EVOLUTION OF POPULATIONS
Genes and Variation
When Darwin developed his theory of evolution, he didn’t know how **HEREDITY** worked.

Mendel’s work on **inheritance in peas** was published during Darwin’s lifetime, but **NOT recognized** as important until _______________.
TODAY we can understand how evolution works better than Darwin ever could because of our knowledge about genes and DNA.
A **population** is a group of individuals of the same species that can interbreed and produce fertile offspring.
Because members of a population interbreed, they share a common group of genes called a **GENE POOL**

A gene pool consists of **ALL the genes** present in a population, including all the different **alleles**.
The **relative frequency** is the number of times that an allele occurs in the gene pool compared to the occurrence of other alleles in the gene pool.

**Sample Population**

- 48% heterozygous black
- 16% homozygous black
- 36% homozygous brown

**Frequency of Alleles**

- allele for brown fur
- allele for black fur

Image from BIOLOGY by Miller and Levine; Prentice Hall Publishing ©2006
RELATIVE FREQUENCY is often expressed as a percentage.

EX: In this population
Dominant B allele (black) = 40%
Recessive b allele (brown) = 60%
RELATIVE FREQUENCY has **NOTHING** to do with whether an allele is **DOMINANT** or **RECESSIVE**

In this population, the recessive allele is more frequent.
IN GENETIC TERMS

**EVOLUTION**

is any change in the relative frequency of alleles in a population

If the relative frequency of the B allele in this mouse population changed over time to 30%, the population is evolving.
BIOLOGISTS can now explain how the variation that DARWIN saw is produced!

A **mutation** is any change in a sequence of DNA.

**SOURCES OF MUTATIONS:**

- Mistakes in replication
- Chemicals
- Radiation

http://sickle.bwh.harvard.edu/scd_background.html
Many mutations are **LETHAL** and result in death.

Some mutations are **silent** and DON’T affect an organism’s **PHENOTYPE** at all.

EX: Changing the code from GGA to GGU doesn’t change the amino acid used
Mutations that change phenotype can affect an organism’s **fitness** (ability to survive and reproduce)
REMEMBER!

GENE SHUFFLING during **MEIOSIS**

Crossing over

Segregation

Independent Assortment

RESULT IN **GENETIC RECOMBINATION**
SEXUAL REPRODUCTION IS THE MAJOR SOURCE OF VARIATION IN POPULATIONS, but it does **NOT** change the **relative frequency** of alleles in population!

Shuffling a deck of cards can shuffle to produce many different hands, but doesn’t change the number of kings or queens in the deck.
During independent assortment, there are 23 chromosome “cards” that can be “shuffled” and “dealt” in 8.4 million combinations! Also, sometimes the “cards” you are dealt are brand-new and unique due to crossing over.
The number of **PHENOTYPES** produced for a given trait depends on the number of **GENES** that control that trait.

EX: Widow’s peak
    No widow’s peak

Single gene traits result in only **TWO** phenotypes.
In real populations, phenotypic ratios are determined not only by which allele is **DOMINANT**, but by **FREQUENCY** of the allele in the population.

Presence of widow’s peak in population can be less common even if it is **DOMINANT**!
POLYGENIC traits are controlled by two or more genes.

A bell shaped curve is typical of polygenic traits.

Graph from BIOLOGY by Miller and Levine; Prentice Hall Publishing ©2006
Each time an organism reproduces, it passes its genes on to the next generation.

So __________ = success in passing on genes

NATURAL SELECTION on single-gene frequencies can lead to changes in ALLELE FREQUENCIES and thus to EVOLUTION.

EX: A population of normally brown lizards. Mutations produce new color choices.

If red lizards are more visible to predators, they might be less likely to survive.

Bird image from: http://www.germanlis.com/creatures/TN_bird_eating_fish.JPG
Chart from BIOLOGY by Miller and Levine; Prentice Hall Publishing ©2006
Black lizards absorb more heat to warm up faster on cold days so they can move faster to get food and avoid predators. The allele for black may increase in frequency.

<table>
<thead>
<tr>
<th>Initial Population</th>
<th>Generation 10</th>
<th>Generation 20</th>
<th>Generation 30</th>
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<td>10%</td>
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<td>30%</td>
<td>60%</td>
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</tbody>
</table>

Chart from BIOLOGY by Miller and Levine; Prentice Hall Publishing ©2006
When traits are controlled by more than one gene, the effects are more complex.

Remember POLYGENIC traits show a bell-curve distribution.
The **FITNESS** of individuals near each other will not be very different, but fitness may vary from one end of curve to the other.

Where fitness varies, **NATURAL SELECTION** can act!
Natural selection can affect the distribution of phenotypes in 3 ways:

- **DIRECTIONAL** selection
- **STABILIZING** selection
- **DISRUPTIVE** selection
DIRECTIONAL SELECTION

Individuals at _____________ of the curve have higher fitness than individuals in middle or at other end.

Graph shifts as some individuals fail to survive at one end and succeed and reproduce at other
Beak size varies in a population

Birds with bigger beaks can feed more easily on harder, thicker shelled seeds.

