Assumptions

1. There is variation among populations
    a. (genetic diversity)
2. Among populations, more offspring will be born than the environment can support
3. There will be competition between members of a population
4. Survival of the fittest
    a. (Natural selection)
5. Success is measured by who leaves the most offspring

Fossils

- The most sound evidence for evolution comes from fossils.
- The fossils show how many species evolved and shows their stages
- They also show how some species went extinct

Rocks

- Sedimentary rocks “record” atmospheric conditions and preserve things from the time period they are from, and they can be dated.

Comparative Anatomy

- The humpback whale (a mammal) evolved from a small, dog-like mammal.
- If you look at the legs of the whale and its ancestors, it has legs which got less and less complex over time, and eventually went away (what is left, is just the femur)

- The arms of humans, cats, whales, and bats are all almost identical. This shows that they all came from a common ancestor (divergent evolution)

- But that common ancestor moved to different places and so diverged more, having a similar structure for a different function.

- Fish and water mammals look the same, but are very different. This is because they had different ancestors that came into the water and all adapted to the same environment. (convergent evolution)

Homologous Structures

- A part of the common ancestor in a divergent evolutionary line that has the same structure but has adapted for a different function

Analogous Structures

- A part of the similar species that came from different ancestors (convergent) that has different origins and different structures but does the same function

Vestigial Structures

- Parts of an organism that when it adapted to its new environment/conditions, it didn't need anymore
- Examples include the tailbone, the appendix, etc.

Embryology

- Embryos of the same common ancestor start out looking similar. So, we can use this to prove the theory of evolution, and to figure out which organisms are most closely related
- Every descendant of a common ancestor has a certain trait characteristic of its common ancestor

Artificial Selection

- Breeding organisms that have favorable traits.
- Like dogs or wheat

Lamarck

- He said that evolution creates the perfect being, which is wrong
- He also said that you can pass environmentally-acquired traits to your children, which is also wrong.

Population Genetics

- Linking evolution to genetics
- Terms:
    - Gene pool - all of the genes in a population
    - Gene frequency - how often a particular allele appears in a population
        - $\frac{\#\ of\ alleles}{total\ \#\ of\ alleles}$
        - Frequency of the dominant allele = p
        - Frequency of the recessive allele = q
        - p + q = 1
- Mutations cause the differences and traits which thrive or die out.

A Bear Example

- Say there are 10 bears.
- Black is dominant over brown.
- If there are 3 homozygous black bears, 2 heterozygous black bears, and 5 brown bears, the gene frequency of the black allele is 40%
- If the black allele becomes more frequent, then the population has evolved. (The environment must be suited for black bears)

Hardy - Weinberg

- Population is in equilibrium if the gene frequencies remain the same over many generations.
    - Must have a large population
    - No immigration/emigration from the population
        - No gene flow
    - No mutations
    - No natural selection
    - Random mating
- This is not the natural way of doing things, this does not happen in the real world.
- In this situation, there would be no evolution

- $P^2 + 2pq + q^2 = 1$
    - P^2 is the amount that are homozygous dominant
    - 2pq is the amount that are heterozygous
    - q^2 is the amount that are homozygous recessive

    - Remember, p and q are the frequencies of the <u>alleles</u>, not the phenotypes.
        - p+q=1
    - This equation can tell you the genotypes, given the genotypes
    - You only have to know the % of homozygous recessive (or just recessive)

A Rabbit Example

- Say we have 100 rabbits
- Black is dominant over white
- 75 are black, 25 are white

- The frequencies of the alleles are 50%

- 25% are homozygous dominant
- 50% are heterozygous
- 25% are homozygous recessive

- If these change over time, evolution is happening.
- These kinds of things let us observe evolution at the genetic level.

Genetic Drift

- Natural selection has the most effect on evolution
- Mutations have some effect

- Genetic Drift: random changes in the gene pool
    - Bottleneck
        - Some sort of thing (like a natural disaster) wipes out random members of a species, and the gene frequency is altered
    - Founders effect
        - If one part of a larger population breaks off and separates from the larger population, the new population will be all like them.
            - Like in a 50-50 environment with black and white mice, if a few white mice move somewhere else and start their own colony, their gene frequency will be 100%

Microevolution

- Changes within a species

Macroevolution

- Formation of a new species
- Speciation

    - The easiest way for a new species to form is to separate a species by a geographical barrier (Allopatric Speciation). And so natural selection happens to the 2 separate groups and pushes them in separate directions.
- Species: A group of organisms that can interbreed and produce fertile offspring in nature

Types of Selection

- Directional Selection
    - When it is not good to be one phenotype over another, the curve shifts toward the favorable trait
- Stabilizing Selection
    - The curve narrows onto the favorable trait, killing off the extremes.
- Disruptive Selection
    - When it is better to be an extreme, so there are 2 little curves at the extremes and a valley in the middle.

