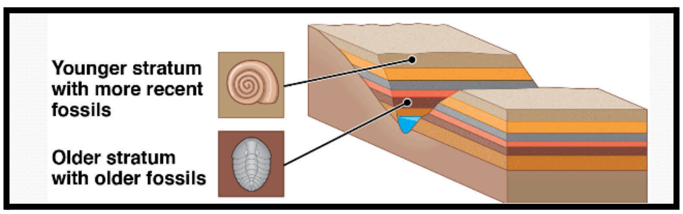
<u>Chapter 19 - Descent with Modification</u>

- Evolutionary change is based on the interactions between *populations* and their *environment* which result in ***adaptations*** to increase ***fitness***.
    - **Evolution:** descent with modification *(Darwin)*
      **Evolution is the change over time in the genetic composition of a population from generation to generation*
- History of ideas regarding species, evolution, and life on Earth as a whole.
  <u>*I don't think this section is that important to memorize</u>
    - Aristotle believed that species are fixed and unchanging. *Scala Naturae:* life-forms arranged in increasing complexity.
    - The Old Testament *(Creationism)* stated that the Earth was only about 6000 years old and that every species was designed by God for a particular purpose.
    - *Carolus Linnaeus* was the founder of **taxonomy**, the *binomial nomenclature* of organisms. → <u>*genus*</u>, <u>*species*</u>
      <u>*Domain – Kingdom – Phylum – Class – Order – Family – Genus – Species*</u>
      *These classifications are based on anatomy and *morphology* (study of the forms/shapes/structures of living things)
    - *George Cuvier* was a paleontologist who studied fossils within the deeper *strata* (rock layers) of the Earth. *Noted that fossils looked very different from current life.*

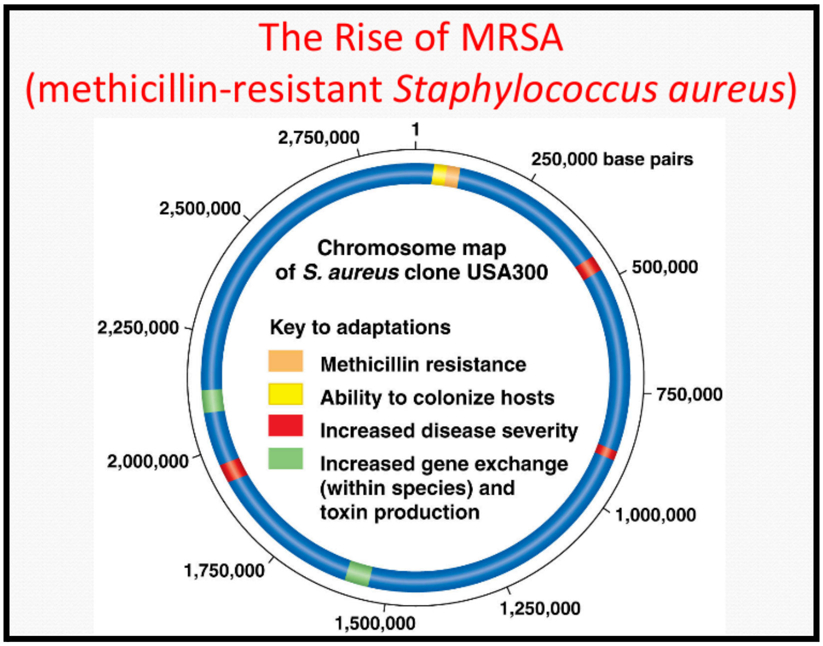


    - *James Hutton* believed that geological change results from a slow and continuous process. *Charles Lyell* believed that if Earth's processes are progressing at the same rate in the past and the present, <u>*then therefore the Earth is very, very old.*</u>
    - *Jean-Baptiste de Lamarck* published his theory of evolution. Recognized that species evolve and modifications can be passed on, but his explanation was flawed.
    - *Thomas Malthus* said that there are more organisms born than those who die. Believed that there *are consequences of overproducing in an environment (<u>human overpopulation for example</u>).*
    - ***Charles Darwin*** was a naturalist who studied organisms, specimens, and fossils. *Managed to figure out evolution (<u>though he called it "**descent with modification**")</u> and **natural selection** when studying finches at the Galapagos Islands. <u>Mechanism for evolution is **natural selection**</u>*: adaptations enhance an organism's ability to survive and reproduce in specific environments.
      *Competition for limited resources can result in differential survival

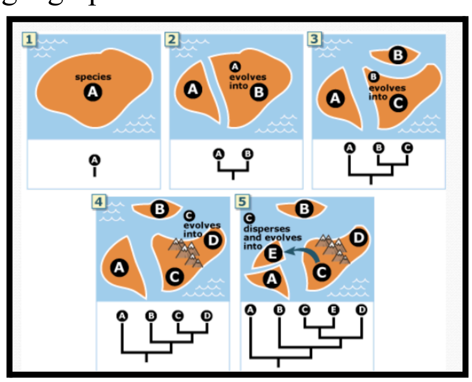
*__Evolutionary fitness__: individuals with more favorable "fit" traits are more likely to survive and pass on their traits/adaptations.

*__<u>Populations evolve, NOT individuals.</u>__

- There are 4 main pieces of evidence for evolution: ***direct observations***, ***homology***, ***fossil record***, ***biogeography***.
  - **Direct observations** – examples: *insects become resistant to pesticides*, *bacteria become resistant to antibiotics (**MRSA**)*, and *the peppered moth*.

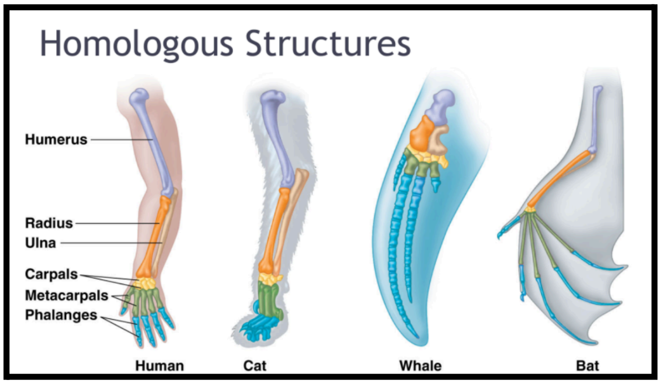


  - **Homology** – (<u>DESCRIPTION ON NEXT PG. IN THIS STUDY GUIDE)</u>
  - **Fossil Record** – *fossils* are remains or traces of organisms from the past found in *sedimentary rocks*. The study of fossils is known as *paleontology*. Studying fossils can show us *evolutionary changes that occur over time and the origins of major new groups of organisms.*
  - **Biogeography** – geographic distribution of a species. Species in nearby geographic areas resemble each other. *Continental drift* and *Pangaea* explains similarities on different continents. ***Endemic species*** are found in a certain geographic location and nowhere else.

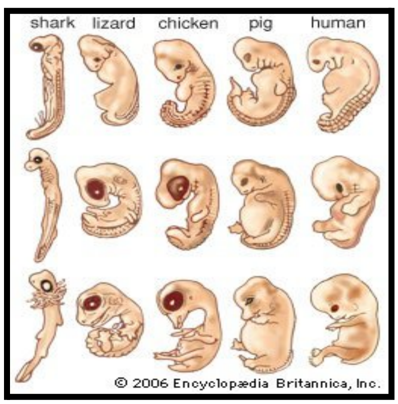


Chapter 20 - Phylogeny

- *Biologists can infer evidence for evolution based on different quantitative and qualitative factors.* ***Phylogeny*** *is the evolutionary history of a species or a group of species.* To determine evolutionary relationships, biologists use **fossils**, **morphology (homologous and analogous structures)**, and **molecular evidence**.
    - **Homology:** characteristics in related species can have *underlying similarities* even though functions may differ. Examples of this include:
      ****Homologous structures:*** similar anatomy from common ancestors



*****Embryonic homologies:*** similar early development. *See how all the embryos look similar in their first stages.*



*****Vestigial organs:*** structures with little or no use (flightless birds)
*****Molecular homologies:*** similar DNA and amino acid sequences.

