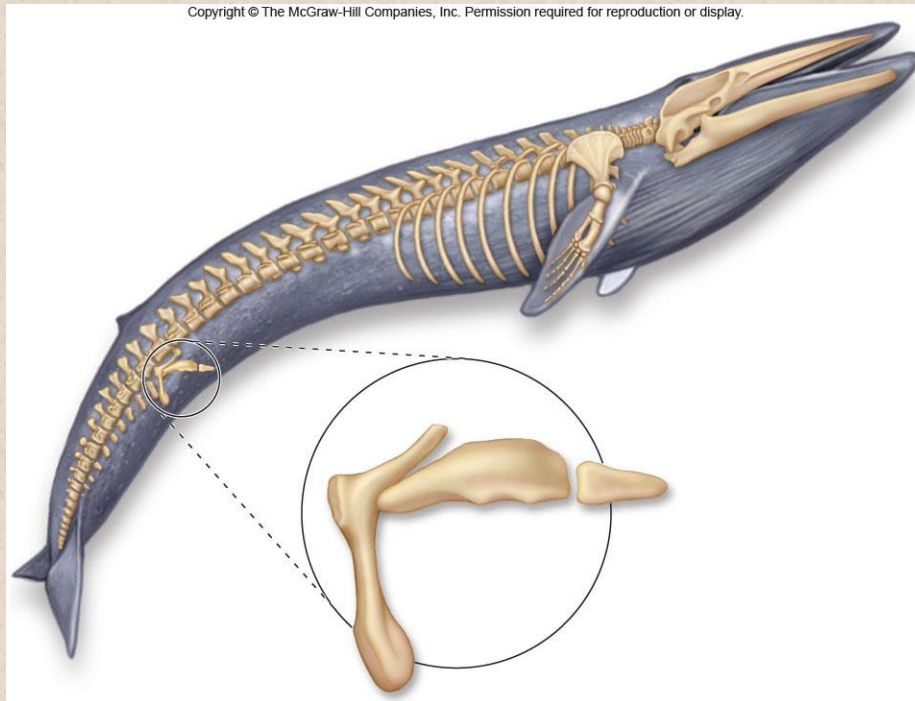
# Convergent Evolution





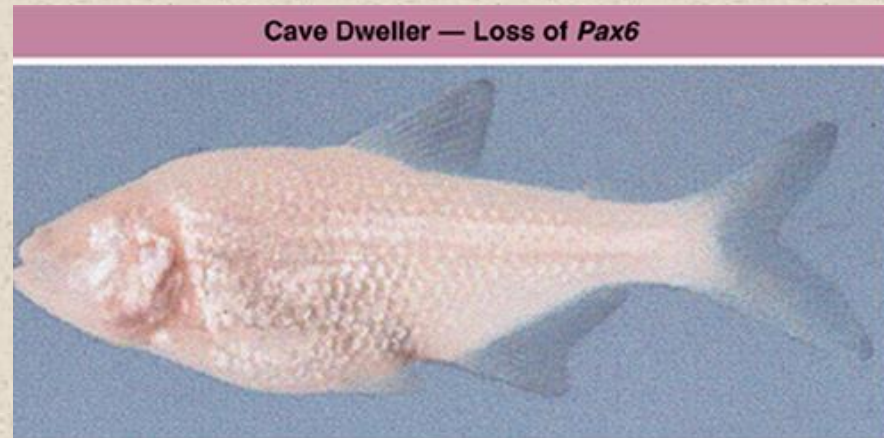
# C. Vestigial Structures

1. reduced form of a body part that would be a functional structure in other organisms (inherited from ancestors)



**Vestigial structures  
of a whale**

- **Examples of vestigial organs:**
  - **Humans: Muscles for wiggling ears**
  - **Humans: Appendix –Tailbone- “GooseBumps”**
  - **Boa Constrictors: Hip bones and tiny hind legs**
  - **Manatees: Fingernails on their fins**
  - **Blind cave fish: Nonfunctional eyes**

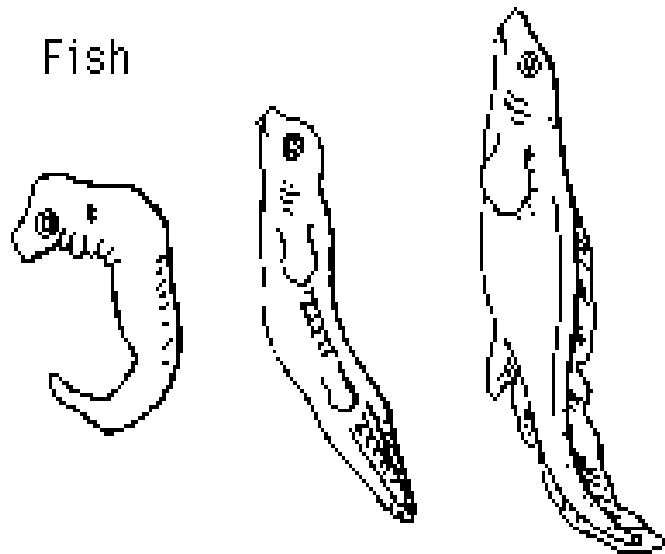


## D. Embryonic Similarities

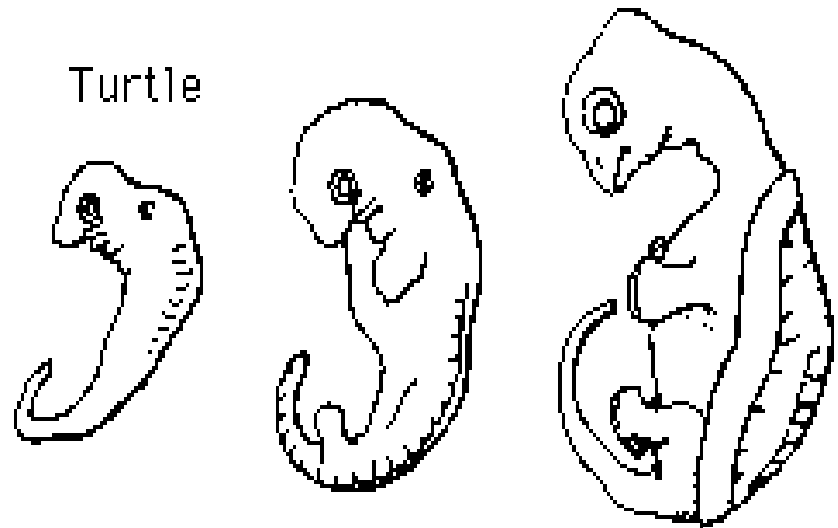
1. Embryos of closely related species have similar patterns of development
2. All vertebrates have tails & gill slits as embryos -- even humans!



