**Chapter 16 - Evolution of Populations**

Section 1 – Genes and Variation

* How Common Is Genetic Variation?
	+ Many genes have at least two forms, or \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
	+ All organisms have genetic variation that is “invisible” because it involves small differences in biochemical processes.
	+ An individual organism is heterozygous for many \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
* Variation and Gene Pools
	+ Genetic variation is studied in \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
	+ A population is a group of individuals of the same \_\_\_\_\_\_\_\_\_\_\_\_\_ that interbreed.
	+ A **gene \_\_\_\_\_\_\_\_\_\_\_\_\_\_** consists of all genes, including all the different alleles, that are present in a population.
	+ The **relative \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** of an allele is the number of times the allele occurs in a gene pool, compared with the number of times other alleles for the same gene occur.
	+ Relative frequency is often expressed as a percentage.



* How is evolution defined in genetic terms?
	+ In genetic terms, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is any change in the relative frequency of alleles in a population.
* Sources of Genetic Variation
	+ The two main sources of genetic variation are \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and the genetic shuffling that results from sexual \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
* Mutations
	+ A mutation is any change in a sequence of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
	+ Mutations occur because of mistakes in DNA replication or as a result of radiation or chemicals in the environment.
	+ Mutations do not always \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ an organism’s phenotype.
* Gene Shuffling
	+ Most heritable differences are due to gene \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
	+ Crossing-over increases the number of genotypes that can appear in offspring.
	+ Sexual reproduction produces different \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, but it does not change the relative frequency of alleles in a population.
* What determines the numbers of phenotypes for a given trait?
* Single-Gene and Polygenic Traits
	+ The number of phenotypes produced for a given trait depends on how many genes \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ the trait.
	+ A **single-gene trait** is controlled by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ gene that has two alleles. Variation in this gene leads to only two possible phenotypes.
		- The allele for a widow’s peak is dominant over the allele for a hairline with \_\_\_\_\_\_\_\_\_\_ peak.
		- However, the presence of a widow’s peak may be less common in a population.
		- In real populations, phenotypic ratios are determined by the frequency of alleles as well as by whether the alleles are \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ or recessive.
	+ Many traits are controlled by two or more genes and are called **\_\_\_\_\_\_\_\_\_\_\_\_\_\_ traits.**
		- One polygenic trait can have many possible genotypes and phenotypes.
		- \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ in humans is a polygenic trait.
	+ A \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_-shaped curve is typical of polygenic traits.
	+ A bell-shaped curve is also called \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ distribution.

Section 2 – Evolution as Genetic Change (Part 1)

* Natural selection affects which individuals survive and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and which do not.
* If an individual dies without reproducing, it does not contribute its alleles to the population’s gene \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
* If an individual produces many offspring, its alleles stay in the gene pool and may \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ in frequency.
* Evolution is any change over time in the relative frequencies of alleles in a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
* **Populations, not individual organisms, can evolve over time.**
* Natural Selection on Single-Gene Traits
	+ How does natural selection affect single-gene traits?
	+ Natural selection on single-gene traits can lead to changes in allele frequencies and thus to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
	+ Organisms of one color may produce fewer offspring than organisms of other colors.
		- For example, a lizard population is normally \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, but has mutations that produce red and black forms.
		- Red lizards are more visible to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, so they will be less likely to survive and reproduce. Therefore, the allele for red color will become rare.
		- Black lizards may warm up faster on cold days. This may give them energy to avoid predators. In turn, they may produce more \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
		- The allele for black color will \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ in relative frequency.

Black

Red

Brown

* Natural Selection on Polygenic Traits
	+ How does natural selection affect polygenic traits?
* Natural selection can affect the distributions of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ in any of three ways:
	+ **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ selection**
	+ **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ selection**
	+ **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ selection**
* Directional Selection
	+ When individuals at one end of the curve have higher fitness than individuals in the middle or at the other end, **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ selection** takes place.
	+ The range of phenotypes shifts as some individuals survive and reproduce while others do not.
		- In this case, birds with \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ beaks have higher fitness. Therefore, the average beak size increases.
* Stabilizing Selection
	+ When individuals near the center of the curve have higher fitness than individuals at either end of the curve, **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ selection** takes place.
	+ This keeps the center of the curve at its current position, but it \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ the overall graph.
		- Human babies born at an average mass are more likely to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ than babies born either much smaller or much larger than average.



* Disruptive Selection
	+ When individuals at the upper and lower ends of the curve have higher fitness than individuals near the middle, **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ selection** takes place.
	+ If the pressure of natural selection is strong enough and long enough, the curve will \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, creating two distinct phenotypes.
		- If average-sized seeds become \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, a bird population will split into two groups: one that eats small seeds and one that eats large seeds.



Section 2 – Evolution as Genetic Change (Part 2)

* Genetic Drift
* What is genetic drift?
	+ A random change in allele frequency is called **genetic \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**.
	+ In small populations, individuals that carry a particular allele may leave more descendants than other individuals do, just by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
	+ Over time, a series of chance occurrences of this type can cause an allele to become \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ in a population.
		- Genetic drift may occur when a small group of individuals colonizes a new \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
		- Individuals may carry alleles in different relative frequencies than did the larger population from which they \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
		- The new population will be genetically different from the parent population.