Reproductive Barriers

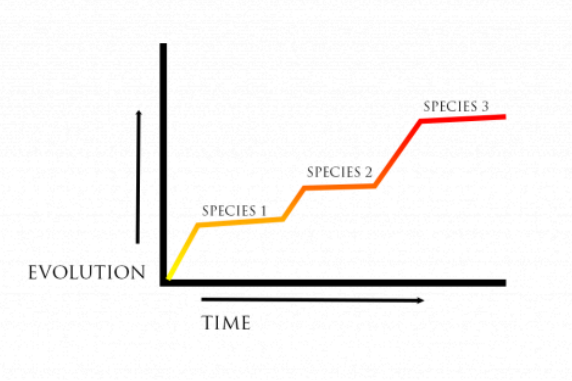
- Geographic Isolation - Once 2 species are separated enough, they cannot mate with each other and produce fertile offspring. They are now Reproductively Isolated. (Allopatric Speciation)
    - If the 2 groups still mate with each other, the gene pools will stay in sync and they will not form 2 new species.
- Habitat Isolation - If 2 groups are in the same place, but do not interact with each other, they are Habitually Isolated. (Sympatric Speciation)
- Temporal Isolation - If the mating seasons of a species start to happen at different times, they will also not breed with each other. (Sympatric Speciation)
- Behavioral Isolation - Different mating rituals, like dances. (Sympatric Speciation)

Rate of Evolution

- A gradual evolution is a straight, smooth line. This is what darwin thought happened.
    - The stages in the middle are called transitional stages.
- But this is not what happens. It actually looks more like a staircase.

Punctuated Equilibrium

- A theory by Stephen Gould and Niles Eldredge
- Evolution happens in a staircase, not gradually.



The Dinosaurs

- All of the dinosaur fossils are found below a strata layer that formed 65 million years ago. After that, there are none.
- The meteor that made the dinosaurs go extinct hit somewhere in Mexico, setting off firestorms, earthquakes, clouds of ash, and tsunamis.
- The ash cloud blocked out the sun, so the plants died, then the herbivores who ate the plants died, then the carnivores who ate the herbivores died.
- *Mass Extinction*

Alvarez

- Asteroids have a high amount of Iridium
- So this family by the name of Alvarez tested the strata layer of that ash for Iridium, and everywhere around the world had the same kind of layer.

Adaptive Radiation

- When the dinosaurs died, the small mammals at the time were able to then evolve and flourish and get bigger.

Taxonomy

- Linnaeus
- Taxonomy
    - How we classify things
    - Important because everything gets a name, and everyone agrees it is called that.
- Binomial Nomenclature
    - 2-part format of the scientific name of an organism
    - Latinized
        - Used a dead language because the meaning of words in dead languages don’t change
    - Genus-species

- You get more and more specific with each classification
    - Domain
    - Kingdom
    - Phylum
    - Class
    - Order
    - Family
    - Genus
        - Capitalized
        - italics
    - Species
        - lowercase

        - Italics

    - **D**ear **K**ing **P**hillip **C**ame **O**ver **F**or **G**ood **S**ushi
- Animals:
    - Eukaryotic
    - Multicellular
    - Heterotrophic
    - No cell walls
    - Muscle tissue
    - Nervous tissue

Phylogenetic Trees

- A family tree of species
- A split in a branch represents a common ancestor
- The further away a common ancestor is, the more different a species will be

Clades

- A clade is a group of species which includes a common ancestor and *all* its descendants
- Clades can be nested

Outgroup Comparison

- A branch of a common ancestor and a timeline of who broke off when, and which traits each one gained.
- The first species is called the outgroup
    - This does not have any shared characteristics
- After each broken off species, a new trait is introduced. Every species after this trait is introduced has this trait.

The Origin of Life

- Earth formed 4.6B years ago
- 3.5 BYA were the first anaerobic organisms
    - We know this because of compounds only formed by bacteria were found at this time period
- 2.7 BYA there was oxygen in the atmosphere
- 1.8 BYA were the first eukaryotes

Early Earth (Intertidal Theory)

- The following gases were found in Early Earth's atmosphere
    - Methane (CH_4)
    - Nitrogen (NH_3)
    - Water (H_2O)
    - Carbon Dioxide (CO_2)
    - Hydrogen (H_2)
- All of the elements necessary for life are present here, and the gases in the atmosphere are dissolved in the water.
- So all of the molecules are dissolved in the water, and lightning keeps striking the ocean, so they are reacting and reacting and eventually (by chance), the raw materials of life (Amino Acids, phospholipids, enzymes, etc.) formed and fell into the right place at the right time.

- So, this theory states that life formed in the Intertidal Zone where the energy source is lightning.

- Theory by Oparin and Haldane
- Oxygen would have actually been bad for it at this point

Miller's + Urey's Experiment

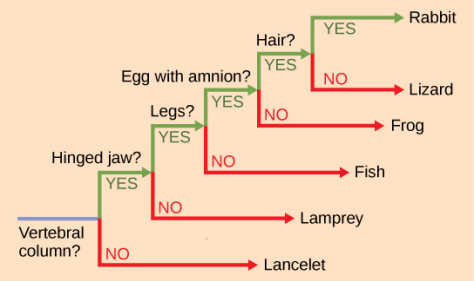
- Miller and Urey made an experiment to simulate early earth, and he tested his "sea" for organic molecules after a week and found some.
- People re-did these experiments and everyone finds different organic compounds, which is good.

Early Earth (Hydrothermal Vent Theory)

- This theory states that the organic compounds formed by a hydrothermal vent at the bottom of the ocean, where the energy source is heat.

Phylogenetic Trees...In Detail

- Species are grouped by shared traits/genes
- The more shared traits, the more closely related the species are.



Endosymbiosis

- How did we go from prokaryotic cells to eukaryotic cells?
- Some cells happened to be very specialized (like chloroplasts and mitochondria), and bigger cells swallowed them.
- Eventually, the smaller cell became completely dependent. They also have their own genes, which resemble prokaryotic genes.