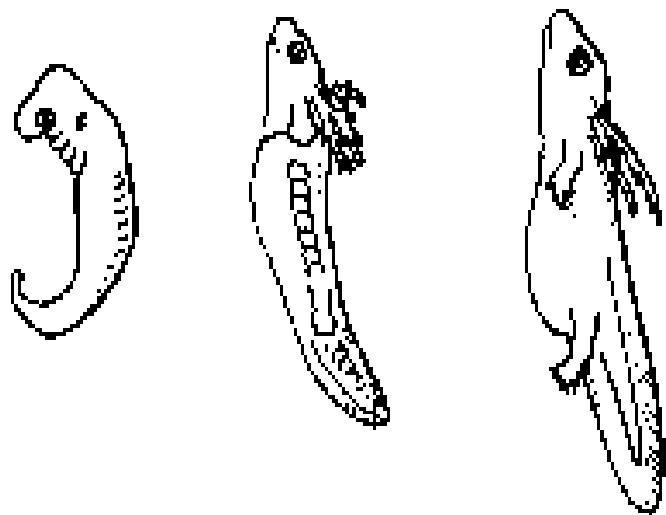
Fish



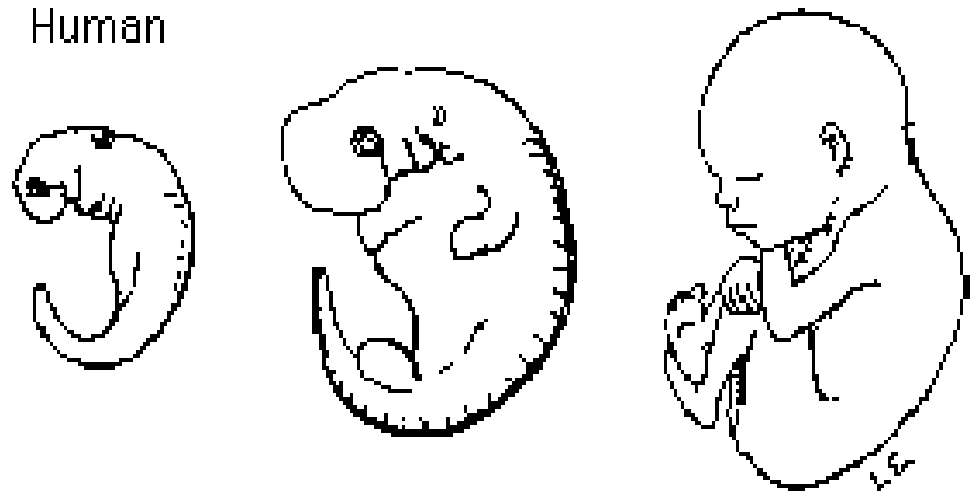
Turtle



Salamander



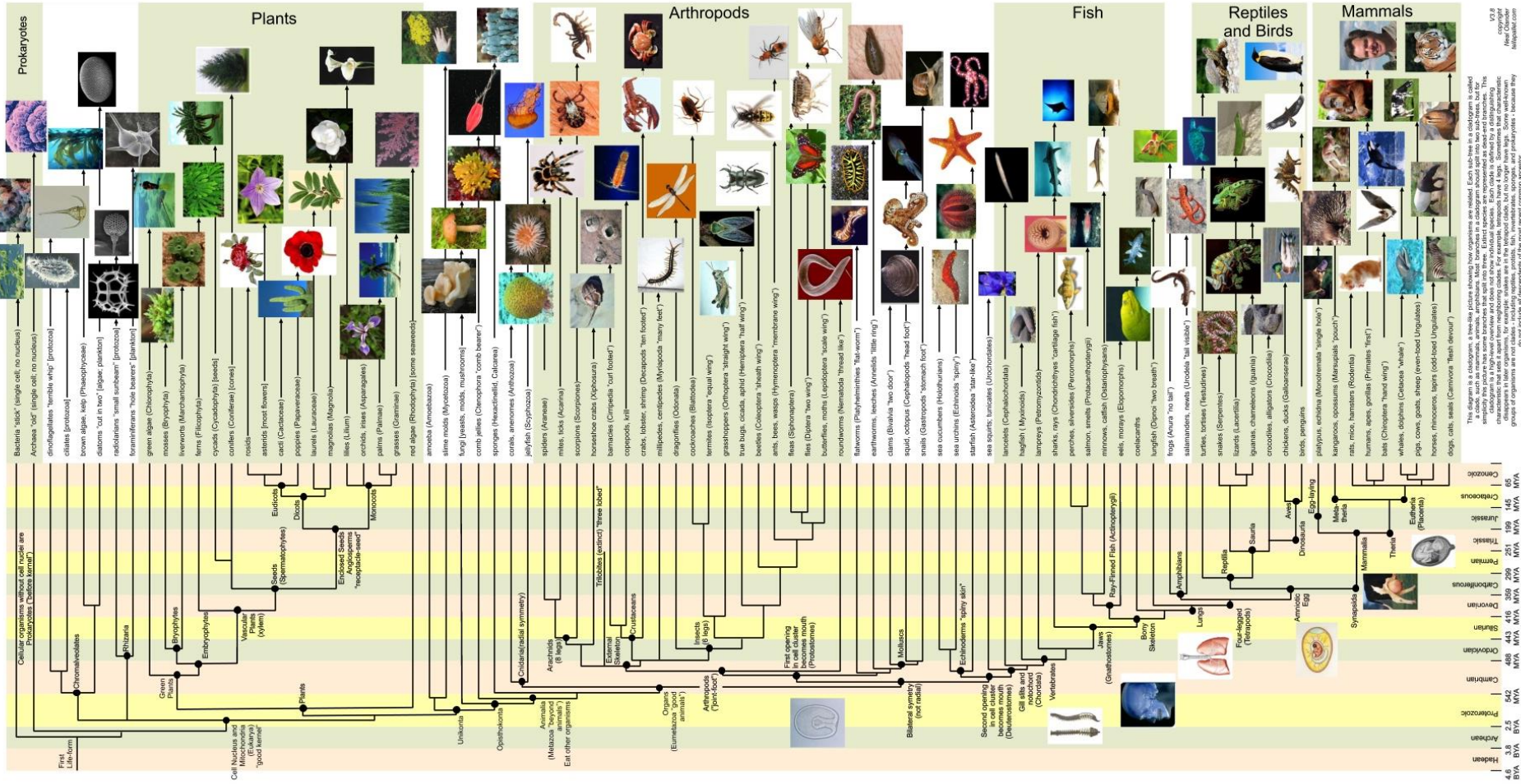
Human



## E. Comparative biochemistry

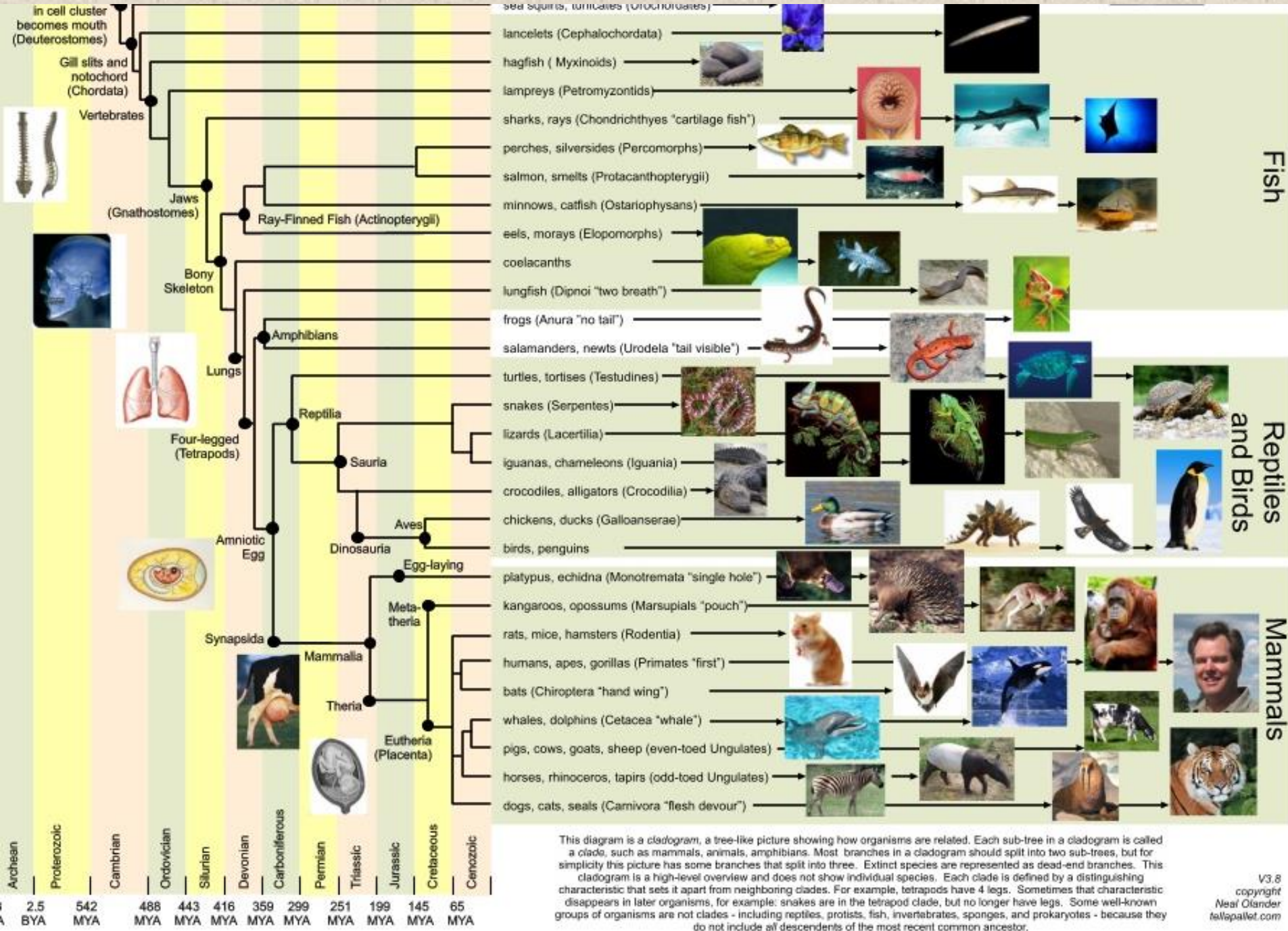
1. Species that share more DNA sequences are more closely related
2. Comparisons can help us build a cladogram (“family tree”) to show how organisms are related

# Tree of Life



This diagram is a cladogram, a tree-like picture showing how organisms are related. Each sub-tree in a cladogram is called a clade. The clade is named after the organism that is the most common ancestor of all the organisms in the clade. The diagram is a cladogram, a tree-like picture showing how organisms are related. Each sub-tree in a cladogram is called a clade. The clade is named after the organism that is the most common ancestor of all the organisms in the clade. The diagram is a cladogram, a tree-like picture showing how organisms are related. Each sub-tree in a cladogram is called a clade. The clade is named after the organism that is the most common ancestor of all the organisms in the clade.