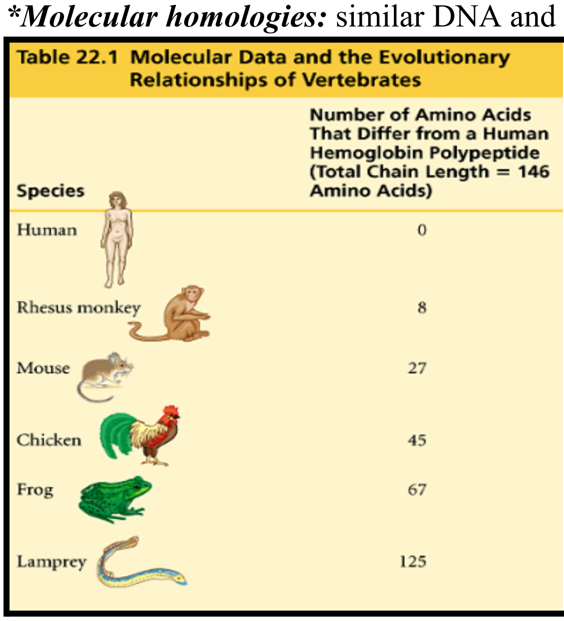
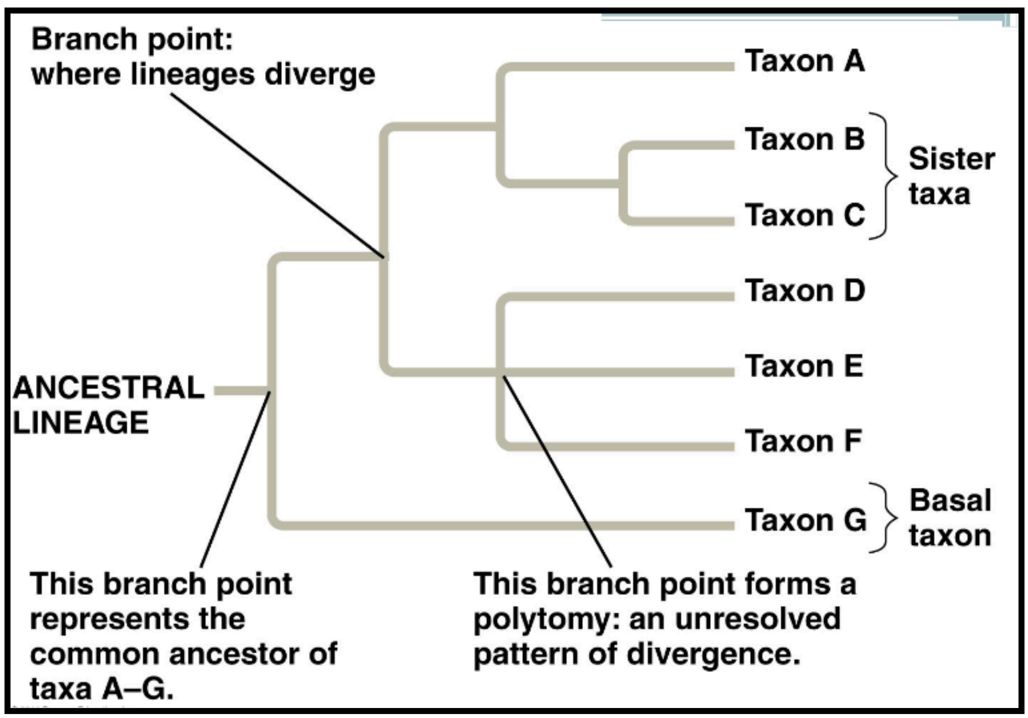


Table 22.1 Molecular Data and the Evolutionary Relationships of Vertebrates

Species	Number of Amino Acids That Differ from a Human Hemoglobin Polypeptide (Total Chain Length = 146 Amino Acids)
Human	0
Rhesus monkey	8
Mouse	27
Chicken	45
Frog	67
Lamprey	125

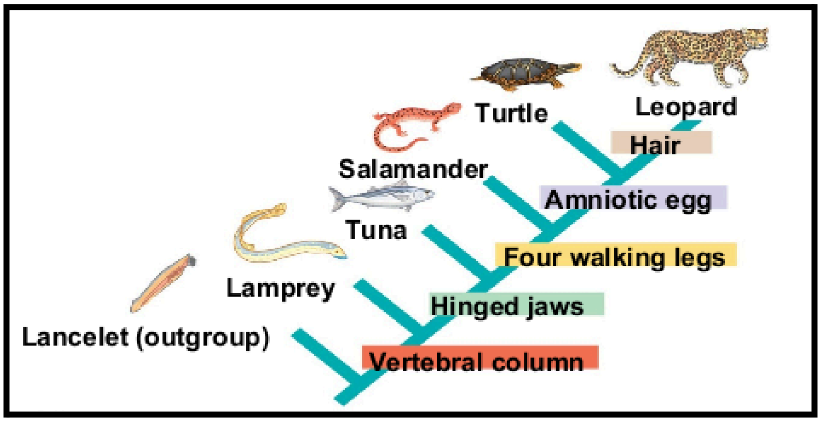
- **Convergent evolution** is when *distantly related and/or located* species resemble one another. This occurs when *similar environmental problems cause similar evolutionary solutions*.
    - **Analogous structures:** similar structures in different, distantly related species that function in similar environments.
    - *A good example of convergent evolution is wings. Many different creatures have wings, ranging from bugs to bats to birds. These species are all distantly related, however, they all evolved a wing structure independently of one another.*
- **Systematics** is classifying organisms and determining their evolutionary relationships. Systematics is divided into ***taxonomy***, which refers to *classifying organisms*, and ***phylogenetics***, which refers to *studying evolutionary histories*.
    - **Taxonomy** is classifying and naming organisms. Life is divided into **8 classes:** *Domain → Kingdom → Phylum → Class → Order → Family → Genus → Species.*
      *You can remember this as the acronym "Dear King Philip Came Over For Good Spaghetti"
    - In **phylogenetics**, biologists must use a **phylogenetic tree**, which is a branching diagram that shows the evolutionary history of a group of organisms.



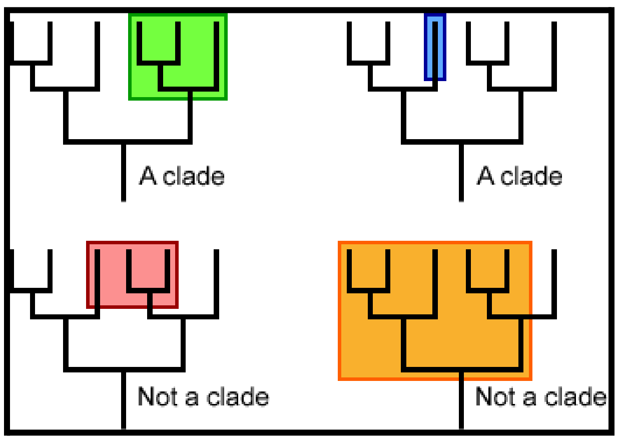
    - ****Basal taxon:** the taxon that remains unbranched is called the basal taxon*
      ****Sister taxa:** taxa that stem from the same point, they are referred to as sister taxa*

.

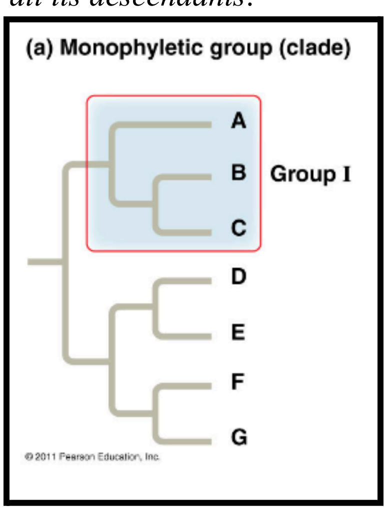
- **Cladograms** are diagrams that depict *patterns of shared characteristics* among taxa.



