**Sexual Reproduction Learning Objectives**

1. **In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle and mitosis or meiosis plus fertilization.**
   1. Meiosis, a reduction division, followed by fertilization ensures genetic diversity in sexually reproducing organisms.
      1. Meiosis ensures that each gamete receives one complete haploid (1n) set of chromosomes.
      2. During meiosis, homologous chromosomes are paired, with one homologue originating from the maternal parent and the other from the paternal parent. Orientation of the chromosome pairs is random with respect to the cell poles.
      3. Separation of the homologous chromosomes ensures that each gamete receives a haploid (1n) set of chromosomes composed of both maternal and paternal chromosomes.
      4. During meiosis, homologous chromatids exchange genetic material via a process called “crossing over,” which increases genetic variation in the resultant gametes.
      5. Fertilization involves the fusion of two gametes, increases genetic variation in populations by providing for new combinations of genetic information in the zygote, and restores the diploid number of chromosomes.
2. **The chromosomal basis of inheritance provides an understanding of the pattern of passage (transmission) of genes from parent to offspring.**
   1. Rules of probability can be applied to analyze passage of single gene traits from parent to offspring.
   2. Segregation and independent assortment of chromosomes result in genetic variation.
      1. Segregation and independent assortment can be applied to genes that are on different chromosomes.
      2. Genes that are adjacent and close to each other on the same chromosome tend to move as a unit; the probability that they will segregate as a unit is a function of the distance between them.
      3. The pattern of inheritance (monohybrid, dihybrid, sex-linked, and genes linked on the same homologous chromosome) can often be predicted from data that gives the parent genotype/phenotype and/or the offspring phenotypes/genotypes.
   3. Certain human genetic disorders can be attributed to the inheritance of single gene traits or specific chromosomal changes, such as nondisjunction.
      1. *For example:*

• Sickle cell anemia

• Tay-Sachs disease

• Huntington’s disease

• X-linked color blindness

• Trisomy 21/Down syndrome

• Klinefelter’s syndrome

* 1. Many ethical, social and medical issues surround human genetic disorders.
     1. *For example:*

• Reproduction issues

• Civic issues such as ownership of genetic information, privacy, historical contexts, etc.

1. **The inheritance pattern of many traits cannot be explained by simple Mendelian genetics.**
   1. Many traits are the product of multiple genes and/or physiological processes.
   2. Patterns of inheritance of many traits do not follow ratios predicted by Mendel’s laws and can be identified by quantitative analysis, where observed phenotypic ratios statistically differ from the predicted ratios.
   3. Some traits are determined by genes on sex chromosomes.
      1. *For example:*

• Sex-linked genes reside on sex chromosomes (X in humans).

• In mammals and flies, the Y chromosome is very small and carries few genes.

• In mammals and flies, females are XX and males are XY; as such, X-linked recessive traits are always expressed in males.

• Some traits are sex limited, and expression depends on the sex of the individual, such as milk production in female mammals and pattern baldness in males.

* 1. Some traits result from nonnuclear inheritance.
     1. Chloroplasts and mitochondria are randomly assorted to gametes and daughter cells; thus, traits determined by chloroplast and mitochondrial DNA do not follow simple Mendelian rules.
     2. In animals, mitochondrial DNA is transmitted by the egg and not by sperm; as such, mitochondrial-determined traits are maternally inherited.

***X Epistasis and pleiotropy are beyond the scope of the course and the AP Exam.***

1. **Changes in genotype can result in changes in phenotype.**
   1. Errors in mitosis or meiosis can result in changes in phenotype.
      1. Changes in chromosome number often result in new phenotypes, including sterility caused by triploidy and increased vigor of other polyploids.
      2. Changes in chromosome number often result in human disorders with developmental limitations, including Trisomy 21 (Down syndrome) and XO (Turner syndrome).
2. **Biological systems have multiple processes that increase genetic variation.**
   1. Sexual reproduction in eukaryotes involving gamete formation, including crossing-over during meiosis and the random assortment of chromosomes during meiosis, and fertilization serve to increase variation. Reproduction processes that increase genetic variation are evolutionarily conserved and are shared by various organisms.

***X The details of sexual reproduction cycles in various plants and animals are beyond the scope of the course and the AP Exam. However, the similarities of the processes that provide for genetic variation are relevant and should be the focus of instruction.***

1. **Variation in molecular units provides cells with a wider range of functions.**
   1. Multiple copies of alleles or genes (gene duplication) may provide new phenotypes.
      1. A heterozygote may be a more advantageous genotype than a homozygote under particular conditions, since with two different alleles, the organism has two forms of proteins that may provide functional resilience in response to environmental stresses.
      2. Gene duplication creates a situation in which one copy of the gene maintains its original function, while the duplicate may evolve a new function.
2. **Environmental factors influence the expression of the genotype in an organism.**
   1. Environmental factors influence many traits both directly and indirectly.
      1. *For example:*

• Height and weight in humans, flower color based on soil pH, seasonal fur color, effect of increased UV on melanin production, etc.