## F. Adaptations

1. Beneficial variations that increase chances for survival & reproduction
2. Camouflage: blend in with environment
3. Warning coloration: predators learn to avoid species that are toxic by recognizing patterns
4. Mimicry: copy the warning patterns to avoid predators





Camouflage





Monarch  
*Danous plexipous*

Viceroy  
*Limenitis archippus*



Coral Snake  
Venomous



Milk Snake

Warning Color  
&  
Mimicry





The Australian hammer orchid has taken advantage of a mating ritual of the Thynnid wasp, which involves a female wasp waiting on top of a branch or plant for a male to spot her. The hammer orchid's flower mimics the female wasp looking upward for a male flying by, complete with a fake shiny head and furry body. The orchid even releases an enticing female wasp pheromone.

When the male wasp tries to mate with the dummy female, he fails, but the orchid succeeds in getting pollen on the wasp. He flies away, only to be fooled again by another orchid pulling the same trick. In the process, the wasp transfers pollen from flower to flower.

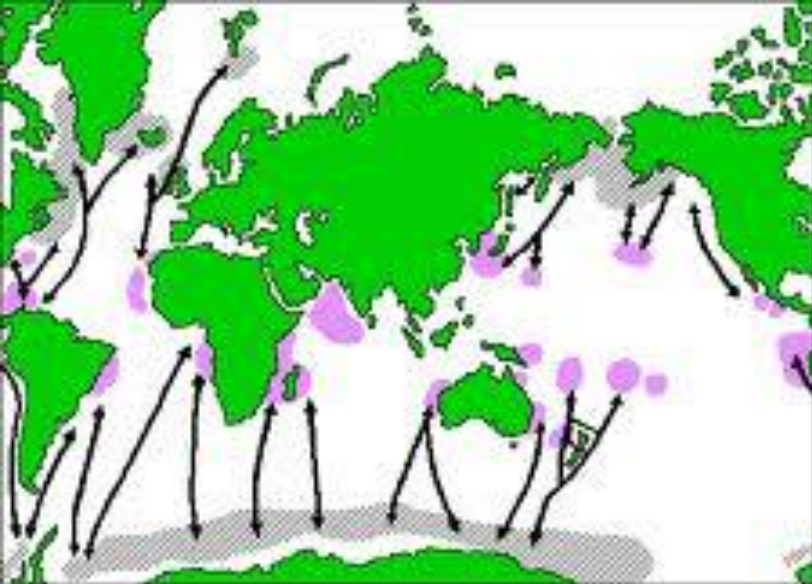
Place a real female wasp next to the orchid mimic, and a male wasp will spot the real deal. For this reason, [natural selection](#) has favored flowers that happen to bloom in the period when male wasps are flying but females are not out yet.