Suppose a food shortage causes small and medium size seeds to run low.

Birds with bigger beaks would be selected for and increase in numbers in population.

http://www.animalbehavior.org/ABS/Stars/ONI/Podos_-_finch_graphic.jpg
STABILIZING SELECTION

Individuals in **CENTER** of the curve have higher fitness than individuals at either end.

Graph stays in same place but narrows as more organisms in middle are produced.
Male birds use their plumage to attract mates. Male birds in the population with less brilliant and showy plumage are less likely to attract a mate, while male birds with showy plumage are more likely to attract a mate.

Male birds with showier, brightly-colored plumage also attract predators, and are less likely to live long enough to find a mate. The most fit, then, is the male bird in the middle—showy, but not too showy.
Human babies born with low birth weight are less likely to survive.

Babies born too large have difficulty being born.

Average size babies are selected for.

http://www.animalbehavior.org/ABS/Stars/ONI/Podos_-_finch_graphic.jpg
DISRUPTIVE SELECTION

Individuals at _____________ of the curve have higher fitness than individuals in middle.

Can cause graph to split into two.

Selection creates __________________PHENOTYPES

EXTREMES

TWO DISTINCT
EXAMPLE OF DISRUPTIVE SELECTION

Suppose bird population lives in area where climate change causes medium size seeds become scarce while large and small seeds are still plentiful.

Birds with bigger or smaller beaks would have greater fitness and the population may split into TWO GROUPS. One that eats small seeds and one that eats large seeds.

http://www.animalbehavior.org/ABS/Stars/ONI/Podos__finch_graphic.jpg
Natural selection is NOT the only source of evolutionary change.

REMEMBER!
Genetics is controlled by **PROBABILITY**

The smaller the population . . .
the farther the **actual** results may be from the **predicted** outcomes.
In a small population this random change in allele frequency based on chance is called **GENETIC DRIFT**.

Genetic drift can occur when a **small** group of individuals colonizes a **new** habitat.

[Image: http://www.ucmp.berkeley.edu/fosrec/Filson.html]
Individuals may carry alleles in **different** relative frequencies than in the larger population.

The population they “found” will be different from the parent population . . . not through natural selection but by **chance**

http://www.ucmp.berkeley.edu/fosrec/Filson.html
A situation in which allele frequencies change as a result of the migration of a small subgroup of the population = **FOUNDING EFFECT**
ARE THERE ANY CONDITIONS IN WHICH EVOLUTION WILL NOT OCCUR?

IS THERE A WAY TO TELL IF THIS IS HAPPENING?

HARDY-WEINBERG PRINCIPLE
HARDY-WEINBERG PRINCIPLE states that allele frequency in a population will remain \textit{constant} unless one or more \textit{factors} cause the frequency to \textit{change}.

In a situation in which allele frequencies remain constant \( (= \text{Genetic equilibrium}) \), populations will NOT EVOLVE!
They developed an equation that predicted the relative frequency of alleles in a population based on the frequency of the phenotypes in a population.
The Hardy-Weinberg Equation

\[ p^2 + 2pq + q^2 = 1 \]

- \( p^2 \) = the frequency of homozygous dominant genotype
- \( 2pq \) = the frequency of heterozygous genotype
- \( q^2 \) = the frequency of homozygous recessive genotype
5 CONDITIONS REQUIRED TO MAINTAIN GENETIC EQUILIBRIUM FROM GENERATION TO GENERATION

1. Must be random mating
2. Population must be large
3. No movement in or out
4. No mutations
5. No natural selection
In order for **Random mating** to occur, all members of the population must have equal opportunity to produce offspring.

In natural populations, like **lions**, **wolves**, **elk**, or **mountain sheep**, members compete or even fight for the opportunity to mate so mating is **NOT RANDOM**

http://www.wasatchcomputers.net/gallery/elk_fight.jpg
Mating in populations is rarely **random**

Many species select mates based on certain **traits** such as size or strength.
For **genetic equilibrium** to occur, a population must be **large**, so **genetic drift** doesn’t cause changes in allele frequency by random chance.
NO MIGRATION can occur, since movement in and out of the population changes the frequency of alleles.
For **genetic equilibrium** to occur, there must be **NO mutations**, which introduce new **alleles**, and **NO natural selection** can take place which gives any one **phenotype** a survival advantage over another.
In some populations, these conditions may be met or nearly met over long periods of time, and little or no _______ occurs.

BUT in most populations it is _________ for _______ conditions of Hardy-Weinberg to be met.

In MOST populations . . . 

EVOLUTION happens!
5 Factors that cause a population to evolve

1. Variation
2. Natural selection
3. Sexual selection
4. Gene flow
5. Genetic drift
Variation

- Crossing over
- Independent assortment
- Random fertilization
- Mutations
Natural selection

Fitness
Adaptation
Phenotypic variations
Sexual selection

Choosing a mate
Selecting traits
Competition for mates
Gene flow

Movement of individuals
Immigration
Emigration
Genetic drift

Reduction in size of a population
Disease
War
Competition