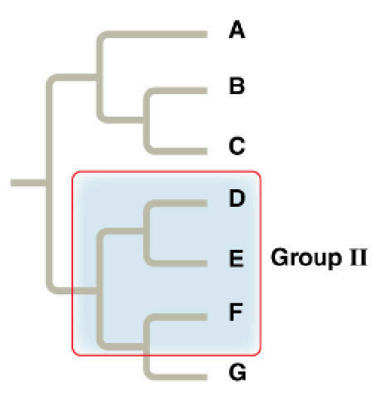
  - A ***clade*** is a group of species that includes an ancestral species *and* all of its descendants.



  - A **shared ancestral character** is a character that *originated/was present in an ancestor* of the taxon.
  - A **shared derived character** is an *evolutionary novelty* unique to a particular clade that was not present in the original ancestor of the cladogram.
  - A **monophyletic group** is a valid *clade* that consists of the *ancestor species and all its descendants*.

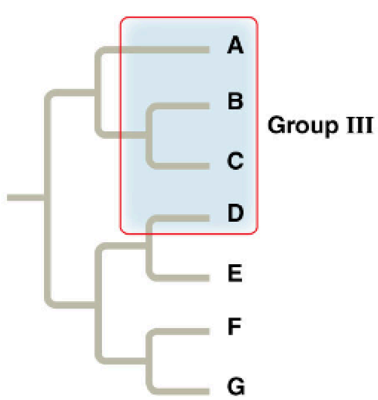


- A **paraphyletic group** consists of ancestor species and some, *but not all*, of the descendants.



(b) Paraphyletic group

- A **polyphyletic group** consists of *various taxa from different ancestors*.

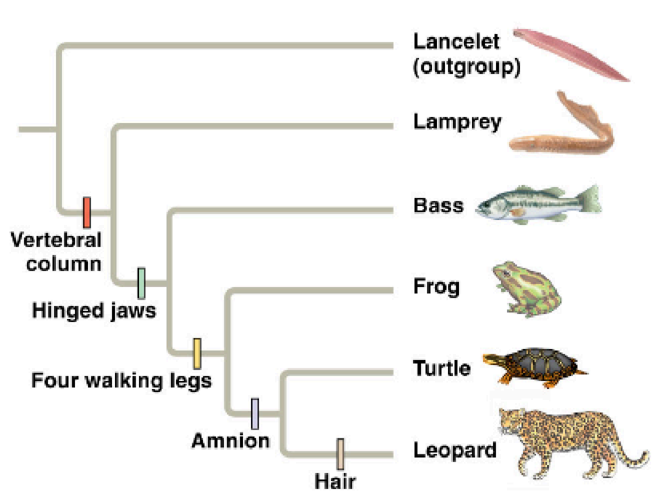


(c) Polyphyletic group

- Constructing a phylogenetic tree.
  - You can use a **character table** to figure out where a trait originated. *A "0" indicates that a character is absent; a "1" indicates that a character is present.*

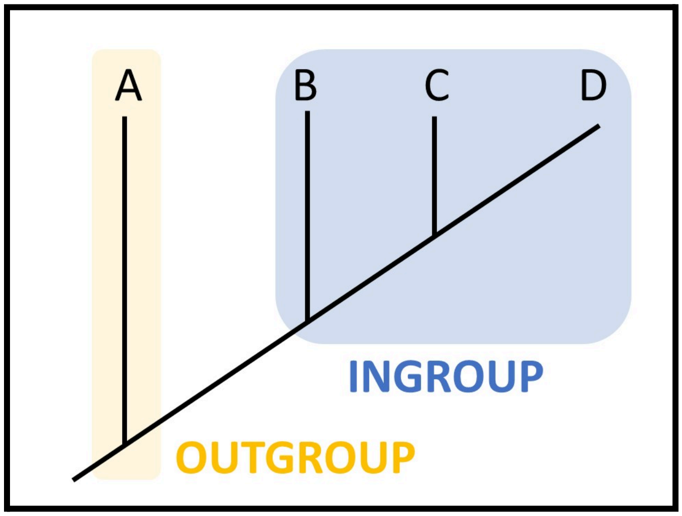
CHARACTERS \ TAXA	Lancelet (outgroup)	Lamprey	Bass	Frog	Turtle	Leopard
Vertebral column (backbone)	0	1	1	1	1	1
Hinged jaws	0	0	1	1	1	1
Four walking legs	0	0	0	1	1	1
Amnion	0	0	0	0	1	1
Hair	0	0	0	0	0	1

(a) Character table

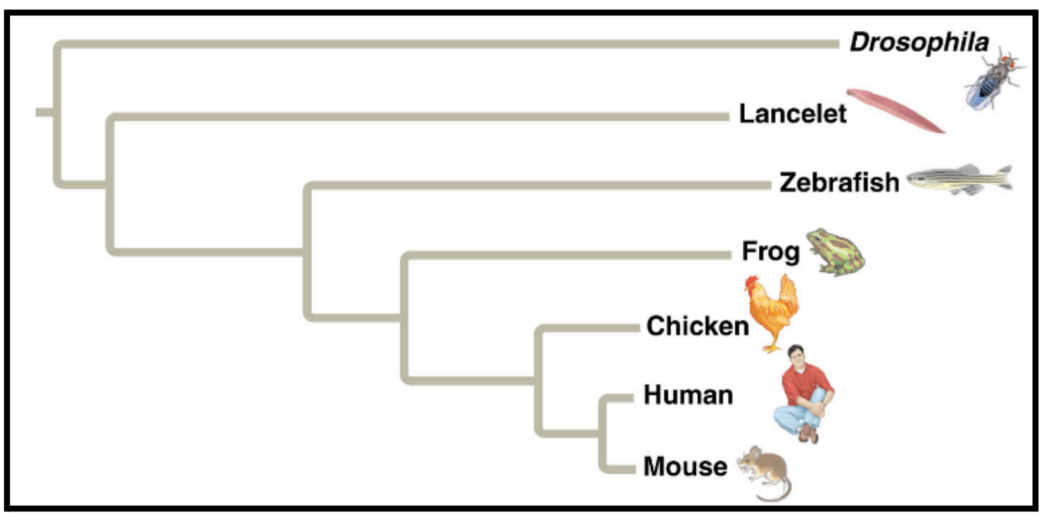


(b) Phylogenetic tree

- An **outgroup** is a species or group of species *that is closely related* to the **ingroup** (*the group of species that are being studied*). The outgroup is a *species or group of species that have diverged before the ingroup*. Systematists compare each ingroup species with the outgroup to *differentiate between shared derived and shared ancestral characteristics*. Characters shared by the outgroup *and* ingroup are ancestral characters that predate the divergence of both groups from a common ancestor.

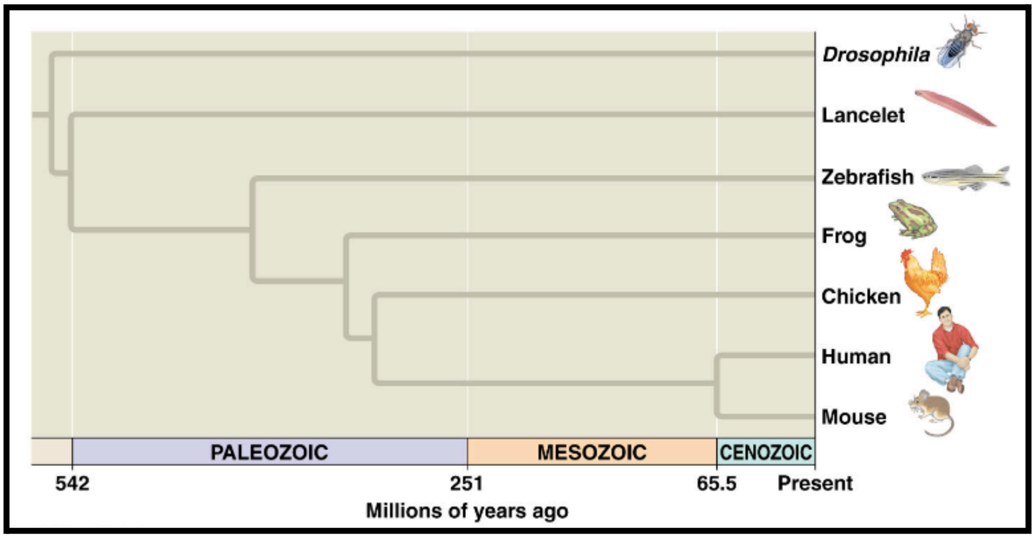


- *Branch lengths may represent genetic change.* The length of each branch is respective to the number of genetic changes that have occurred in a species over its existence.

