Chapter 20
Mechanisms for Evolution
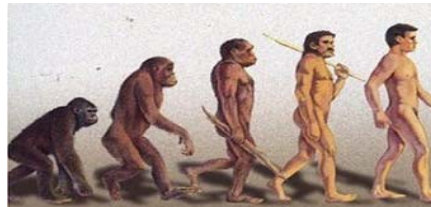
Biology 3201

20.1 – Population Genetics

☐ Evolution can be divided into two levels

1. **Macro-evolution**

2. **Micro-evolution**

Macroevolution vs. Microevolution

- Evolution on a large scale. It includes changes such as the evolution of new species from a common ancestor or the evolution of one species into two
- Ex. Evolution of the camel

- Evolution on a smaller scale. This is evolution within a particular species. It is also the change in the gene frequencies of a population over time
- Ex: Peppered moths

Heredity and Evolution

- Darwin's theory took a long time to gain acceptance because it was difficult to explain how traits were inherited

- Darwin's theory stated that new variants (variations) of a species arise in populations continuously. Some variants survive and produce more offspring while others die off

- However, the belief of the time was that characteristics which an individual obtained were blended as a result of an averaging of the characteristics from the organisms parents.

What was needed to get support?

- A way of explaining how variations arise by chance in populations

- Through the work of Gregor Mendel and others, the idea of natural selection gained support.

- In the 1930s, as the field of population genetics emerged, scientists showed that variations in a population could arise through changes called **mutations** in genes

- Since mutations can provide genetic variations within a population, evolution was now known to depend on both random genetic mutation and the mechanism of natural selection. This modern view of evolution is what we call **modern synthesis**

Population Genetics

- **Population** → a group of a single species which occupy a particular area.

- **Gene pool** → All of the genes in a population of organisms.

- Genetic variation can occur within a population or within an organism that makes up the population

Studying Populations

- Scientists use electrophoresis and polymerase chain reactions (PCR) to study variations in populations

- Population geneticists study the frequencies of alleles and genotypes in a population.
- By studying these frequencies they can determine any changes in the genetic variability of a population and thus determine if the population is undergoing micro-evolution.
- **Frequency** → number of occurrences of a particular allele in a population divided by the total number of alleles in a population.
- The frequencies of both alleles and genotypes within a population are called the populations **genetic structure**.

Section Review

- See Fig. 20.7, P. 679

- Do Practice problems, P. 680
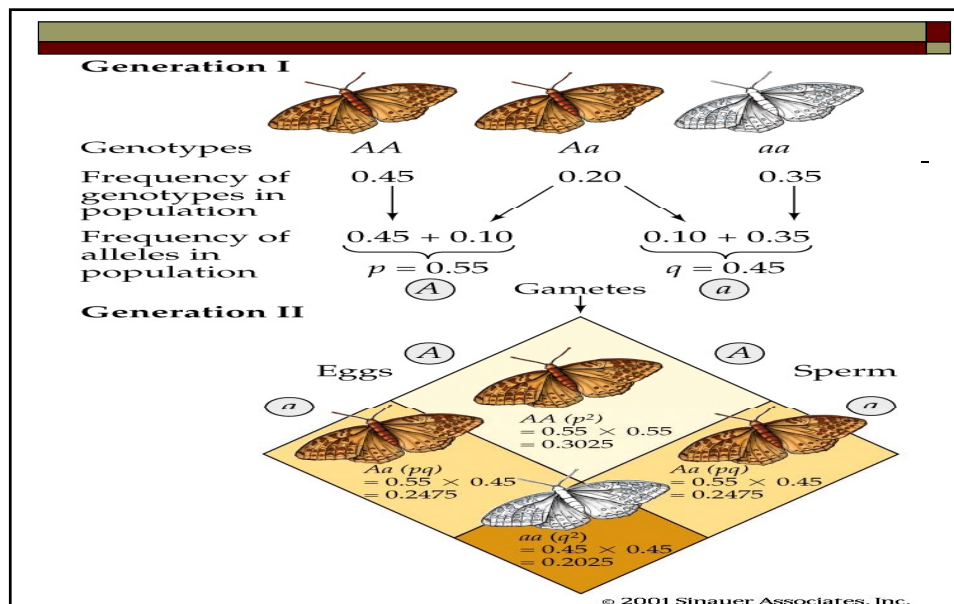
Section 20.2
Hardy-Weinberg Principle

☐ In order for a population to undergo change it must have genetic variation

☐ One way to determine how a population does change over time is to develop a model of a population that does not change from one generation to the next and compare this hypothetical model to an actual population which does change. This is called the **Hardy-Weinberg principle**

