SECTION 6.1

CHROMOSOMES AND MEIOSIS

Reinforcement

KEY CONCEPT  Gametes have half the number of chromosomes that body cells have.

Your body is made of two basic cell types. One basic type are somatic cells, also called body cells, which make up almost all of your tissues and organs. The second basic type are germ cells, which are located in your reproductive organs. They are the cells that will undergo meiosis and form gametes. Gametes are sex cells. They include eggs and sperm cells.

Each species has a characteristic number of chromosomes per cell. Body cells are diploid, which means that each cell has two copies of each chromosome, one from each parent. Gametes are haploid, which means that each cell has one copy of each chromosome. Gametes join together during fertilization, which is the actual fusion of egg and sperm, and restores the diploid number.

The diploid chromosome number in humans is 46. Your cells need both copies of each chromosome to function properly. Each pair of chromosomes is called homologous. Homologous chromosomes are a pair of chromosomes that have the same overall appearance and carry the same genes. One comes from the mother, and one comes from the father. Thus, one chromosome from a pair of homologous chromosomes might carry a gene that codes for green eye color, while the other carries a gene that codes for brown eye color.

For reference, each pair of homologous chromosomes has been numbered, from largest to smallest. Chromosome pairs 1 through 22 are autosomes. Autosomes are chromosomes that contain genes for characteristics not directly related to sex. The two other chromosomes are sex chromosomes, chromosomes that directly control the development of sexual characteristics. In humans, a woman has two X chromosomes, and a man has an X and a Y chromosome. The Y chromosome is very small and carries few genes.

Meiosis is a form of nuclear division that reduces chromosome number from diploid to haploid. Each haploid cell produced by meiosis has 22 autosomes and 1 sex chromosome.

1. How do gametes differ from somatic cells?

2. The prefix homo- means “the same.” Explain how this meaning relates to the definition of homologous chromosomes.

3. How does meiosis relate to haploid cells? How does fertilization relate to diploid cells?
SECTION 6.2 PROCESS OF MEIOSIS

Reinforcement

KEY CONCEPT During meiosis, diploid cells undergo two cell divisions that result in haploid cells.

Meiosis occurs after a cell has already duplicated its DNA. Cells go through two rounds of cell division during meiosis. During the first round, meiosis I, homologous chromosomes separate from each other. During the second round, meiosis II, sister chromatids separate from each other. Meiosis produces genetically unique haploid cells that will go through more steps to form mature gametes.

Meiosis is a continuous process, but scientists have divided it into phases.

- **Prophase I:** The nuclear membrane breaks down, and the spindle fibers assemble. The duplicated chromosomes condense, and homologous chromosomes pair up. The sex chromosomes also pair together.
- **Metaphase I:** The homologous chromosome pairs randomly line up along the middle of the cell. Because this is random, there are a mixture of chromosomes from both parents on each side of the cell equator.
- **Anaphase I:** The paired homologous chromosomes separate from each other and move to opposite sides of the cell.
- **Telophase I:** The nuclear membrane forms in some species, the spindle fibers break apart, and the cell undergoes cytokinesis. Each cell has 23 duplicated chromosomes.
- **Prophase II:** The nuclear membrane breaks down if necessary and the spindle fibers assemble again.
- **Metaphase II:** The chromosomes line up along the middle of the cell.
- **Anaphase II:** The sister chromatids are pulled apart from each other and move to opposite sides of the cell.
- **Telophase II:** The nuclear membranes form again, the spindle fibers break apart, and the cell undergoes cytokinesis.

The haploid cells produced by meiosis are not capable of fertilization. They must undergo additional steps to form mature gametes. During **gametogenesis**, sperm cells—the male gametes—and eggs—the female gametes—become specialized to carry out their functions. Sperm cells lose much of their cytoplasm and develop a tail. Eggs receive almost all of the cytoplasm during the divisions in meiosis. This is necessary for an embryo to have all the materials needed to begin life after fertilization. The smaller cells produced by meiosis in the female are called **polar bodies**, and they are eventually broken down.

1. During which phase do homologous chromosomes separate?

2. During which phase do sister chromatids separate?
SECTION 6.3
MENDEL AND HEREDITY
Reinforcement

KEY CONCEPT
Mendel’s research showed that traits are inherited as discrete units.