## F. Adaptations (Continued)

**5. Migration** – Seasonal movement in search of Food

**6. Hibernation**– Seasonal Slumber needed for survival – Heart Rate and breathing rates drop severely





Summer Feeding Areas  
Winter Breeding Areas

Migration Routes







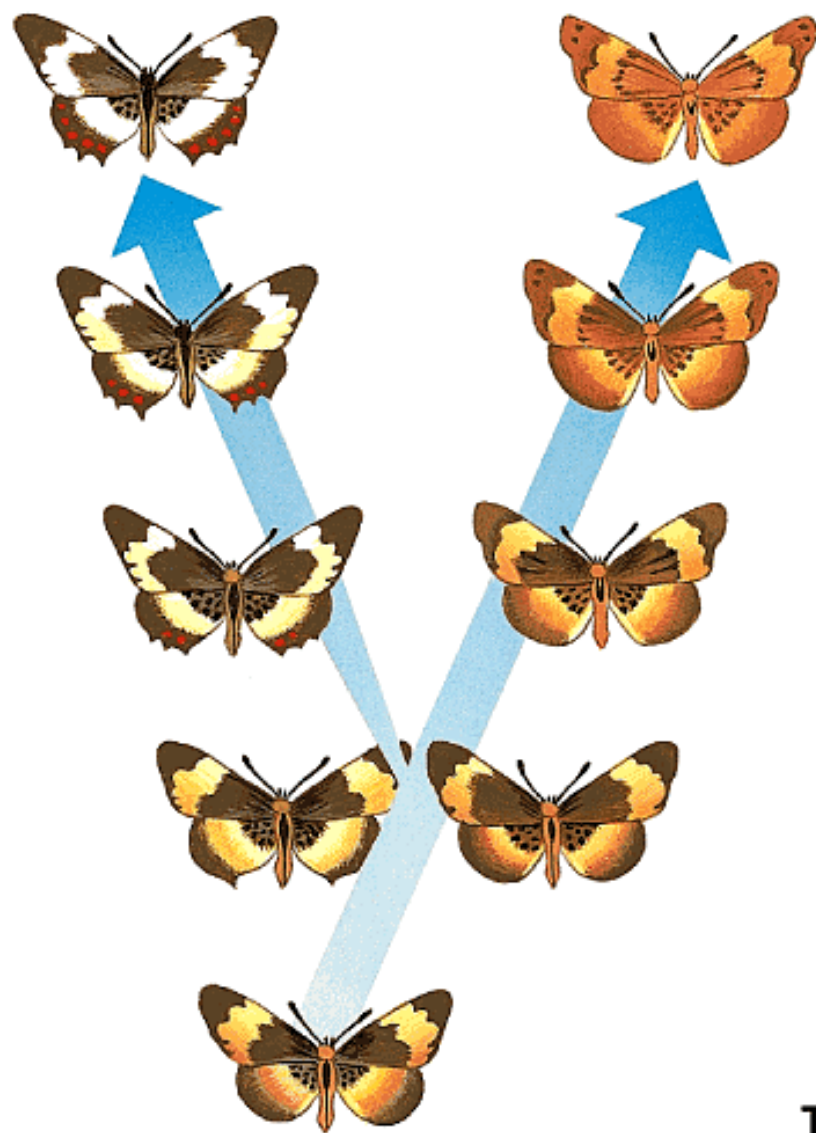
## VI. Modern Evolutionary Biology

A. Combines Darwin's theories with new information about genetics & population biology

B. Hardy-Weinberg

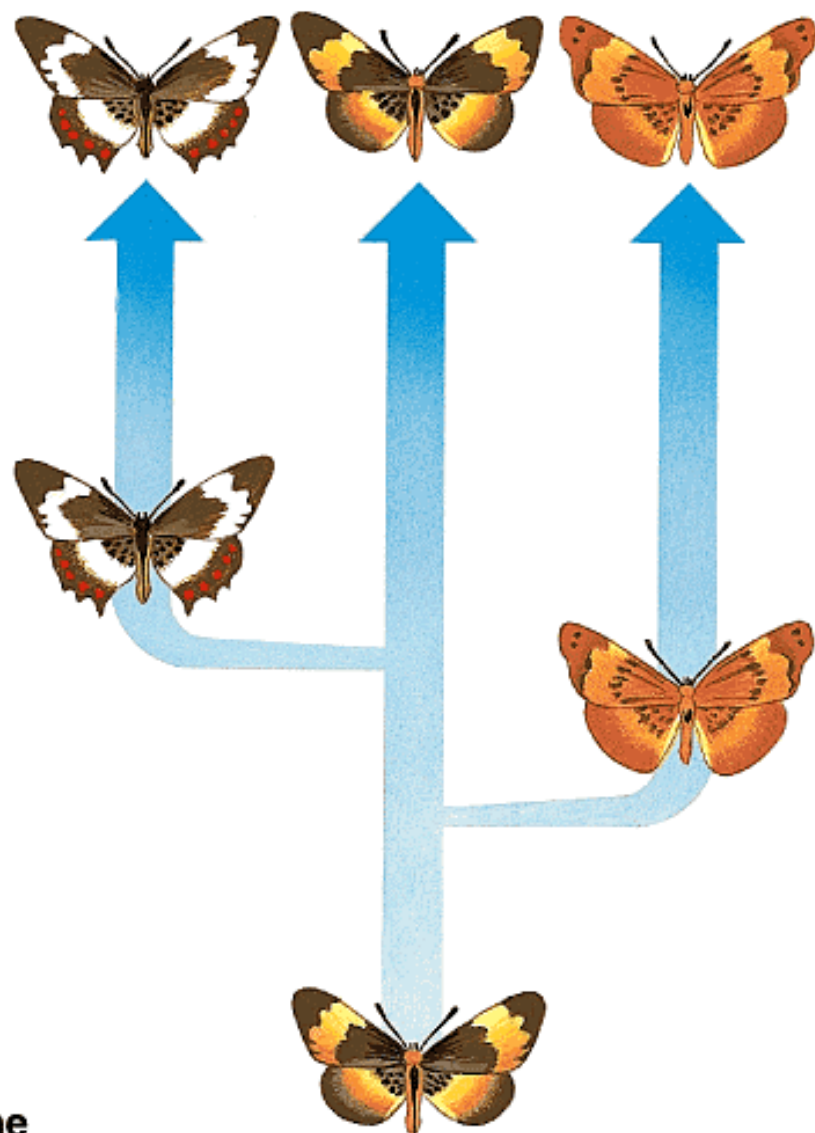
1. Genetic equilibrium: allele frequencies in a population remain stable from one generation to the next
2. Evolution = equilibrium upset
3. punctuated equilibrium: pattern of evolution in which long stable periods are interrupted by brief periods of rapid change





Morphological  
change

**(a) Gradualism model**



Morphological  
change

**(b) Punctuated equilibrium model**

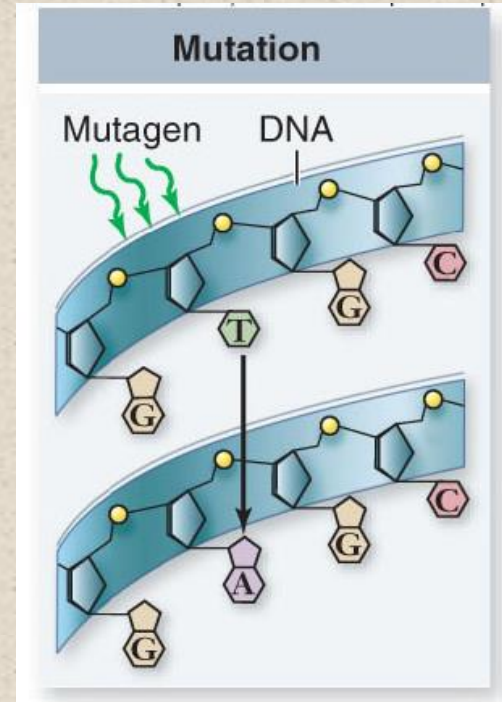
4. Five conditions must be met in order to maintain genetic equilibrium:

- No mutation
- Large population
- Random mating
- No migration in or out of population
- No natural selection

## C. Agents of Evolutionary Change

### 1. **Mutation:** A change in a cell's DNA

- Ultimate source of genetic variation



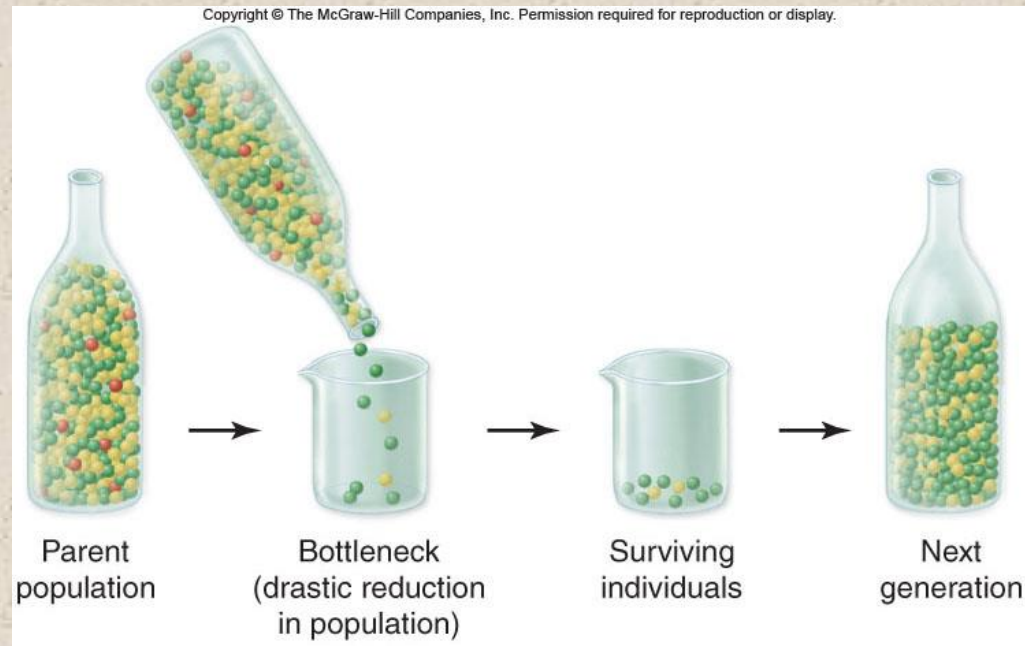


## 2. **Small population:** Random changes called genetic drift

**a) founder effect** –  
When a few individuals start a population



**b) bottleneck effect** –  
drastic reduction in population, and gene pool size



### 3. **Nonrandom Mating:** mating with specific genotypes

- a) Sexual selection: changes in the frequency of a trait based on the ability to attract a mate
  - Peacock tails
  - Antlers/male size

# Agents of Evolutionary Change

4. **Gene flow:** movement from one population to another
- Tends to make populations more alike