The Principle: Mathematically

$$p^2 + 2pq + q^2 = 1$$

☐ **p** → frequency of a dominant allele
☐ **q** → frequency of a recessive allele
☐ **p^2** → frequency of individuals who are homozygous for the dominant allele. Example: AA
☐ **2pq** → frequency of individuals who are heterozygous for alleles. Example Aa
☐ **q^2** → frequency of individuals who are homozygous for the recessive allele. Example aa

☐ In the Hardy-Weinberg principle, **p + q = 1**

☐ **Read over the example on page 681 in textbook**

Generation I

Genotypes | *AA* | *Aa* | *aa*
Frequency of genotypes in population | 0.45 | 0.20 | 0.35

Frequency of alleles in population: 0.45 + 0.10 $p = 0.55$ (A)   0.10 + 0.35 $q = 0.45$ (a)

Gametes

Generation II

(A) Eggs   (A) Sperm   (a)

$AA (p^2) = 0.55 \times 0.55 = 0.3025$

$Aa (pq) = 0.55 \times 0.45 = 0.2475$

$Aa (pq) = 0.55 \times 0.45 = 0.2475$

$aa (q^2) = 0.45 \times 0.45 = 0.2025$

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The Details

- The Hardy-Weinberg principle predicts the expected allele and genotype frequencies in an ideal population which is not subjected to selective pressure

- There are five conditions that MUST be met to maintain Hardy-Weinberg Equilibrium

The 5 Conditions of Hardy-Weinberg

1. **Random mating** →Mating must be totally random i.e. Females cannot select male mates with a particular genotype
2. **No mutations** → There must be no mutations of alleles (genes) in the gene pool of a population.
3. **Isolation** → Populations must be isolated from each other so that there is no exchange of genetic material between them.
4. **Large population size** → Number of organisms in the population must be very large
5. **No natural selection** → There can be no advantage of one genotype over another due to the process of natural selection.

☐ Natural populations **cannot** meet all of the conditions above, therefore Hardy-Weinberg equilibrium can only be met in an artificial environment such as a laboratory

20.3
Mechanisms for Genetic Variation

☐ **Five mechanisms that can lead to microevolution**

1. Mutation

2. Genetic Drift

3. Gene Flow

4. Non-Random Mating

5. Natural selection

Mutations I

☐ Mutations allow new alleles (genes) to form in a population and thus provides the variation needed for evolution to occur
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☐ When DNA mutates three things can occur to a body cell:

1. It dies
2. It malfunctions.
3. It multiplies into a tumor.

The mutation disappears when the organism dies

Mutations II

- In a gamete cells mutations are passed on to subsequent generations. The inherited mutations may have favorable, unfavorable or neutral effects on a population.

- **Favorable mutations** provide a selective advantage and may result in certain individuals that are capable of producing a disproportionate number of offspring, thus increasing the frequency of that allele in a population.

- **Neutral or unfavorable mutations** can be a source of variation which ultimately help a population survive given the right circumstances.

- Any mutation which gives an organism an advantage will help it survive and produce offspring when other organisms without the mutation will tend to die off. This results in changes to populations, changing the gene pool of the population, thus resulting in change or evolution.
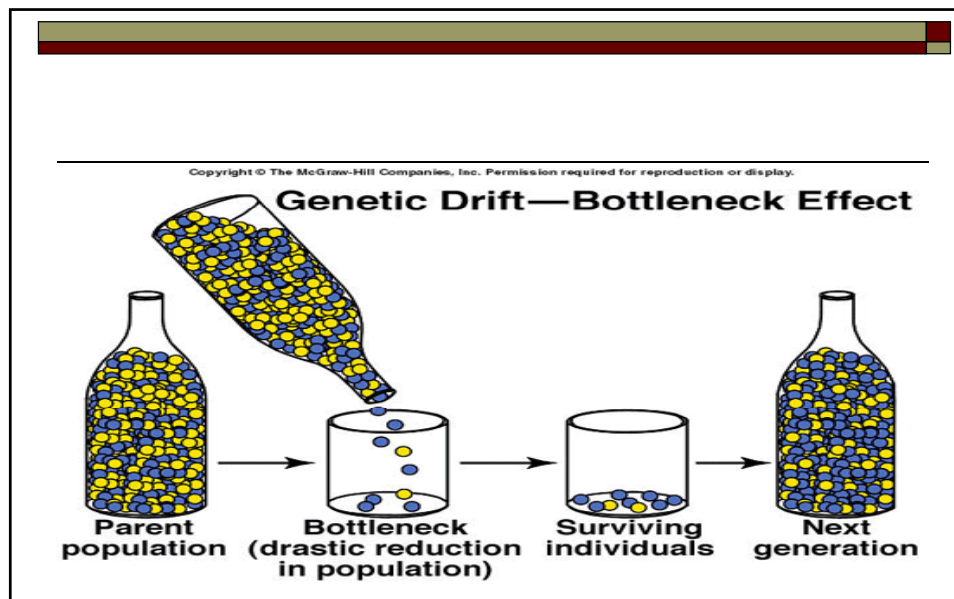
Genetic Drift I