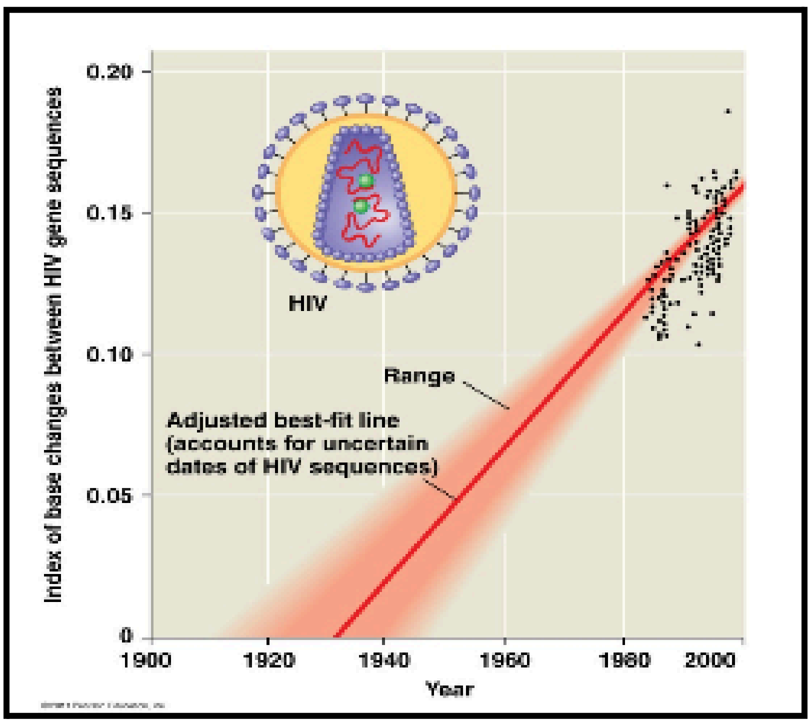


Drosophila has experienced more genetic change throughout its existence than the human race because we humans haven't been around that long, for example.

- *Branch lengths may also represent time.*



- **Molecular clocks** can be used when DNA is observed to evolve at a constant rate. *Can be used to estimate past evolutionary events.* A good example of this is using a molecular clock to estimate the origin of HIV in humans.

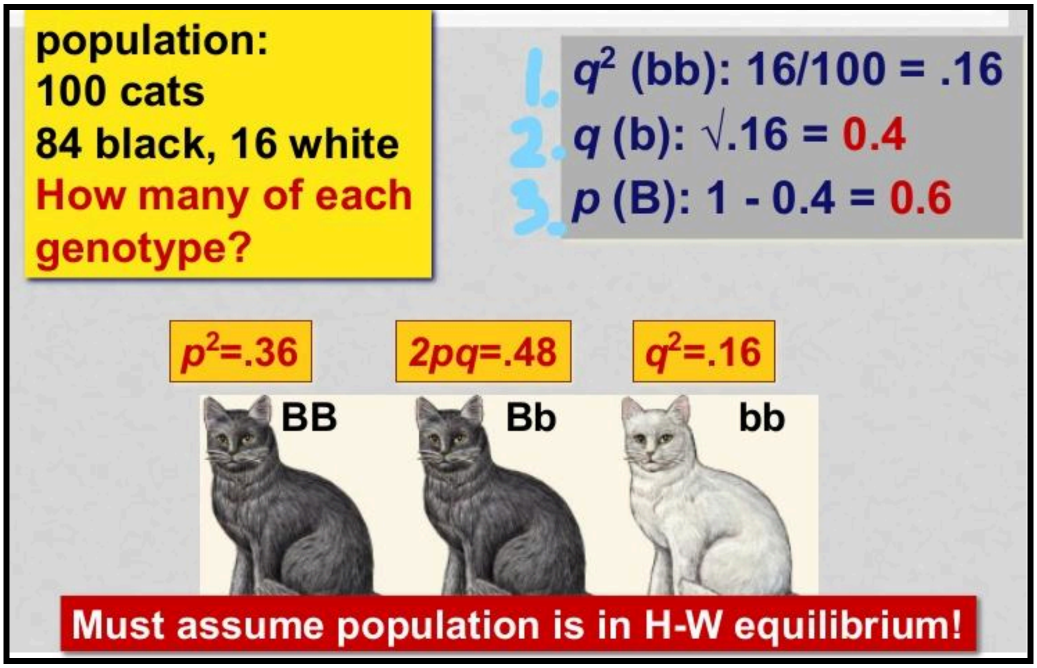


[A pretty good cladogram practice video]

Chapter 21 - The Evolution of Populations

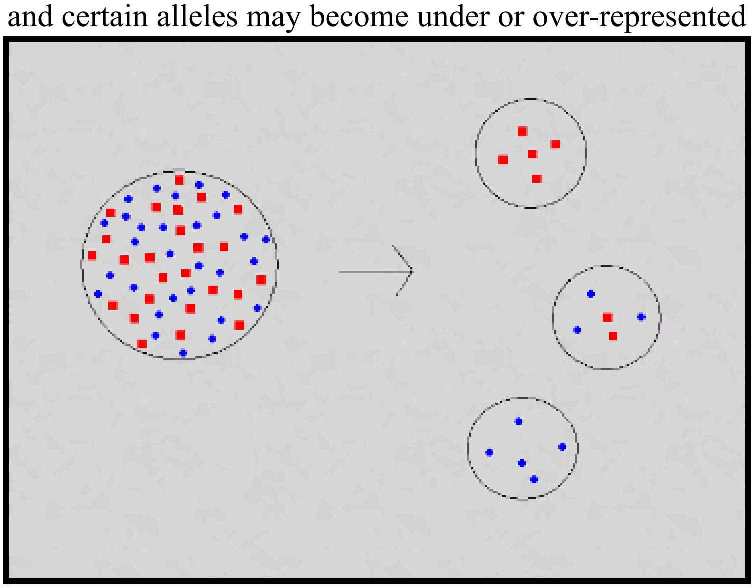
- The smallest unit of evolution is known as **microevolution**, which is the change in allele frequencies of a population over time. *Evolution is based on **genetic variation**.*
    - Sources of *genetic variation* include:
      ***point mutations** (changes in one base pair)*
      ***chromosomal mutations** (deletions, duplications, disruptions, rearrangements; these are all usually quite harmful)*
      ***sexual recombination** contributes to most of the genetic recombination in a population (includes crossing over, the independent assortment of chromosomes, and random fertilization)*
    - **Population genetics** is the study of how populations change genetically over time. A **population** is a group of same species individuals that live in the same area and interbreed, producing fertile offspring.
    - **Gene pool:** all of the alleles for all the genes in all the members of the population. A ***diploid species*** has 2 alleles for a gene (*homozygous dominant/recessive and heterozygous*). ***Fixed allele:*** *all members of the population only have 1 allele for a particular trait.* The more fixed alleles a population has, the <u>lower</u> the species' diversity is. ***Allele frequency*** is how common is a particular allele in a population (How much of allele "A" compared to "a")
- The **Hardy-Weinberg Equilibrium Principle** may be used to calculate allele/genotypic/and phenotypic frequencies in a hypothetical population. States that the allele and genotype frequencies of a population will remain constant from generation to generation *(equilibrium)*. This *serves as a model null hypothesis*.
    - For the H-W Equilibrium to be applicable, these conditions must be met:
        1. No mutations
        2. Random mating
        3. No natural selection
        4. Extremely large population size
        5. No gene flow

        **If <u>at least one</u> of these conditions is NOT met, then the population is EVOLVING. <u>NOT IN HW EQUILIBRIUM</u>*
    - **p** = *frequency of dominant allele (A)* / **q** = *frequency of recessive allele (a)*
    - **$p + q = 1$**
    - The **Hardy-Weinberg Equation:** $p^2 + 2pq + q^2 = 1$
      *p^2 → AA
      *$2pq$ → Aa
      *q^2 → aa

