❖ **3 Mendel, Hardy, and Weinberg**

• Reading: 7th edition 454-458; 6th edition 446-449

❖ **Response to the *Origin***

➢ *Wide acceptance of the fact of evolution*
• The publication of the *Origin* led to a scientific revolution. Most scientists quickly accepted Darwin's claim that evolution had occurred.
➢ *Disagreements about the pattern and mechanism*
• There was and still is disagreement about the pattern and mechanism proposed by Darwin.
• Many of Darwin's supporters did not agree with the gradual pattern. They thought that discontinuous changes also occurred. They argued that the absence of intermediate forms does not prove that they existed. If change had been discontinuous it was not necessary to explain what advantages intermediate forms had.
• Some supporters of Darwin's theory thought that natural selection was not sufficient to cause all of evolution.   Everyone agreed that that natural selection could cause changes in the way described in the *Origin*. The question was whether it was sufficient to have caused all changes in the history of life or whether additional mechanisms were needed.

❖ **Mendel plus Darwin**

➢ *Darwin did not have a convincing explanation for inheritance*
• The theory of natural selection was criticized because Darwin could not explain why differences among individuals persisted and how those differences are inherited. It appeared that natural selection would eliminate variation within species. In later editions of the *Origin*, Darwin changed his discussion of inheritance, but he never effectively resolved this problem.
➢ *Mendelian inheritance was rediscovered in 1900.*
• Mendel, in 1865, discovered what is now called Mendelian inheritance by studying characters in the common garden pea. His work was ignored at the time, but his achievements were later recognized when the same rules were rediscovered in 1900 and soon found to apply to a wide variety of plant and animal species, including humans.
• By the 1920s, there was general agreement that all of biological inheritance was attributable to Mendelian genes.
• The addition of Mendelian inheritance to Darwin's theory of natural selection led to what is called the "modern synthesis" or "neo-Darwinism."

❖ **Population genetics**

• Population genetics was developed in part to show that Darwin's theory of natural selection acting on Mendelian genes can cause evolution to occur and can also account for variation within species.

➢ *What is a population?*
- In theory, a population is a group of individuals of the same species that can freely interbreed and that is partly or wholly isolated from other populations of the same species.
- In practice, a population is often the group available for study or the group for which one has some data.
- A population is the basic unit of evolution. A species is made up of at least one and usually more than one population.

➢ *Genotype, phenotype, and allele frequencies*
- Calculating genotype frequencies and allele frequencies requires simple arithmetic. In the example of flower color on p. 456 in the text, the frequency of C^R, is 0.8 or 80%.
- Phenotype frequencies are derived from the genotype frequencies and dominance relationships of alleles.
- The essence of neo-Darwinism is that evolution results from changes in allele frequencies caused by natural selection and other factors. Species evolve because allele frequencies change. The genotype of each individual does not change.

❖ **Hardy and Weinberg**

➢ *The Hardy-Weinberg (HW) frequencies.*
- Soon after the rediscovery of Mendelism, G. H. Hardy and Wilhelm Weinberg independently predicted the allele and genotype frequencies in a group of offspring, given allele frequencies in their parents.
- They demonstrated that if the parents choose mates independently of genotype (randomly mate), then the fractions of the genotypes of the offspring are p^2, 2pq, q^2, where p and q are the frequencies of the two alleles (p+q=1). These are the Hardy-Weinberg (HW) frequencies.
- Note that the HW frequencies do not depend on the genotype frequencies in the parents, only on the allele frequencies.

➢ *Implication of the Hardy-Weinberg formula for evolution*
- Allele frequencies do not change as a result of random mating, which means that genetic variation is not lost.
- In later generations, allele and genotype frequencies remain the same. Consequently, if allele and genotype frequencies do change from one generation to the next, it is because some other force causes them to change.

➢ *Implication of the Hardy-Weinberg formula for human genetics*
- Genotypes in human populations (and in most species that do not self-fertilize) are usually very close to their HW frequencies.
- HW frequencies are the basis for genetic fingerprinting, which is used to establish that a suspect is the source of a biological sample (blood, skin etc.) found at a crime scene. As a simplified example, suppose that a crime-scene sample is found to be homozygous for an allele that is in frequency 0.01 in the general population, and a person suspected of the crime is homozygous for that allele. The implication is that the suspect is the source of the sample, because the chance that a randomly chosen individual left that sample is only 1/10,000. At present, 13 genetic loci, called the Combined DNA Index System (CODIS) loci are used

to establish genetic identity. CODIS loci are thought to have no effect on phenotype. State and federal databases currently contain records of more than 3 million genotypes.

- If an allele is in low frequency, 2pq is much larger than the frequency of individuals homozygous for that allele. Therefore, for a recessive genetic disease, there are many more heterozygous carriers of causative alleles than individuals with that disease. For example, the frequency of cystic fibrosis (CF) alleles in European populations is about 2% (1/2500 per live birth), implying that about 4% of the European population are carriers. Note that it does not matter whether the frequency of a causative allele is called p or q.

➢ *When deviations from HW frequencies are seen, the reason is usually interesting.*

- In many plant species few heterozygous individuals are found. For example, in wild oats, the genotype frequencies of one gene were found to be 0.548, 0.071, and 0.381. The explanation is that most reproduction in wild oats is by self-fertilization.

- An excess of heterozygous adults suggests that natural selection favors heterozygous newborns. For example, in a group of 30,923 adults in West Africa typed for the A and S alleles of the β-globin gene, 25,374 AA, 5482 AS, and 67 SS adults were found. The genotype frequencies are 0.821, 0.177 and 0.002 and allele frequencies are 0.909 and 0.091. The HW frequencies are 0.826, 0.165, 0.008. The differences between the observed and expected genotype frequencies are small but, because the sample is so large, the differences in the numbers of individuals with the three genotypes is important: we would expect to find 203 SS individuals but only 67 were present. This data set indicates that AA and SS individuals have a lower chance of surviving to adulthood than do AS individuals in the region where the sample was taken.

❖ **Sample questions (correct answer is underlined)**

➢ *Which statement best describes the neo-Darwinian synthesis?*
a. Evolution is caused by changes within species in allele frequencies.
b. Evolution is caused by Mendelian inheritance.
c. Evolution occurs because some individuals are heterozygous at some loci.
d. Evolution occurs because some individuals are homozygous at some loci..
e. Evolution of characters affected by Mendelian alleles cannot occur.
➢ *Which of the following population samples is closest to the Hardy-Weinberg frequencies?*
a. AA 600, Aa 300, aa 100.
b. AA 500, Aa 500, aa 500.
c. AA 700, Aa 200, aa 100.
d. AA 340, Aa 320, aa 340.
e. AA 640, Aa 320, aa 40
➢ *If one individual in 1,000,000 has a genetic disease caused by a recessive Mendelian allele, roughly what fraction of individuals in a randomly mating population are heterozygous carriers of this disease allele?*
a. 2/1,000,000.
b. 2/100,000.

    c. 2/10,000.
    d. <u>2/1,000</u>.
    e. 2/100.
    ➢ *If the frequencies of the three genotypes in a population, AA, Aa, and aa are 0.5, 0.2, and 0.3 (in order), the frequency of the A allele is*
    a. 0.3.
    b. 0.4.
    c. 0.5.
    d. <u>0.6</u>.
    e. 0.7.