## 5. Natural selection:

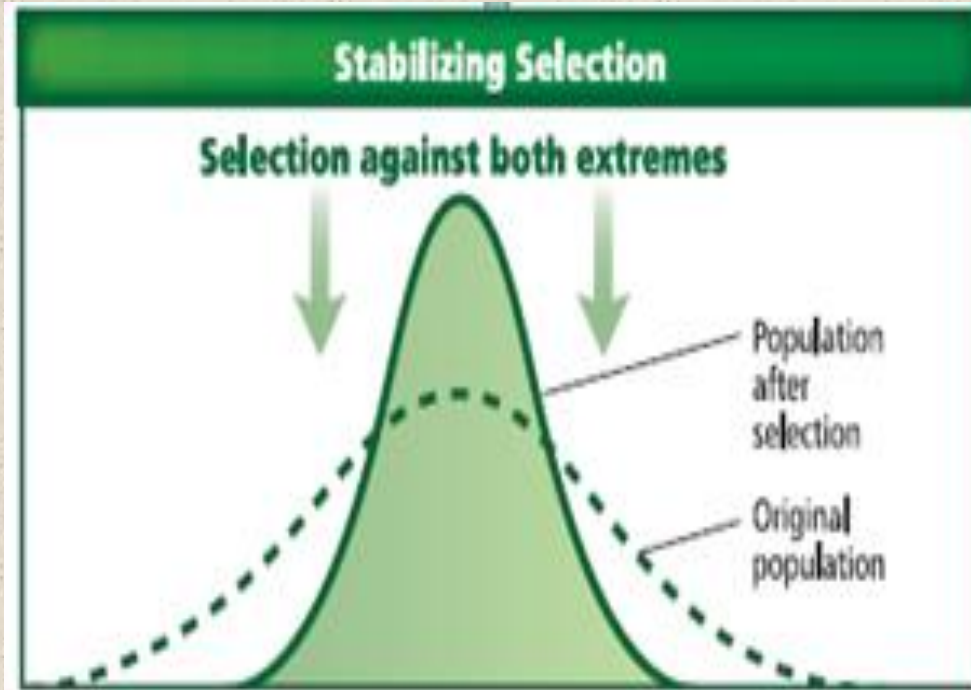
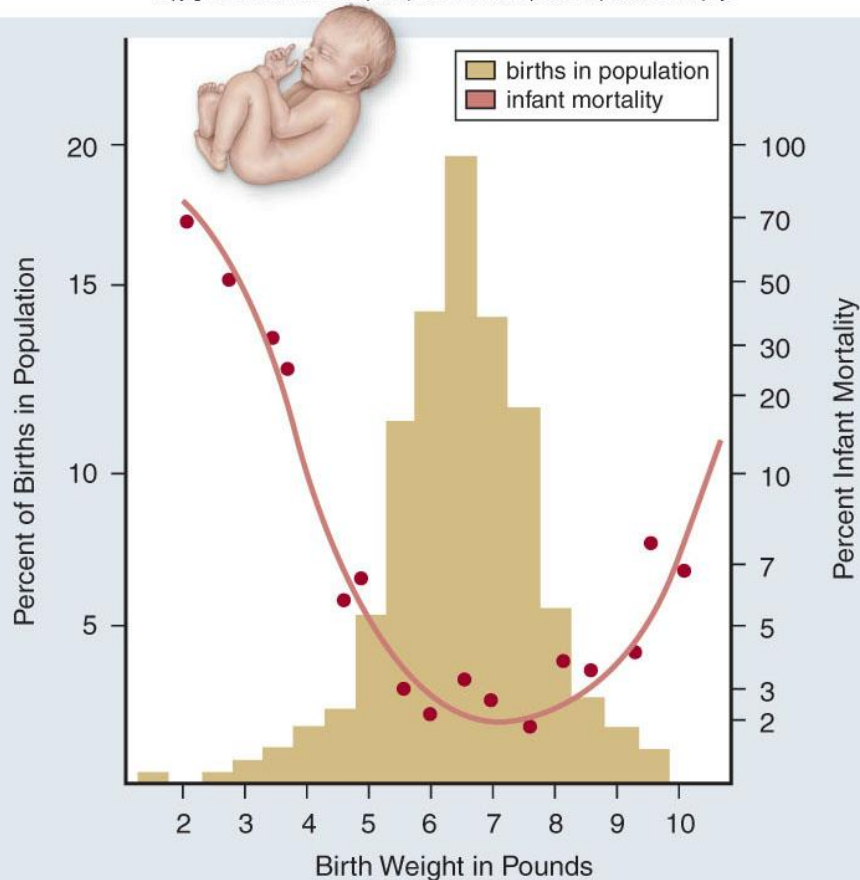
environmental conditions  
determine which individuals  
in a population produce the  
most offspring



# a) Stabilizing selection: average phenotype is favored

- birth weight in human babies

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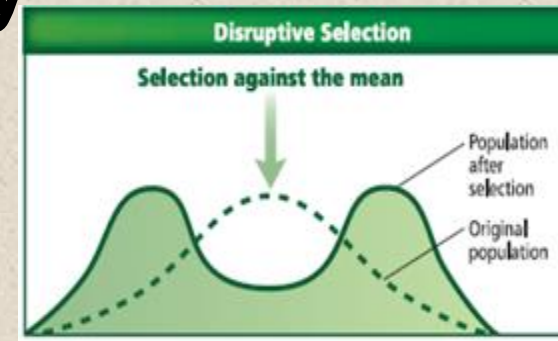
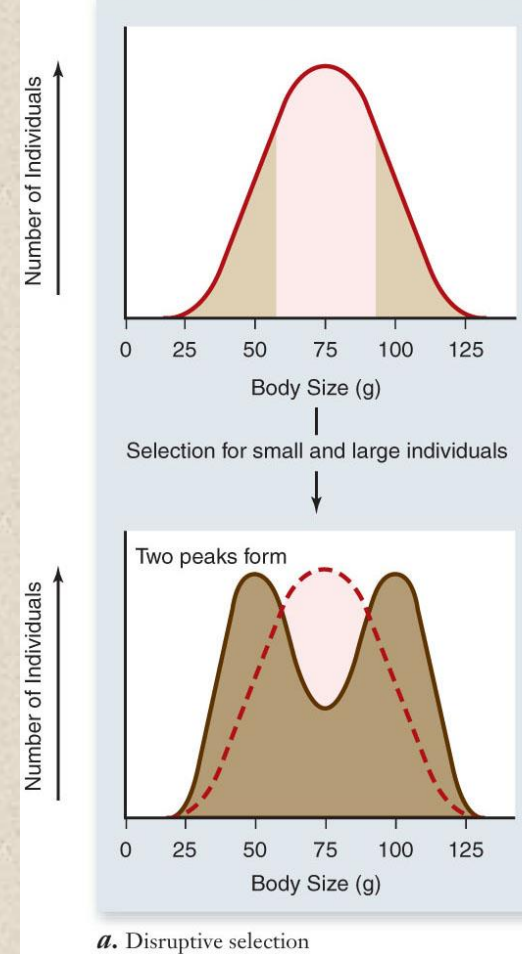
## b.) Disruptive selection:

individuals at either extreme favored over average

- Northern water snakes in different habitats



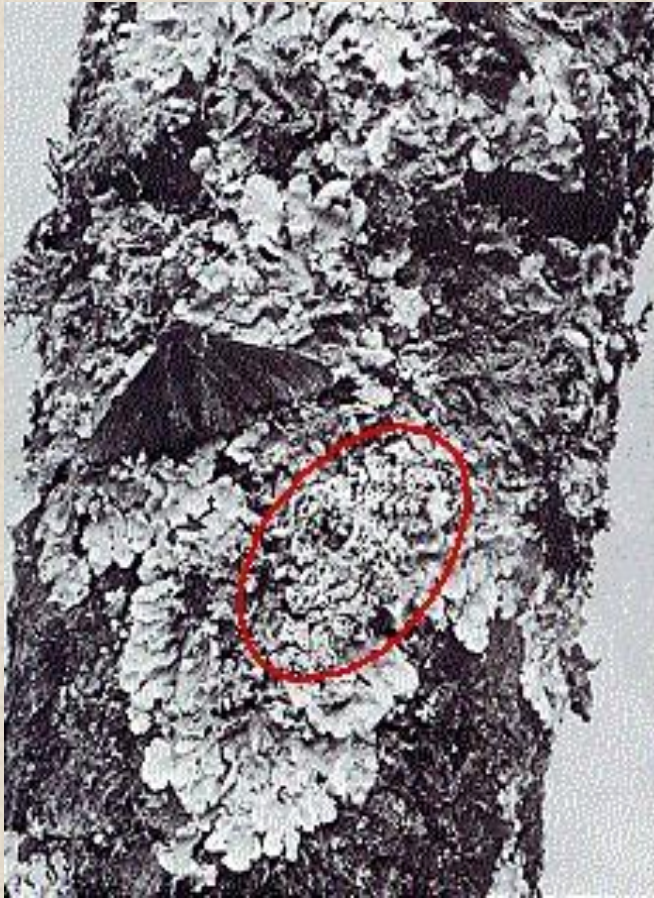
- Oak Tree Forest with many trees producing big acorns and many trees producing small acorns





