THE EVOLUTION OF POPULATIONS

HOW DOES A POPULATION OF PENGUINS EVOLVE?

Every year, king penguins return to breed in the same colony in which they are born. These colonies help penguins to guard, protect and defend their young. By ensuring the success of their young, penguins pass on their genes to future generations. Variation in these genes is the basis for the evolution of populations.

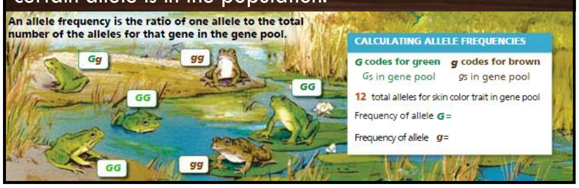
WHAT IS GENETIC VARIATION?

Genetic variation in a population increases the chance that some individuals will survive.

Genetic variation is stored in a population's gene pool.

- A gene pool is the combined alleles of all the individual's in a population.
- Different combinations of alleles in a gene pool can be expressed when organisms mate and have offspring.

An allele frequency is a measure of how common a certain allele is in the population.



SOURCES OF GENETIC VARIATION

Two main sources of Genetic Variation:

1. **Mutations**- a random change in the DNA of a gene.
   - Mutations in gametes can be passed down to offspring.
   - Mutations increase genetic variation in a gene pool.
2. **Recombination**- new allele combinations form in offspring through a process called recombination.
   - Occurs during meiosis- each parent's alleles are arranged in new ways which results in many different combinations in the gametes (we've shown this through the FOIL method).

Apply

An Olympic gold medalist in cross-country skiing has a gene, which causes him to produce 50% more hemoglobin than the average person. Based on this information, which of these statements is true?

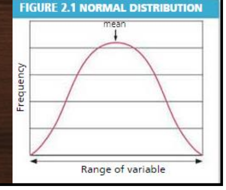
A. Evolution is present as shown by a mutation in genes.
B. This mutated trait will be passed on only if present in somatic cells.
C. Evolution has not occurred until this mutated trait is passed on from generation to generation in a population.
D. None of the above

NATURAL SELECTION ACTS ON DISTRIBUTIONS OF TRAITS

Anytime you stand in a large crowd of people, you are likely to observe a wide range of heights. If you were to organize this crowd according to height, from shortest to tallest, you would notice a pattern in distribution. Relatively few people would be at each extreme height (very short & very tall) with the majority of people being in the middle (medium height).

- When graphed, you'd see a bell shaped curve.
- This type of distribution in which the frequency is highest near the mean value and decreases toward each extreme is called a normal distribution.

FIGURE 2.1 NORMAL DISTRIBUTION



NATURAL SELECTION CAN CHANGE THE DISTRIBUTION OF A POLYGENIC TRAIT IN ONE OF THREE WAYS

Microevolution is the observable change in the allele frequencies of a population over time.

- Occurs on a small scale-within a single population
- Natural selection can lead to microevolution

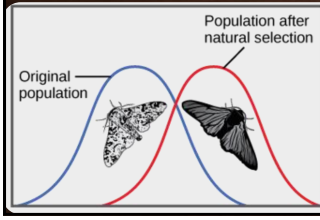
Natural selection can change the distribution of a polygenic trait along one of three paths:

1. Directional Selection
2. Stabilizing Selection
3. Disruptive Selection

DIRECTIONAL SELECTION

Directional Selection occurs when phenotypes at one extreme of a trait's range are favored.

- One extreme of the trait's range is **selected against** by nature.
- An extreme phenotype that was once less common in a population becomes more common because that trait was better suited for its environment.
  - Example: Dark-colored peppered moths during the Industrial Revolution.

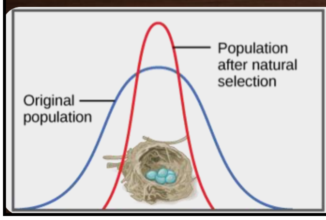


Light-colored peppered moths are better camouflaged against a pristine environment; likewise, dark-colored peppered moths are better camouflaged against a sooty environment. Thus, as the Industrial Revolution progressed in nineteenth-century England, the color of the moth population shifted from light to dark, an example of directional selection.

STABILIZING SELECTION

Stabilizing Selection occurs when an intermediate (average) phenotype is favored and becomes more common in a population.

- Both extremes of the trait's range are **selected against** by nature.
- In some populations, these extreme phenotypes may be lost altogether.