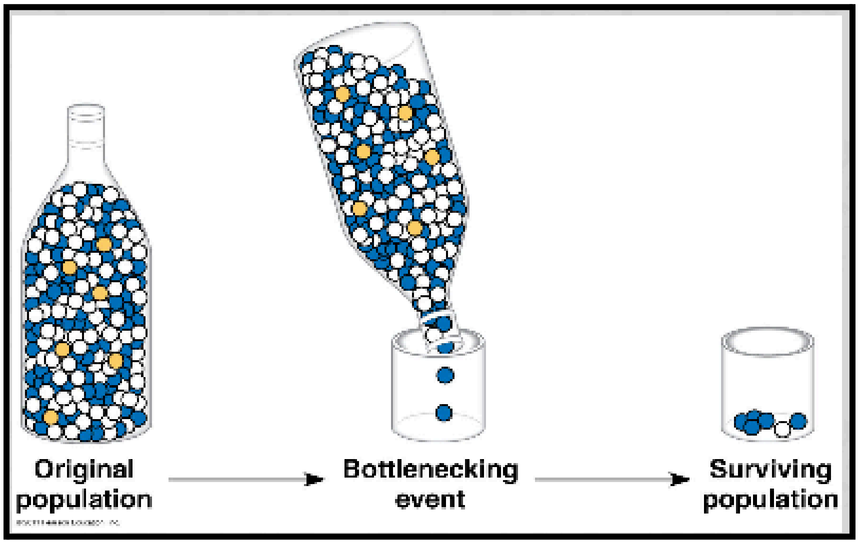


A common sample problem for H-W equilibrium. Note: it is best to always start your calculations by looking at the* ***homozygous recessive* *genotype because* <u>*homozygous dominant and heterozygous share the same phenotype*</u> *and it is impossible to differentiate without more data.*

- As we talked about earlier, the *minor causes for evolution* consist of mutations and nonrandom mating. **Major effects of evolution** include *natural selection, genetic drift, and gene flow*.
    - **Natural selection:** individuals with variations better suited to the environment are more likely to survive and pass their alleles on to the next generation.
    - **Genetic drift:** small populations have greater chances of fluctuations in allele frequencies from one generation to another. Examples: *founder effect* and *bottleneck effect.*
      ****Founder effect:*** a few individuals become isolated from the larger population, and certain alleles may become under or over-represented in the new population.

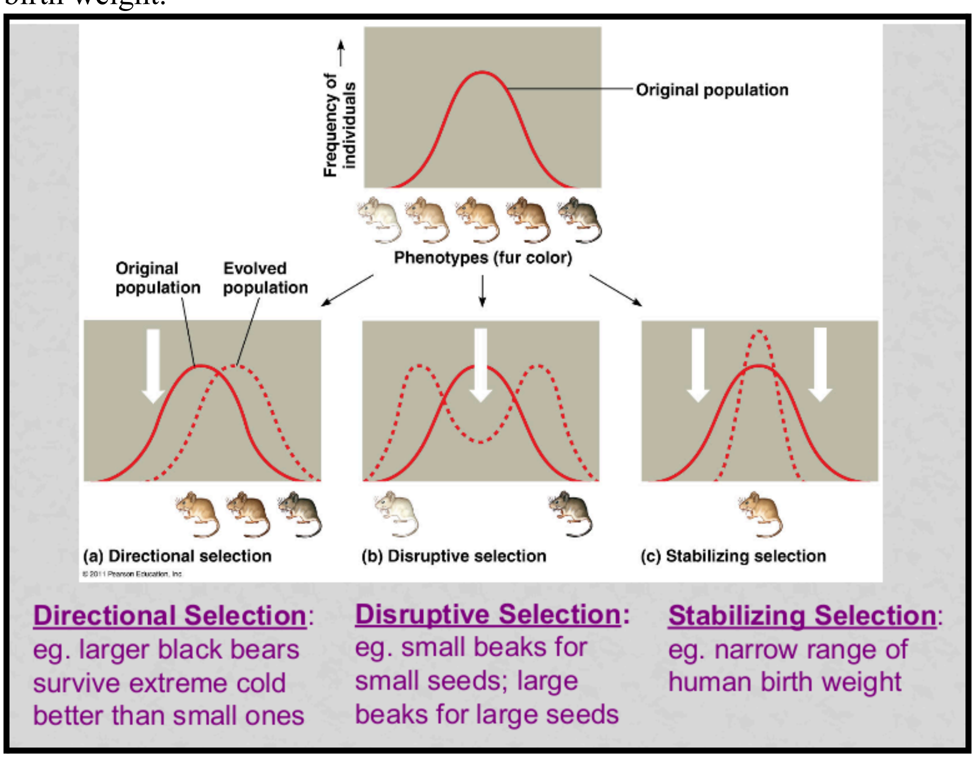


*__*Bottleneck effect:*__ a sudden change in an environment drastically reduces population size.



- **Gene flow:** movement of fertile individuals between populations. This causes populations to gain/lose alleles. Reduces the genetic differences between different populations.

- Modes of natural selection include **directional selection**, **disruptive selection**, and **stabilizing selection**.
    - ***Directional selection*** favors individuals at one end of the phenotypic range. Most common during times of environmental change or when moving to new habitats.
    - ***Disruptive selection*** favors extreme over intermediate phenotypes. Occurs when the environment favors an extreme phenotype.
    - ***Stabilizing selection*** favors intermediate over extreme phenotypes. Reduces variation and maintains the current average. A good example of this is human birth weight.

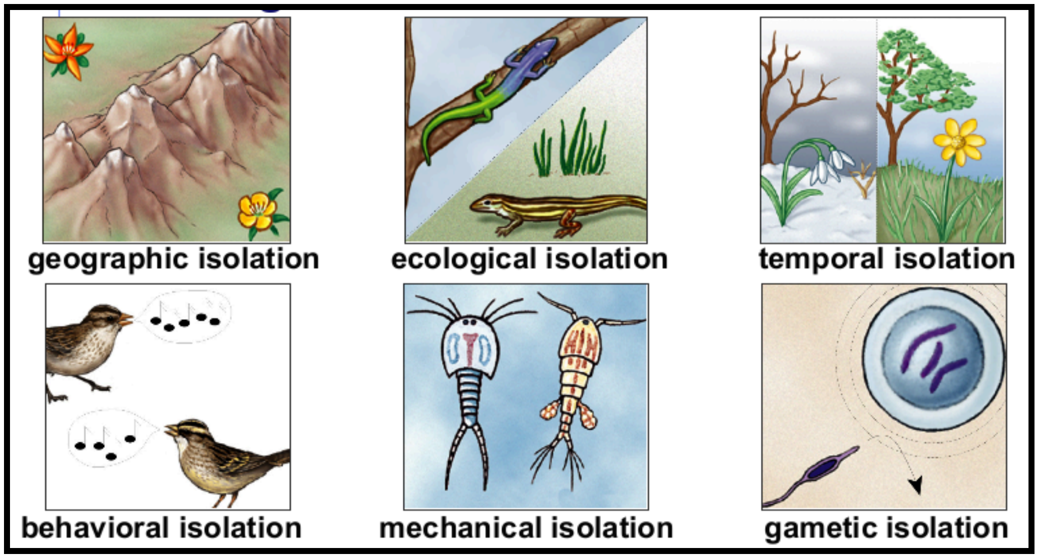


- **Sexual selection** is a form of natural selection, *certain individuals are more likely to obtain mates*.
    - ***Sexual dimorphism:*** the difference between 2 sexes in size, color, ornamentation, and behavior.
    - ***Intrasexual selection:*** selection within same sex (*example: male lions compete for females*)
    - ***Intersexual selection:*** mates are chosen (*example: female birds choose the showiest/most colorful male birds, or some dude gets rejected by his crush (╥﹏╥)*)
- **Heterozygote advantage** is when the heterozygote genotype is the most advantageous. *A good example of this is sickle cell disease.*
    - ***Diploidy:*** hide recessive alleles that are less favorable
    - In sickle cell disease in Africa, *<u>homozygote dominants</u> exhibit severe anemia, abnormal blood cell shape, and often die at an early age. <u>Homozygote recessives</u> are prone to malaria. <u>Heterozygotes</u> are less susceptible to malaria whilst not having sickle cell disease.*