c) **Directional selection:** an extreme version of a trait is favored

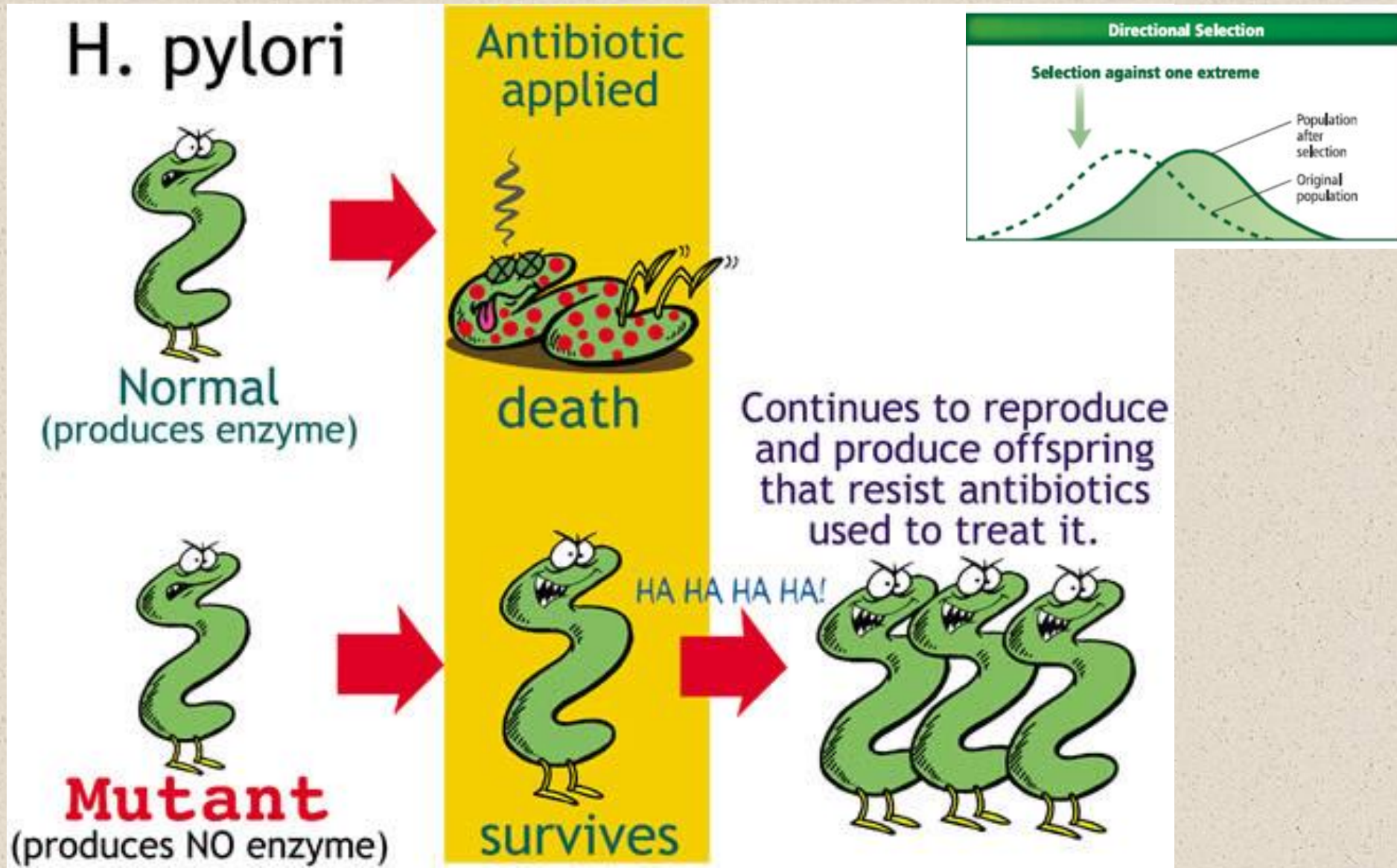
- Industrial melanism





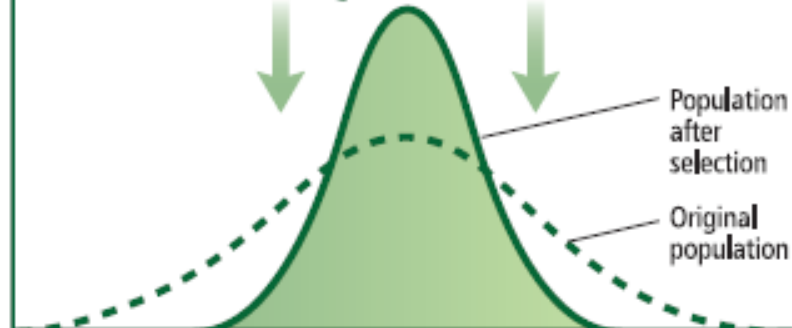
# Directional selection:

- Bacterial resistance to antibiotics



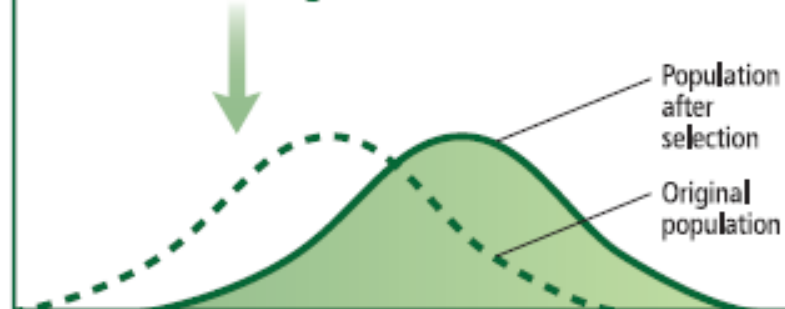
### Stabilizing Selection

Selection against both extremes



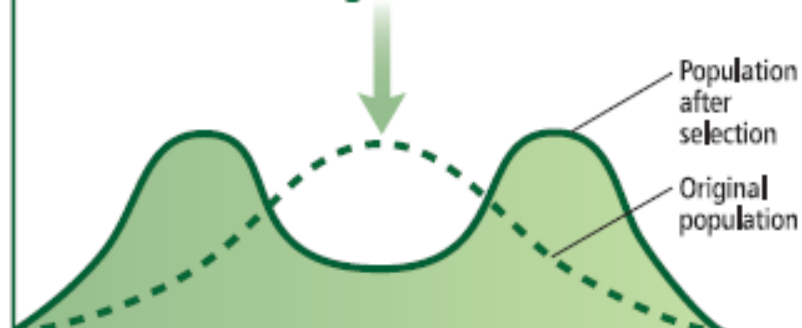
### Directional Selection

Selection against one extreme



### Disruptive Selection

Selection against the mean

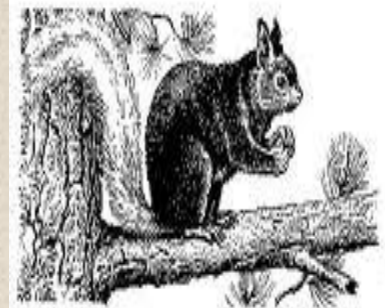




## **C. Speciation**

1. Occurs when a population becomes isolated
2. Natural selection works on the two populations independently, so different traits evolve
3. Become so different that they cannot produce fertile offspring even if the populations are reunited