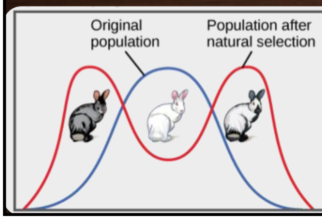


Robins typically lay four eggs, an example of stabilizing selection. Larger clutches may result in malnourished chicks, while smaller clutches may result in no viable offspring.

DISRUPTIVE SELECTION

Disruptive Selection occurs when both extreme phenotypes are favored.

- Individuals with the intermediate phenotype of the trait's range are **selected against** by nature.
- By favoring both extreme phenotypes, disruptive selection can lead to the formation of new species.



In a hyphothetical population, gray and Himalayan (gray and white) rabbits are better able to blend with a rocky environment than white rabbits, resulting in disruptive selection.

NATURAL SELECTION IS NOT THE ONLY MECHANISM THROUGH WHICH POPULATIONS EVOLVE

1. GENE FLOW

Gene flow is the movement of alleles between populations.

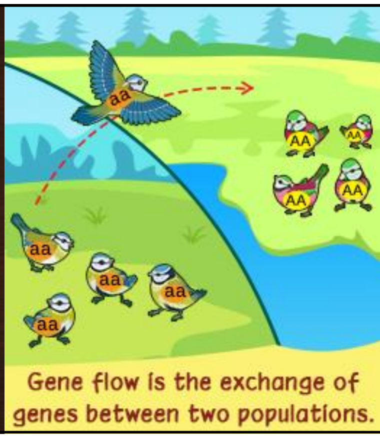
- When an organism joins a new population and reproduces, its alleles become part of that population's gene pool.
  - At the same time, these alleles are removed from the gene pool of its former population.

For many animals, gene flow occurs when individuals move between populations *(migration)*.

Gene flow **increases** the genetic variation of the receiving population.

Gene flow between neighboring populations keeps their gene pools similar.

- The less gene flow that occurs between two populations, the more genetically different the two populations can become.
- A lack of gene flow also increases the chance that the two populations will evolve into different species.



2. GENETIC DRIFT

Genetic Drift is a change in allele frequencies due to chance.

- Genetic drift causes a loss of diversity.
- Small populations are more likely to be affected.

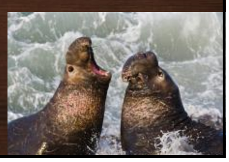
Two processes commonly cause populations to become small enough for genetic drift to occur. Each of these results in a populations with different allele frequencies than existed in the original population.

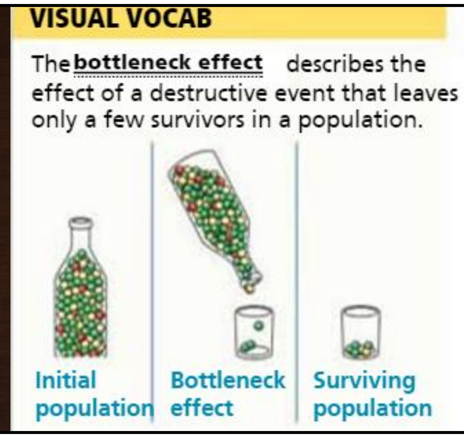
1. Bottleneck Effect
2. Founder Effect

BOTTLENECK EFFECT

The **bottleneck effect** is genetic drift that occurs after an event **greatly reduces the size of a population as well as genetic variation.**

- Factors such as disease, starvation, or drought, that kill a large proportion of a population produce a **bottleneck population.**
- Example: Overhunting of northern elephant seals during the 1800s. By the 1890s, the population was reduced to about 20 seals. These 20 seals did not represent the original population. Since hunting has ended, the population has grown to over 100,000 individuals, but the population has very little genetic variation.



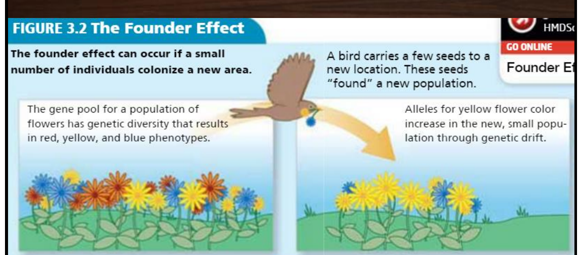


FOUNDER EFFECT

The **founder effect** is genetic drift that occurs after a small number of individuals colonize a new area.

When a few individuals start a new population (migrate), they carry only a small sample of the parent population's genetic variation.

- Some alleles may be totally missing from the new population and other rare alleles might occur at relatively high frequencies.



GENETIC DRIFT: ELLIS-VAN CREVELD SYNDROME

Example: The Amish of Lancaster County, Pennsylvania, have a high rate of Ellis-van Creveld syndrome tracing back to one of the community's founding couples.