- In a small population, the frequencies of particular alleles can be changed drastically by chance, this is called **genetic drift**.

- The smaller a sample size, the greater the chance of sampling error within a population.

- In population genetics, the sample size can greatly affect the gene pool of a population, the smaller the population, the less likely the parent gene pool will be reflected in the next generation, however, in a large population, there is a greater chance that the parent gene pool will be reflected in the next generation.

Genetic Drift II

- In any population, not all of the individuals in each generation will reproduce. This causes a shift in the allele frequencies in the next generation. With each subsequent generation, failure of all organisms to reproduce causes a further shift in allele frequencies.

- Shift in allele frequencies reduces the variability of a population, thus causing genetic drift.

- Although most populations are large enough to make the effects of genetic drift negligible, there are two situations which can cause genetic drift within these populations.
  1. **The Bottleneck Effect**
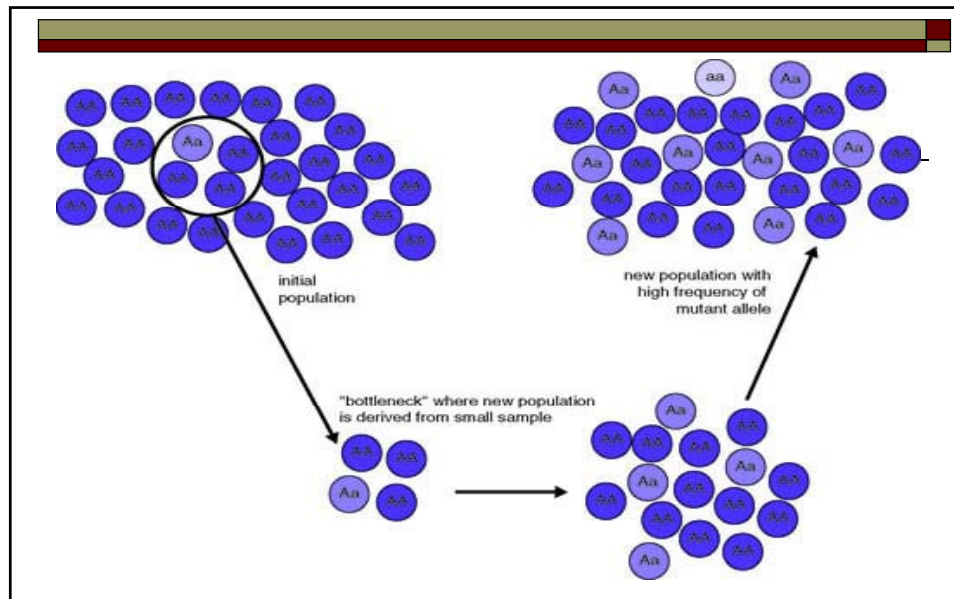 2. **The Founder Effect**

Bottleneck Effect

- □ Natural disasters such as earthquakes, floods, etc. as well as human interferences such as over-hunting or habitat destruction can cause populations to be reduced in numbers to the point where they are almost extinct.
- □ Because most of the original population dies off, the surviving population no longer represents the gene pool of the original population.
- □ Thus, certain alleles will be over-represented while others will be under-represented

Founder Effect

- This occurs when a small population of organisms colonize a new area.
- Due to the small size of the population, there is a good chance that all of the genes from the original parent population are not represented. Thus, any new population which is produced from this new, founder population will have an allele frequency which is different from the original population, this is the **founder effect**.
- As well, since the founding population is in a new environment which is different from that of the original population, different selective pressures will influence the gene pool of the population.
- The founder effect is important on islands and in other isolated habitats.

Gene Flow I

- □ To maintain its genetic equilibrium, the gene pool of a population would have to be completed isolated, however, this rarely occurs.

- □ Quite often new genes either move into or out of a population causing a change in the population's gene pool, this is called **gene flow**.

- □ Gene flow can reduce the genetic differences between populations.