**\*\* Grand Canyon Squirrels**

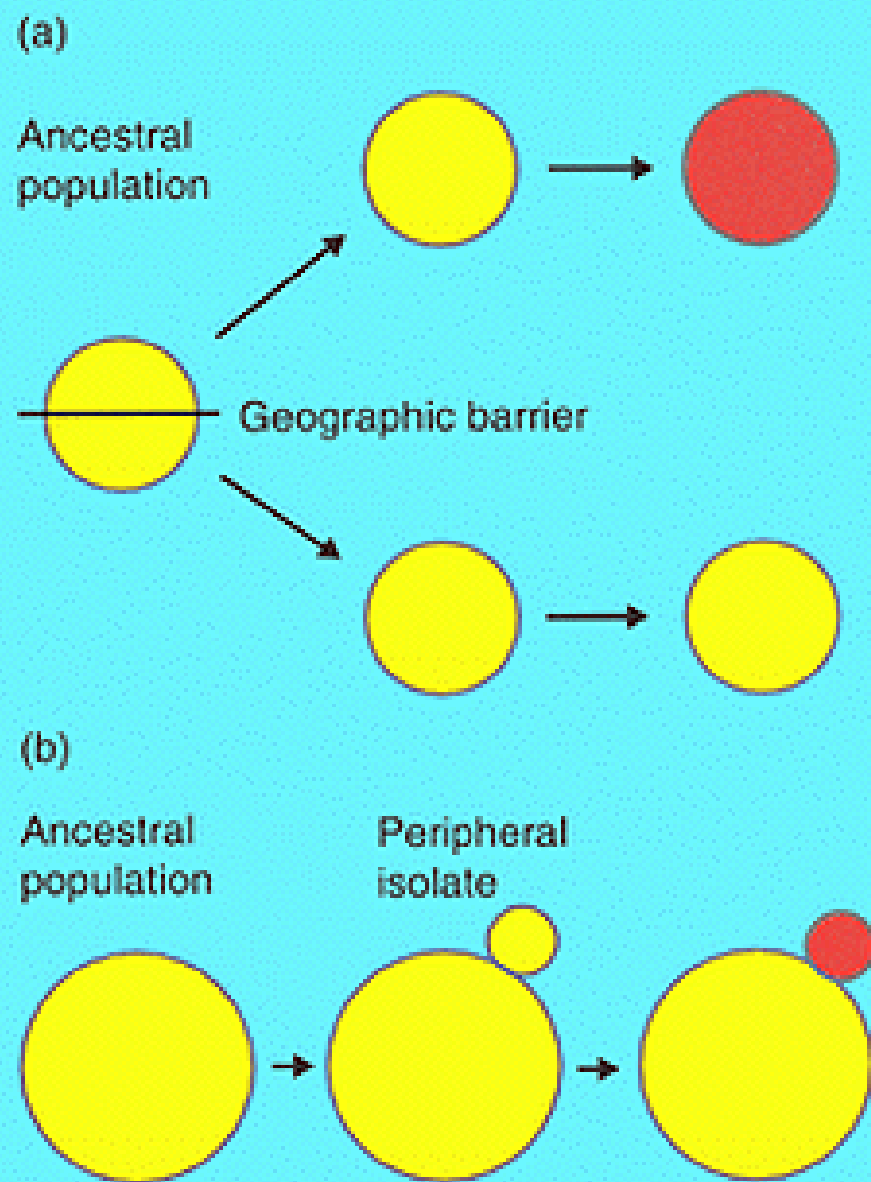


Kariboh Squirrel (North Rim)  
*Sciurus kaibabensis*



Abert Squirrel (South Rim)  
*Sciurus aberti*

**Figure 16.5** Two models of allopatric speciation. Stippling indicates evolution of new species. (a) The "dumb-bell" model in which the ancestral species is divided into two roughly equal halves, each of which forms a new species. (b) The peripheral isolate model, in which the new species forms from a population isolated at the edge of the ancestral species range.





### Allopatric speciation

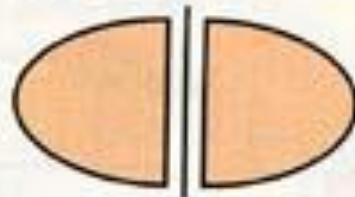
### Parapatric speciation

### Sympatric speciation

Original population



Initial step of speciation process



Barrier formed

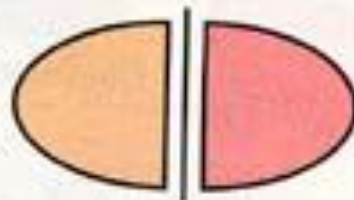


New niche entered

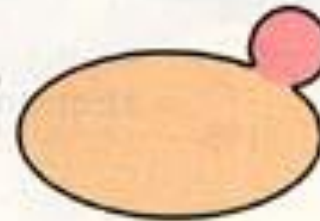


Polymorphism occurs

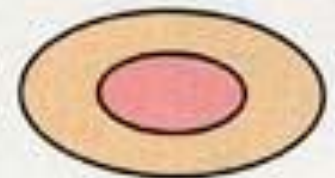
Evolution of reproductive isolating mechanisms



In isolation

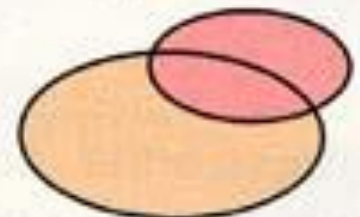
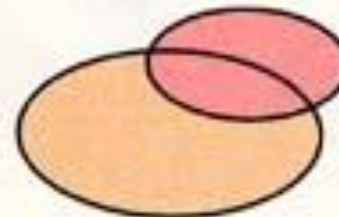
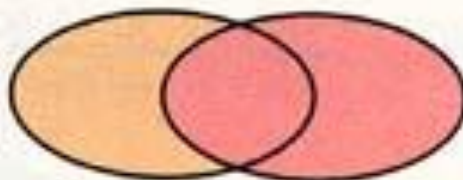


In new niche



Within the population

New, genetically distinct species after equilibration of new ranges



## VIII. Human Origins

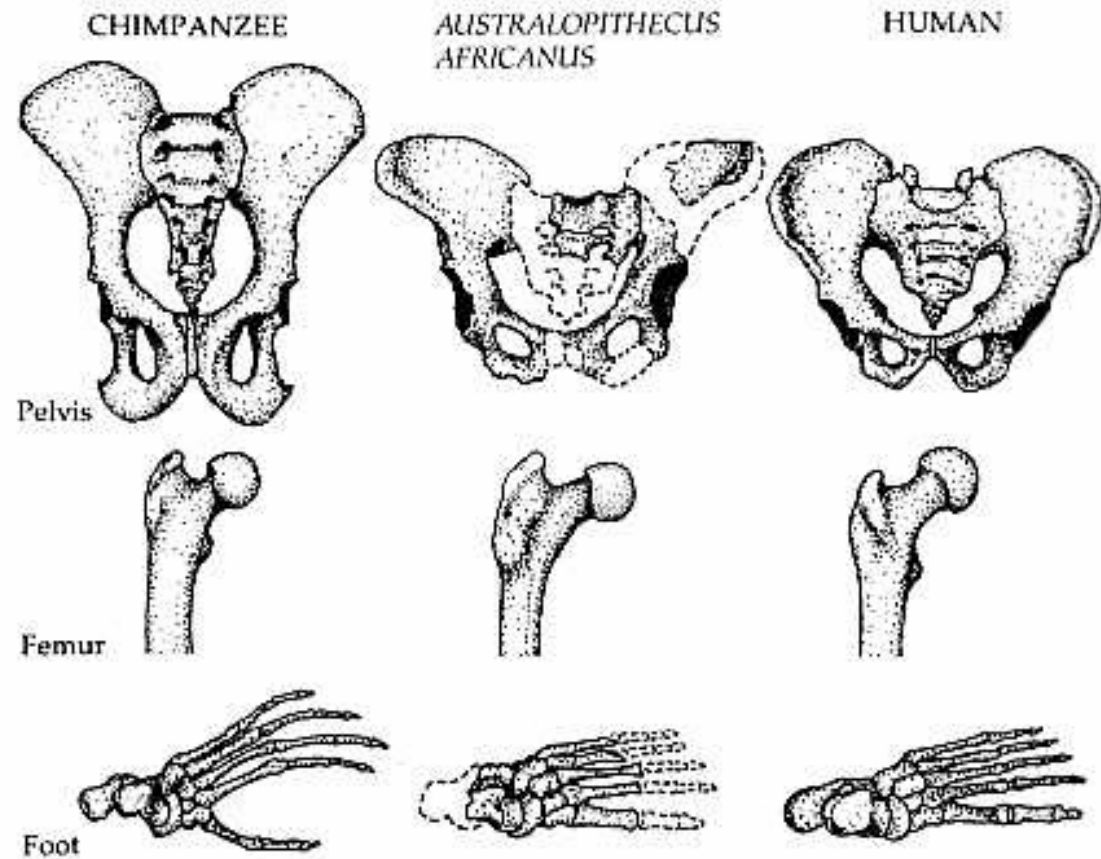
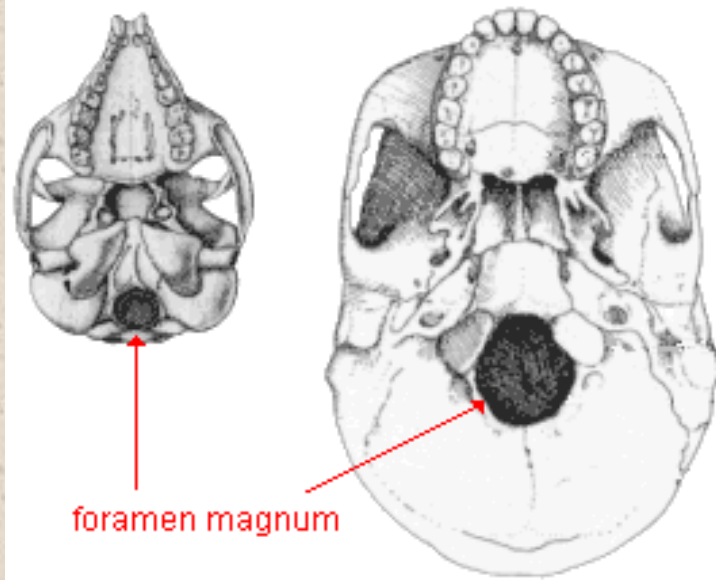
- A. Anthropology: branch of science dealing with the physical, cultural, and social development of the human species
- B. Hominins: early human-like species
  - 1. Split off from other apes between 8 and 5 mya
  - 2. Many different species coexisted
  - 3. Not clear which species were direct ancestors of humans

## 4. Hominin fossils

- a) Lucy: shows a mixture of human and apelike traits – the “missing link”
- b) Hominin characteristics:
  - Bigger brains
  - Thinner and flatter face
  - Lengthened thumbs and flexible wrists
  - **Bipedal (Walk on 2 feet)**
    - Bowl-shaped pelvis
    - S-shaped spine
    - Shorter arms
    - Foramen magnum at the base of the skull