Chapter 22 - The Origin of Species

- **Speciation** is the origin of a species.
    - ***Microevolution*** refers to changes within a single gene pool. ***Macroevolution*** refers to evolutionary change above the species level. *Cumulative effects of speciation over long periods of time*.
    - *Charles Darwin never actually tackled how new species arose.*
    - The **biological species concept** states that a ***species*** is a *group of populations* whose members <u>can interbreed</u> and <u>produce viable, fertile offspring</u> (reproductive compatibility).
    - The *biological species concept* emphasizes the absence of gene flow, *however*, gene flow may occur between distinct species.
      For example, polar bears and brown bears can mate to produce "grolar bears"
    - Other definitions of species:
      ***Morphological:** by body shape, size, and other structural features
      ***Ecological:** niche/role in the community
      ***Phylogenetic:** share common ancestry, branch on the tree of life

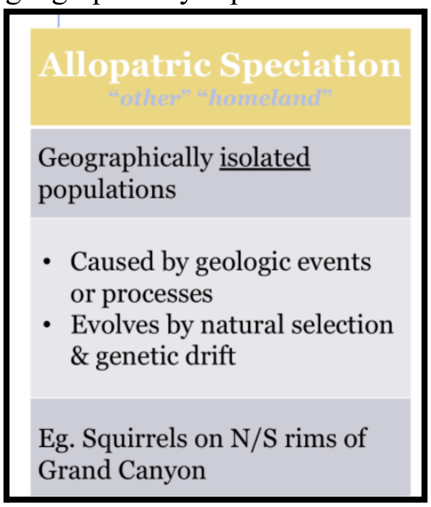
- Types of reproductive barriers. ***Reproductive isolation*** is the existence of biological barriers that impede members of two species from interbreeding and producing viable, fertile offspring:
    - **Prezygotic barriers** (also known as **pre-reproductive barriers**)**:** *are obstacles to mating or to fertilization if mating occurs*. ***Habitat isolation***, ***temporal isolation***, ***behavioral isolation***, ***mechanical isolation***, ***gametic isolation***

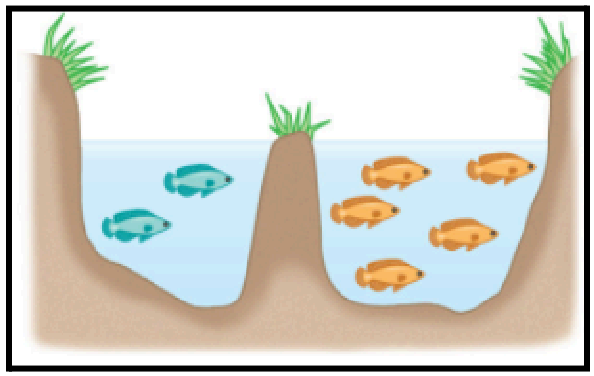


- ***Geographic isolation:*** a physical/geographic barrier that prevents two species from coming together and interbreeding.
  *Example: *two different flower species are located on opposite sides of a vast mountain range, never come in contact*
- ***Ecological isolation:*** two species occur in the same region, but occupy different habitats so they *rarely* encounter each other.
  *Example: *one lizard species lives strictly in the canopies of trees whilst the other lives strictly on the forest floor.*
- ***Temporal isolation:*** two different species breed only during specific/different times of the day, seasons, or years and therefore will not mix gametes.
  *Example: *one flower only lives/breeds during winter, whilst the other flower only lives/breeds during the summer.*
- ***Behavioral isolation:*** unique behavior patterns and rituals isolate species. Behavioral patterns help individuals identify members of their species and attract mates of the same species.
  *Example: *some birds sing specific songs as part of a mating ritual*
- ***Mechanical isolation:*** morphological differences can prevent successful mating.
  *Example: *Difference in reproductive organs' shape and size does not allow them to fit together. (͡° ͜ʖ ͡°)*
- ***Gametic isolation:*** sperm of one species may not be able to fertilize eggs of another species. There is either a *biochemical barrier* in which sperm cannot penetrate the egg or a *chemical incompatibility* where sperm cannot survive in the female reproductive tract.

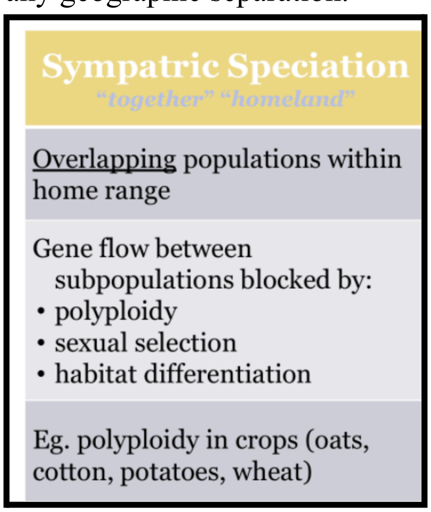
- ***Postzygotic barriers:** *prevent a hybrid zygote from developing into a viable adult.* ***Reduced hybrid viability****,* ***reduced hybrid fertility****,* ***hybrid breakdown***
  ****Reduced hybrid viability:*** genes of different parent species may interact and impair the hybrid's development.
  ****Reduced hybrid fertility:*** some hybrids may be sterile due to d*iffering numbers/structures of chromosomes* in parents. This causes meiosis to fail in hybrids and that prevents them from producing normal gametes.
  ****Hybrid breakdown:*** hybrids may be fertile and viable in the first generation, *but when they mate their offspring are feeble or sterile.*

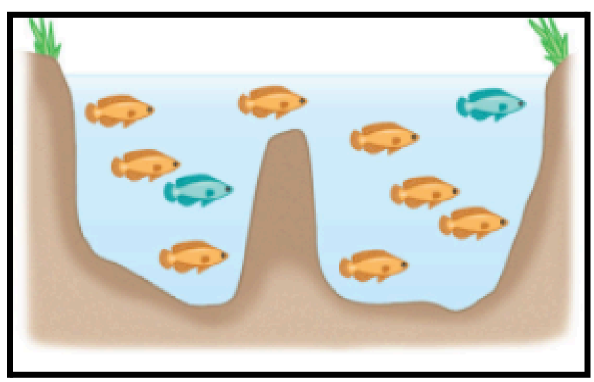
- There are *2 main modes of speciation:* **Allopatric speciation** and **sympatric speciation**.
  - In **allopatric speciation**, a population forms a new species due to it being geographically separated from its parent population.



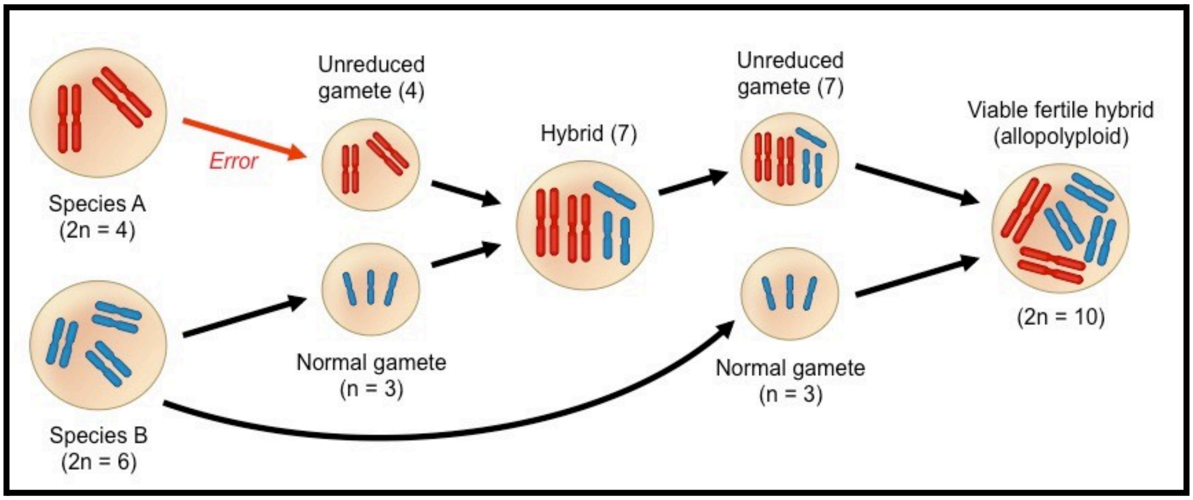


  - In **sympatric speciation**, a subset of a population forms a new species without any geographic separation.