Descendents of Pop. A

Descendents of Pop. B

Founding Population A

Founding Population B

Sample of Original Population

* + When allele frequencies change due to migration of a small subgroup of a population it is known as the **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ effect.**
* Evolution Versus Genetic Equilibrium
	+ The **Hardy-Weinberg \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** states that allele frequencies in a population will remain constant unless one or more factors cause those frequencies to change.
	+ When allele frequencies remain constant it is called **genetic \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**.
* What five conditions are needed to maintain genetic equilibrium?
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_ conditions are required to maintain genetic equilibrium from generation to generation:
	+ **there must be random \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_,**
	+ **the population must be very large,**
	+ **there can be no \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ into or out of the population,**
	+ **there can be no \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, and**
	+ **there can be no natural \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.**
* Random Mating
	+ Random mating ensures that each individual has an equal chance of passing on its alleles to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
	+ In natural populations, mating is rarely completely random. Many species select mates based on particular heritable \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
* Large Population
	+ Genetic drift has less effect on large populations than on small ones.
	+ Allele frequencies of large populations are less likely to be \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ through the process of genetic drift.
* No Movement Into or Out of the Population
	+ Because individuals may bring new \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ into a population, there must be no movement of individuals into or out of a population.
	+ The population's gene pool must be kept together and kept separate from the gene pools of other \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
* No Mutations
	+ If genes mutate, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ alleles may be introduced into the population, and allele frequencies will change.
* No Natural Selection
	+ All genotypes in the population must have equal probabilities of survival and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
	+ No phenotype can have a selective advantage over another.
	+ There can be no natural \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ operating on the population.

Section 3 – The Process of Speciation (Part 1)

* Natural selection and chance events can change the relative frequencies of alleles in a population and lead to speciation.
* **Speciation** is the formation of new \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
* A species is a group of organisms that breed with one another and produce fertile \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
* What factors are involved in the formation of new species?
	+ The gene pools of two populations must become \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ for them to become new species.
* Isolating Mechanisms
	+ As new species evolve, populations become reproductively \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ from each other.
	+ When the members of two populations cannot interbreed and produce fertile offspring, reproductive \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ has occurred.
* Reproductive isolation can develop in a variety of ways, including:
	+ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ isolation
	+ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ isolation
	+ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ isolation
* Behavioral Isolation
	+ **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ isolation** occurs when two populations are capable of interbreeding but have differences in courtship rituals or other reproductive strategies that involve \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
* Geographic Isolation
	+ **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ isolation** occurs when two populations are separated by geographic barriers such as rivers or mountains.
	+ Geographic barriers do not guarantee the formation of new species.
	+ If two formerly separated populations can still interbreed, they remain a single \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
	+ Potential geographic barriers may separate certain types of organisms but not others.
* Temporal Isolation
	+ **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ isolation** occurs when two or more species reproduce at different \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
* Testing Natural Selection in Nature
	+ Studies showing natural selection in action involve descendants of the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ that Darwin observed in the Galápagos Islands.
	+ The finches Darwin saw were different, but he hypothesized that they had descended from a common \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

**THIS IS A VERY IMPORTANT PAGE**





Section 3 – The Process of Speciation (Part 2)

* Peter and Rosemary \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ tested Darwin’s hypothesis, which relied on two testable assumptions:
	+ For beak size and shape to evolve, there must be enough heritable variation in those traits to provide raw material for \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ selection.
	+ Differences in beak size and shape must produce differences in \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, causing natural selection to occur.
* The Grants tested these hypotheses on the medium ground \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ on Daphne Major, one of the Galápagos Islands.
	+ During the rainy season, there is plenty of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
	+ During droughts, food becomes scarce.
	+ Individual birds with different-sized beaks had different chances of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ during a drought.
	+ When food was scarce, individuals with large beaks were more likely to \_\_\_\_\_\_\_\_\_\_\_\_\_.
	+ The Grants provided evidence of the process of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
	+ Beak size can be \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ by natural selection.
* Speciation in Darwin's Finches
	+ Speciation in the Galápagos finches occurred by:
		- **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of a new population**
		- **geographic isolation**
		- **changes in new population's gene \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
		- **reproductive \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
		- **ecological competition**
* Founders Arrive
	+ A few finches—species A—\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ from South America to one of the Galápagos Islands.
	+ There, they survive and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
* Geographic Isolation
	+ Some birds from species A cross to a second \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
	+ The two populations no longer share a gene \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.



* Changes in the Gene Pool
	+ Seed sizes on the second island favor birds with \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ beaks.
	+ The population on the second island evolves into population B, with larger \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.



* Reproductive Isolation
	+ If population B birds cross back to the first island, they will not \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ with birds from population A.
	+ Populations A and B are separate \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
* Ecological Competition
	+ As species A and B compete for available seeds on the first island, they continue to evolve in a way that increases the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ between them.
	+ A new species—C—may evolve.
* Continued Evolution
	+ This process of isolation, genetic change, and reproductive isolation probably repeated itself often \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ the entire Galápagos island chain.
* Studying Evolution Since Darwin
	+ Scientific evidence supports the theory that living species descended with \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ from common ancestors that lived in the ancient past.
	+ Scientists predict that as new \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ are found, they will continue to expand our understanding of how species evolved.