Ellis-van Creveld syndrome is an inherited disorder of bone growth that results in very short stature (dwarfism).

- This syndrome is also characterized by the presence of extra fingers and toes (polydactyly) and dental abnormalities

EFFECTS OF GENETIC DRIFT

1. Populations lose genetic variation.
2. Without genetic diversity, no matter how large a population may become in the future, it will be less resistant to diseases and less able to cope with environmental change.
3. Lethal alleles may become more common in the gene pool due to chance alone.

Apply

T/F … correct each of the false statements.

__1. Genetic drift and gene flow increase variation in a population.

__2. Gene flow increases the genetic variation in a gene pool when an organism migrates into another population.

__3. Genetic drift is a result of chance such as a catastrophic event (ie: bubonic plague).

__4. Genetic drift can lead to increase in variation of the gene pool.

3. SEXUAL SELECTION

Sexual selection occurs when certain traits increase mating success.

- Mating can have an important effect on the evolution of populations.

Because females are much more limited in the number of offspring they can produce in each reproductive cycle, they are more choosy than males about mates.

There are two types of sexual selection:

1. Intrasexual selection
2. Intersexual selection

INTRASEXUAL SELECTION

Involves competition among males, such as the head-butting of bighorn sheep. The winner of the competition mates with the female.

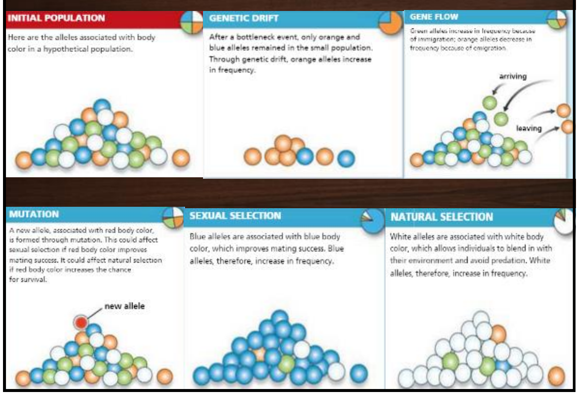
INTERSEXUAL SELECTION

Occurs when males display certain traits that attract the female, such as peacocks fanning out their tails.

HARDY-WEINBERG EQUILIBRIUM

- Research from Godfrey Hardy and Wilhelm Weinberg showed that genotype frequencies stay the same over time as long as certain conditions are met.
- There are five conditions needed for a population to stay in equilibrium. These populations are said to be in **Hardy-Weinberg equilibrium**.
  1. Very large population - No genetic drift can occur.
  2. No emigration or immigration - No gene flow can occur.
  3. No mutations – No new alleles can be added to the gene pool.
  4. Random mating – No sexual selection can occur.
  5. No natural selection – All traits must equally aid in survival.
- If any of the above are not met, then the population will evolve.
- Hardy and Weinberg concluded that evolution should be expected in all populations almost all of the time.
  - Their model shows that there are five factors that can lead to evolution.

5 FACTORS THAT CAN LEAD TO EVOLUTION



THE PROCESS OF SPECIATION

- A species is defined as a group of organisms that can interbreed to produce fertile offspring in nature.
- New species can arise when populations are isolated.
  - As these populations adapt to their environments, their gene pools may change.
  - Random processes such as mutation and genetic drift can also change gene pools.
- Genetic changes add up over many generations and the two isolated populations become more and more genetically different.
- **Reproductive isolation** occurs when members of different populations can no longer mate successfully.
  - Reproductive isolation between populations is the final step of becoming separate species.
- The rise of two or more species from one existing species is called **speciation.**

WHAT LEADS TO REPRODUCTIVE ISOLATION?

1. **Behavioral barriers**- members of a species developing different behaviors that interfere with their ability to interbreed
   - **Behavioral isolation** is caused by differences in courtship or mating behaviors.
   - Example: Male and female fireflies produce patterns of flashes that attract mates of their own species.
2. **Geographic barriers**- physical barriers dividing a population into two or more groups
   - **Geographic isolation** is caused by rivers, mountains, and dried lakebeds, etc.
   - Example: Salamanders with different color patterns in California.
3. **Temporal barriers**- barriers that involve timing
   - **Temporal isolation** exists when timing prevents reproduction between populations.
   - Example: The Monterey pine shreds its pollen in February, while the Bishop pine sheds its pollen in April. These pine species have likely evolved through temporal isolation.