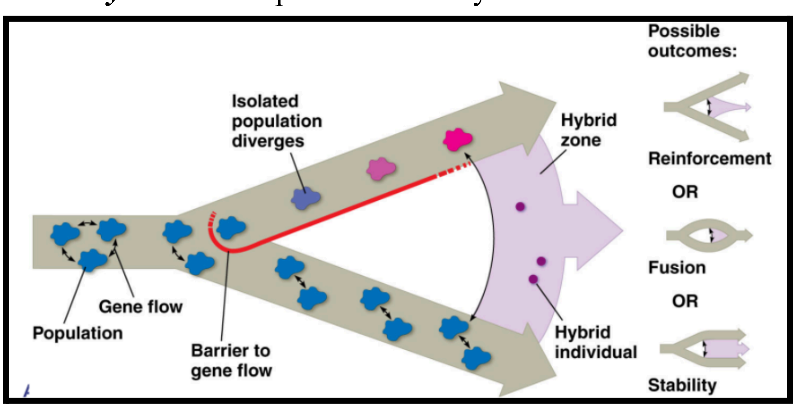




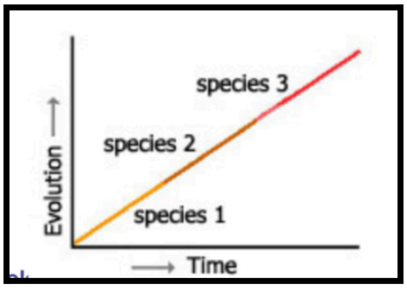
- *How do new species originate?* Populations must become isolated *geographically* or *reproductively*. Isolated species evolve independently. Isolation can either be **allopatric** *(geographic separation "different country")* or **sympatric** *(still live in the same area "same country")*.
- **Sympatric speciation** by *polyploidy*. An **autopolyploid** is an extra set of chromosomes that results from a failure in cell division *(ex: 2n → 4n)*. When 2 species produce a hybrid with a different number of chromosomes it is called an **allopolyploid**. *(Example: many strawberries are allopolyploids with 2n, 4n, 6n, 8n, or even 10n chromosomes)*
- **Polyploidy** is the presence of extra sets of chromosomes due to errors during cell division. Much more common in plants than animals. Offspring have *reduced fertility*.



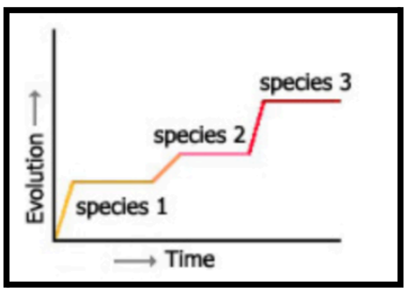
- **Hybrid zones** are incomplete reproductive barriers. *This part isn't really important to know I think.*
  ****Reinforcement:*** strengthening of reproductive barriers, hybrids eventually cease to be formed.
  ****Fusion:*** weakening of reproductive barriers, the two species fuse as more hybrids are formed.
  ****Stability:*** continued production of hybrid individuals.



- The rate of speciation can either occur *gradually* or *rapidly*.
    - **Gradualism** vs **punctuated equilibrium**.
    - In ***gradualism***, a species changes/evolves through a gradual accumulation of small changes over time. *Gradual divergence spans over long periods of time.*

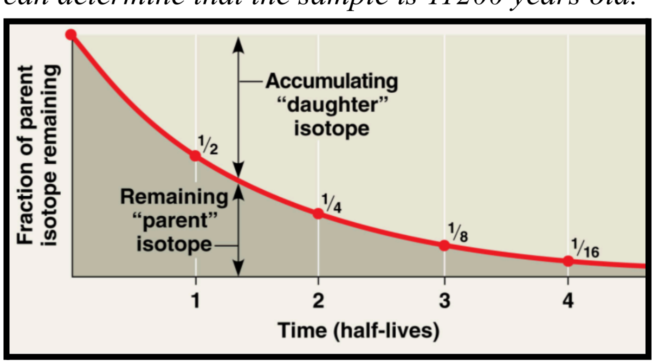


    - In ***punctuated equilibrium***, a species changes/evolves through rapid bursts of change mixed in with long periods of no change. *Rapid bursts of change or long periods of little to no change. Species undergo rapid change when they 1st bud from the parent population.*

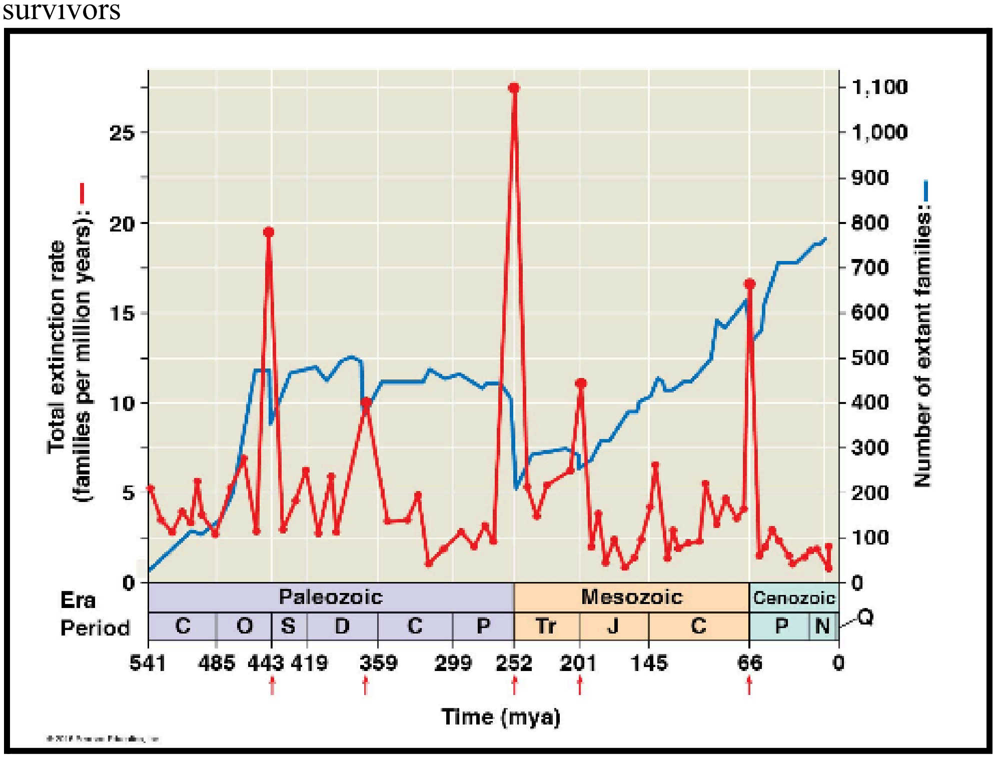


Chapter 23 - Broad Patterns of Evolution

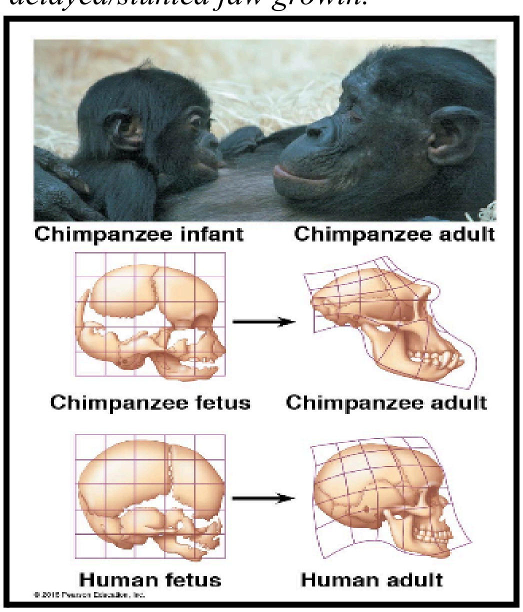
- Broad patterns of evolution are known as **macroevolution**.
    - *Examples include: the* emergence of terrestrial vertebrates, the impact of mass extinction, and the origins of key adaptations such as flight in birds.
- Scientists can date organic material using *carbon-14* and its half-life. This is called ***radiometric dating***.
    - *Carbon-14* has a half-life of about 5600 years. This means that every 5600 years, c-14 will decay and lose half of its mass.
    - *For example:* a sample with only ¼ the normal proportion of c-14 has been reduced twice (½ * ½ = ¼). Since the mass of the c-14 has been halved twice, we subsequently multiply the half-life value, which is 5600 years, by 2. *From this, we can determine that the sample is 11200 years old.*