# Primate and human skulls



## C. The genus Homo

### 1. *Homo habilis*:

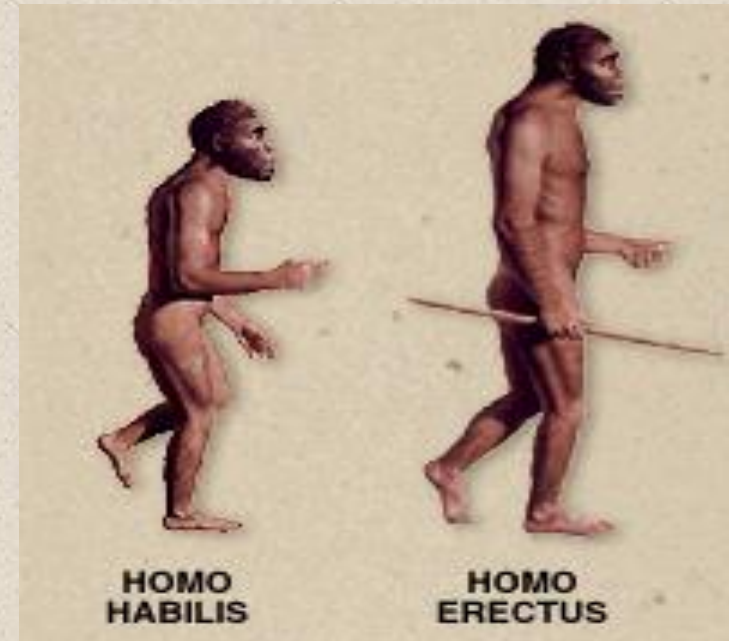
- 2.4 – 1.4 mya
- “handy man”, first to make and use tools

### 2. *Homo ergaster*:

- 1.8 - 1.3 mya
- migrated out of Africa

### 3. *Homo erectus*:

- 1.5 million to 400,000 years ago
- used fire



#### 4. Homo neanderthalensis:

- 200,000-30,000 years ago
- Larger brains than modern humans
- Heavily muscled
- Buried their dead
- Coexisted with modern humans, not direct ancestor

#### 5. Homo sapiens:

- Appeared 195,000 years ago
- Sophisticated tools
- Able to survive in a wide range of environments

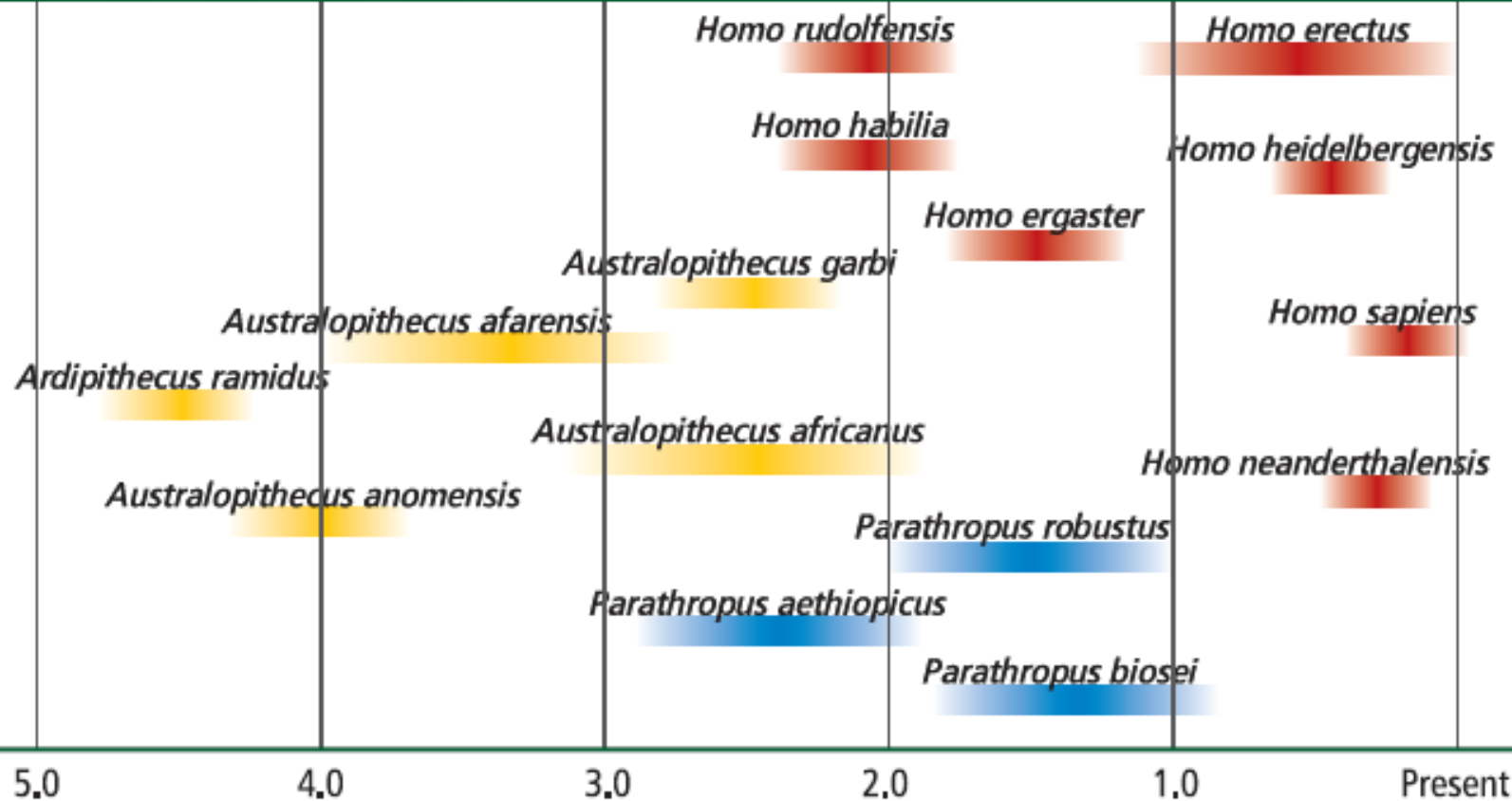


Neanderthal

modern  
human

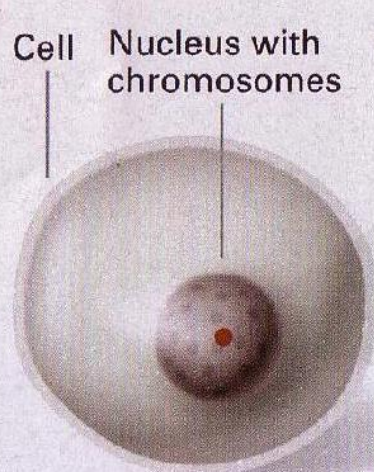


## Early Human Time Line



6. Out-of Africa hypothesis: modern humans evolved once, in Africa, and have since migrated to all parts of the world
  - Chemical evidence: studies of human DNA have shown that modern humans have a common ancestor about 200,000 years ago



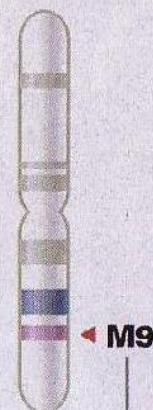
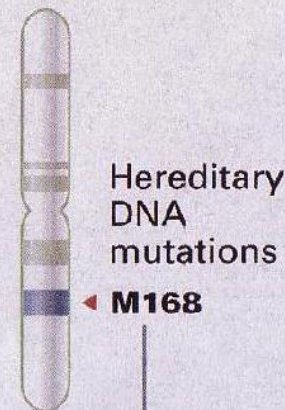
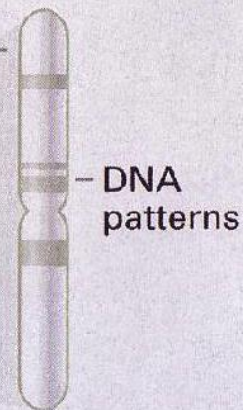


**Ancestral**  
All males share this basic configuration, rooted in Africa.

**Out of Africa**  
Migrants from Africa carried a new marker, M168, found in all non-Africans.

**Eurasian**  
M9, common in Eurasians, appeared in the Middle East or Central Asia.

**Amerindian**  
M3 arose in the Asian population that reached the Americas.



50,000 years ago

40,000

10,000