APPLY YOUR KNOWLEDGE

1. What type of isolation refers to the fact that two crickets do not interbreed because one matures in the spring and the other matures in the fall?
2. Finches throughout the Galapagos islands differed greatly due to which type of isolation?
3. The whistle-like call of the eastern meadowlark can be easily distinguished from the flute-like call of its western cousin. This difference serves as a cue and prevents members of both populations from mating with each other. What type of isolation is this an example of?

EVOLUTION OCCURS IN PATTERNS

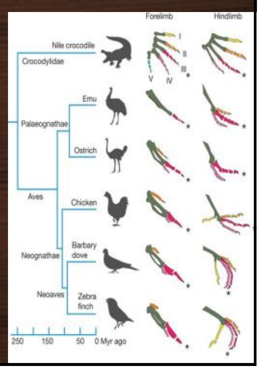
EVOLUTION THROUGH NATURAL SELECTION IS NOT RANDOM

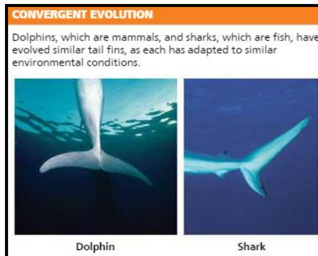
The effects of natural selection add up over many generations and push a population's traits in an advantageous direction.

1. **Convergent Evolution** – evolution toward similar characteristics in distantly related species
   - Similar traits develop because organisms are in **similar environments.**
   - You'd expect to see **analogous structures** present.

EVOLUTION THROUGH NATURAL SELECTION IS NOT RANDOM

2. **Divergent Evolution/Adaptive Radiation**– closely related species evolving in different directions to become increasingly different
   - The descendent species are usually adapted to a wide range of environments.
   - You'd expect to see **homologous structures.**
   - *Example: The variation in Darwin's finches on the Galapagos Islands.*





1. What type of structures are the dolphin and shark tail fins?

2. What type of structures would likely be examples of divergent evolution?

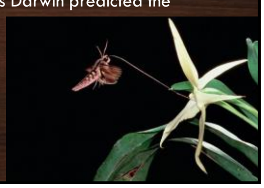
COEVOLUTION

Sometimes the evolutionary paths of two species become connected.

- These relationships form through **coevolution**.

Coevolution is the process in which two or more species evolve in response to changes in each other.

- Example: The Madagascar star orchid produces nectar at the bottom part of its slim, foot-long throat.
- After observing this specimen, Charles Darwin predicted the existence of a moth with a proboscis long enough to reach the nectar.
  - Sure enough, decades later, the giant hawk moth of Madagascar was discovered.



SPECIES CAN BECOME EXTINCT

Just as birth and death are natural events in the life of an individual, the rose and fall of species are natural processes of evolution.

The elimination of a species from Earth is called **extinction**.

- Extinction often occurs when a species as a whole is unable to adapt to a change in its environment.

- **Two types of extinction:**
  1. **Background Extinction-** extinctions that occur continuously but at a very low rate
  2. **Mass Extinction-** extinctions that occur suddenly in geologic time, usually because of a catastrophic event such as an ice age or asteroid impact

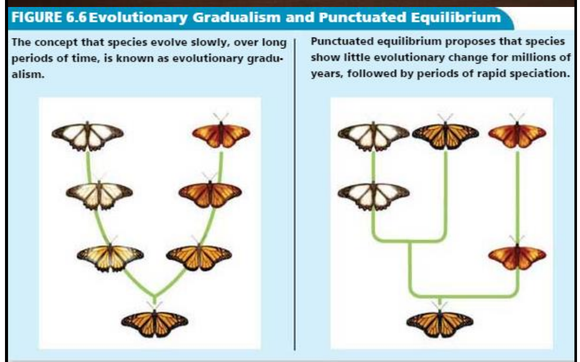
SPECIATION OFTEN OCCURS IN PATTERNS

Paleontologists have noticed repeating patterns in the history of life, reflected in the fossil record.

Two stand out from the rest:

1. **Gradualism**- evolutionary changes occur over long period of time

2. **Punctuated Equilibrium**- bursts of evolutionary activity (speciation) are followed by long periods of stability (stasis)



PUNCTUATED EQUILIBRIUM

Punctuated equilibrium can occur when some outside force, such as a catastrophe, causes disruption to a stable ecosystem.

- After a catastrophe, the organisms that are able to evolve quickly are more likely to survive.
- Other organisms will rapidly move into the area to fill empty **niches**.
- This can result in isolation of a population and lead to speciation.
- Example: The volcanic eruption of Mt. Saint Helens.