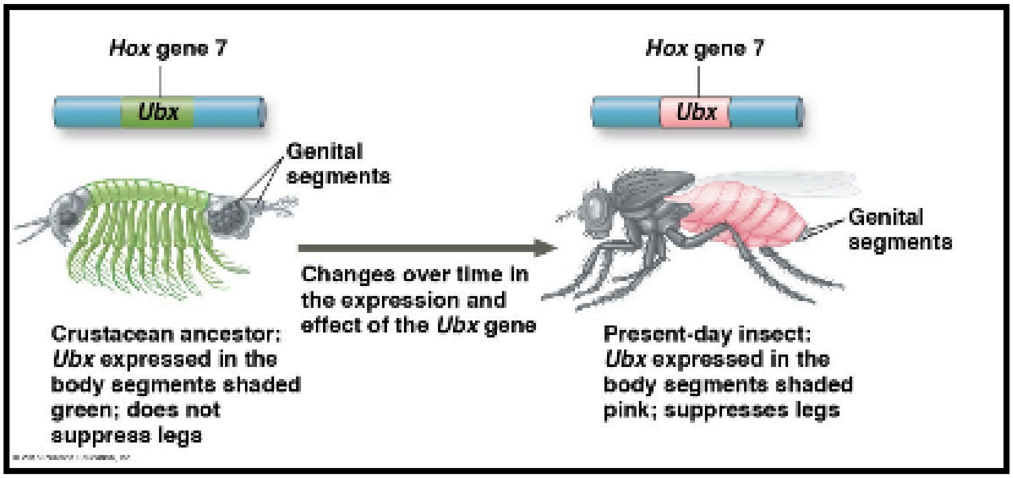
- Scientists study fossils to learn about past lifeforms. This is called ***relative dating***.
    - **Sedimentary rock:** comprised of layers called *strata*
    - **Mineralized:** refers to hardened body structures, such as bones
    - **Organic:** refers to soft, organic tissue. This is rare in fossils but may be found in amber, ice, or tar pits.
    - **Incomplete record:** many organisms not preserved, fossils have been destroyed or not yet found.
- Geologic time scale
    - **Eon → Era → Period → Epoch** *(longest to shortest)*
      *Present day: *Phanerozoic Eon, Cenozoic Era, Quaternary Period, Holocene Epoch*
    - **Pangaea:** supercontinent that formed 250 mya. ***Continental drift*** explains how and why continents move, and this can explain many biogeographic data, *such as finding two similar organism fossils in opposite parts of the world.*
    - The movement of continental plates changes the geography and climate of Earth, *which leads to extinction and speciation*.
- **Mass extinctions** are periods of time where a large portion of life on Earth dies off due to some catastrophic event. Extinction can be caused by changes to a species' environment.
    - Mass extinctions can increase the diversity of life. Major periods in Earth's history *end with mass extinctions* and new ones begin with ***adaptive radiations.***
    - **Adaptive radiation:** when organisms go extinct, they free up large amounts of new land and resources for surviving species. These surviving populations will rapidly *radiate* into these new environments whilst evolving into new species to make use of the new space and resources (*allopatric speciation*). *Many new species arise from a single common ancestor.*
      *Environmental change → extinction → opens up new areas and niches for the survivors



- Important Eras to remember: ***Precambrian***, ***Paleozoic***, ***Mesozoic***, and **Cenozoic**.
  - **Precambrian:** microscopic fossils (*stromatolites)* have been found from this era, which signifies the beginning of photosynthesis, atmospheric O_2, and eukaryotes (endosymbiont theory)
  - **Paleozoic:** an era where the *Cambrian Explosion* occurred. Plants moved onto land, and many animals appeared in the oceans and land. This was then followed by the *Permian Extinction*, where about 96% of all life on Earth was wiped out.
  - **Mesozoic:** "Age of Reptiles" and included dinosaurs and many new plants. The Pangaea supercontinent also formed around this time. This was then followed by the *Cretaceous Extinction*, where an asteroid hit Mexico's coast and decimated the dinosaurs.
  - **Cenozoic:** today's era, age of mammals and specifically *primates* (monke and hoomans)
  - *Note that many of these end with a major extinction event and start with adaptive radiation. The end of the Cenozoic era may come soon if Putin decides to hit the shiny red button on his desk soon…*
- Major changes in body form can result from changes in the sequences and regulation of developmental genes.
  - **Evo-Devo:** stands for "*evolutionary + developmental biology.*" *The evolution of new forms results from changes in DNA* or *the regulation of developmental genes.* *As watched/discussed in class, freshwater stickleback fish lost their ventral spines over thousands of years because it gave them an advantage over fish that did have spines in their new environment. This occurred because of a mutation that affected the regulation of a developmental gene that produced mRNA that corresponded to the creation of spiny structures in specific areas. Since this trait was advantageous, it spread through the entire population eventually.
  - **Heterochrony:** an evolutionary change in the rate or timing of developmental events.
    Somewhere in the human evolutionary lineage, a mutation made it so the skull of an adult human would remain more similar to an infant's/fetus' skull because of delayed/stunted jaw growth.



- **Paedomorphosis:** a condition where an adult retains juvenile structures in an ancestral species. *For example, axolotls are a type of salamander that, despite having few genetic changes to some closely related species, retains certain larval characteristics, such as gills, in its adult stage unlike other salamander species closely related to it.*
- **Homeotic genes:** are master regulatory genes that determine the location and organization of body parts. *For example, the evolution of "Hox genes" changed the insect body plan over time.*



Chapter 24.1 - Early life and the diversification of prokaryote groups

- Conditions on early Earth made the origin of life possible. Chemical and physical processes on Earth billions of years ago may have produced very simple cells through a sequence of stages. *Abiotic synthesis of small organic molecules → joining of small, organic molecules into macromolecules → packing of molecules into* ***protocells*** *(membrane-bound droplets that maintain a consistent internal chemistry → origin of self-replicating molecules.*
  - Earth's early atmosphere likely contained *water vapor* and *chemicals released by volcanic eruptions*. As Earth cooled, the water vapor condensed into oceans and most of the hydrogen in the atmosphere escaped into space.
  - Miller-Urey's experiment demonstrated that *organic molecules could spontaneously form in early Earth's environment*.
  - RNA monomers have been produced spontaneously from simple molecules. Small organic molecules *polymerize when they are concentrated on hot sand, clay, or rock*.
  - Replication and metabolism *are key properties of life that may have appeared together in* ***protocells****, which may have been fluid-filled vesicles with a membrane-like structure.* In water, lipids and other organic molecules *can spontaneously form vesicles with a lipid bilayer*. Adding clay can increase vesicle

formation rates. Vesicles may exhibit simple reproduction and metabolism by maintaining an internal chemical environment.
Possible precursors to cells

- *The first genetic material was probably RNA, not DNA.* RNA molecules called **ribozymes** have been found to catalyze many different reactions, such as making complimentary copies of short stretches of RNA.
- Natural selection has produced self-replicating RNA molecules, ones that were more stable or replicated more quickly would be the most advantageous.
- Vesicles with RNA capable of replication would have been *true* **protocells**.
- RNA could have provided a template for DNA, *the more stable genetic material.*
- Prokaryotes that formed *stromatolites (fossilized rock that provides evidence for the existence of early Earth prokaryotes)* were the earliest forms of life we have identified.