Gene Flow II

- □ Over time, isolated populations can accumulate genetic differences due to the selective pressures of different environments.

- □ Gene flow between these different populations can reduce the differences between these two populations. Eventually, after extensive gene flow, two previously different populations may amalgamate into a single population with identical gene pools.

Non-random Mating I

- ☐ Random mating in a population will allow the population to maintain genetic equilibrium.

- ☐ However, not all organisms mate randomly, some take part in non-random mating.
- ☐ Two types of non-random mating are:
    1. Interbreeding
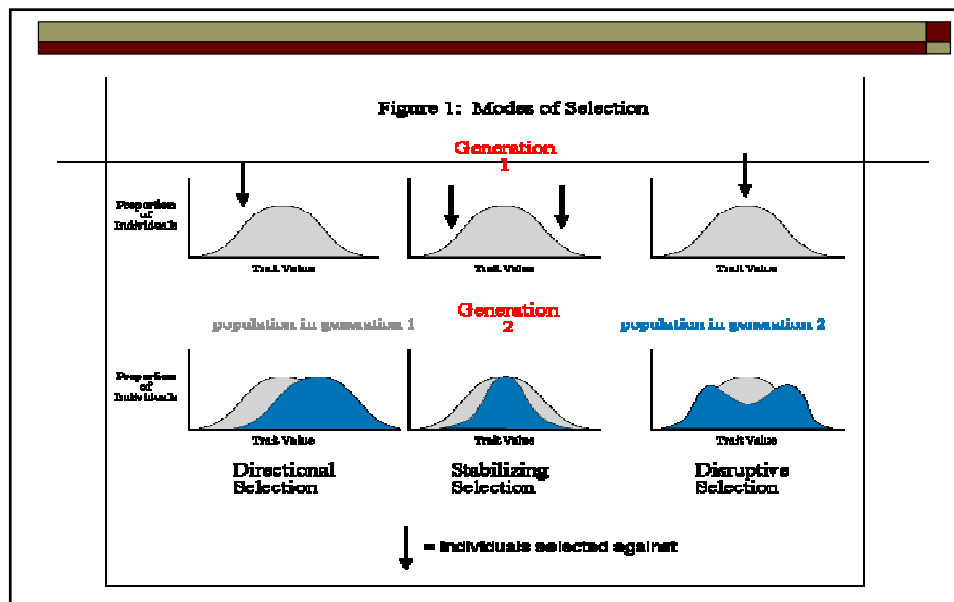   2. Assortative mating

Non-random Mating II

- ☐ Interbreeding, mating between closely related partners, does not change allele frequencies in a population. It results in a more homozygous population.

- ☐ Assortative mating occurs when individuals choose partners which have a similar phenotype to themselves. This type of mating results in a decrease in the genetic diversity of a population.

Natural Selection

- Populations have a range of phenotypes and genotypes and some individuals will leave more offspring than others.
- If even a single allele gives a slight selective advantage to a population, the frequency of the allele in the population will increase from one generation to the next.
- Organisms which have the favorable allele will survive and reproduce and pass this allele on to their offspring.
- Thus, natural selection will cause a change in a population's gene frequencies. There are three ways for this to occur:
    1. **Stabilizing selection**
    2. **Directional selection**
    3. **Disruptive selection**

Natural Selection II

- **Stabilizing selection** favors an intermediate phenotype and actually acts against extreme variations of a phenotype.   Thus, this type of selection reduces variation within a population so that the population will remain relatively constant.

- **Directional selection** favors the phenotypes at one extreme of a range over the other. This type of selection is common during times of environmental change or when a population migrates to a new habitat which has different environmental conditions.   Global climate change can also cause directional selection in some populations.

- **Disruptive selection** occurs when the extremes of a phenotypic range are favored over the intermediate phenotypes. This can result in the intermediate phenotype being eliminated from a population.

Figure 1: Modes of Selection

Sexual Selection I

- Sexual reproduction has evolved several times throughout the course of evolutionary history.

- Evolution has favored mutations that make a species' sperm smaller and eggs larger. Species tend to have many more sperm than eggs. Sperm tend to be mobile whereas eggs tend to be stationary.

- Evolution has also created a wide array of sexual behaviors and sexual attractants.

Sexual Selection II

- Males and females of many animal species have different physical characteristics. This difference between males and females is called **sexual dimorphism**.
- Differences in physical features, behaviors, etc. result in a type of selection which we call **sexual selection**.
- Sexual selection results in reproductive success allowing organisms to better survive and pass on their genetic material to the next generation.

Sexual Selection at work