Traits are inherited characteristics, and genetics is the study of the biological inheritance of traits and variation. Gregor Mendel, an Austrian monk, first recognized that traits are inherited as discrete units. We call these units genes. Mendel conducted his experiments with pea plants, which were an excellent choice because they are easily manipulated, produce large numbers of offspring, and have a short life cycle. Mendel made three important decisions that helped him to see patterns in the resulting offspring.

• Use of purebred plants: Mendel used pea plants that had self-pollinated for so long that they had become genetically uniform, or purebred. This meant that the offspring looked like the parent plant. Because of this characteristic, Mendel knew that any differences he observed in the offspring were the result of his experiments.

• Control over breeding: At the start of his experiments, Mendel removed the male flower parts from the pea plants. He then pollinated the female flower part with pollen from a plant of his choosing, which produced offspring referred to as the F1 generation.

• Observation of “either-or” traits: Mendel studied seven traits that appeared in only two forms. For example, flowers were white or purple; peas were wrinkled or round.

Mendel observed that when he mated, or crossed, a purple-flowered plant with a white-flowered plant, for example, all of the F1 offspring had purple flowers. Mendel next allowed the F1 offspring to self-pollinate; that is, the plant mated with itself. In the resulting offspring, the F2 generation, approximately three-fourths of the flowers were purple and one-fourth were white. Mendel continued to find this 3:1 ratio for each of his crosses, regardless of the specific trait he was examining.

Based on his results, Mendel concluded that traits are inherited as discrete units. He also developed what is known as Mendel’s first law, or the law of segregation. This law states the following:

• Organisms inherit two copies of each unit (gene), one from each parent.

• The two copies separate, or segregate, during gamete formation. As a result, organisms donate only one copy of each unit (gene) in their gametes.

1. In which generation of offspring did Mendel observe a 3:1 ratio in the appearance of the offspring?

2. What is segregating in the law of segregation? When does this segregation occur?
SECTION 6.4
TRAITS, GENES, AND ALLELES
Reinforcement

**KEY CONCEPT** Genes encode proteins that produce a diverse range of traits.

A gene is a segment of DNA that tells the cell how to make a particular polypeptide. The location of a gene on a chromosome is called a locus. A gene has the same locus on both chromosomes in a pair of homologous chromosomes. In genetics, scientists often focus on a single gene or set of genes. Genotype typically refers to the genetic makeup of a particular set of genes. Phenotype refers to the physical characteristics resulting from those genes.

An alternative form of a gene is an allele. The pea plants that Mendel worked with had two alleles for each gene. For example, there was an allele for round peas and an allele for wrinkled peas. Genes are not limited to two alleles, however. Some genes are found in many different forms throughout a population.

Your cells have two alleles for each gene regardless of how many alleles are present in a population. Suppose there were 64 alleles of a hair color gene present in the human population. Your cells would only have two of those alleles, one from your mother and one from your father. If the two alleles are the same, they are homozygous. If the two alleles are different, they are heterozygous.

Some alleles are dominant over others.

- A dominant allele is expressed when two different alleles or two dominant alleles are present. Therefore, both homozygous dominant and heterozygous genotypes can produce the dominant phenotype.

- A recessive allele is expressed only when both alleles are recessive. Therefore, only the homozygous recessive genotype can produce the recessive phenotype.

Alleles may be represented using letters. Uppercase letters represent dominant alleles. Lowercase letters represent recessive alleles.

1. If you were to make an analogy and say that genotype is like blueprints, how would you complete the analogy to describe phenotype?

2. Use the letters B and b to represent the following genotypes: heterozygous, homozygous recessive, homozygous dominant.
KEY CONCEPT  The inheritance of traits follows the rules of probability.

The possible genotypes resulting from a cross can be predicted using a Punnett square. A Punnett square is a grid. The axes are labeled with the alleles of each parent organism. The grid boxes show all of the possible genotypes of the offspring resulting from those two parents.

A monohybrid cross is used when studying only one trait. A cross between a homozygous dominant organism and a homozygous recessive organism produces offspring that are all heterozygous and have the dominant phenotype. A cross between two heterozygous organisms results in a 3:1 phenotypic ratio in the offspring, where three-fourths have the dominant phenotype and one-fourth have the recessive phenotype. The genotypic ratio resulting from this cross is 1:2:1 of homozygous dominant:heterozygous:homozygous recessive.

A testcross is a cross between an organism with an unknown genotype (dominant phenotype) and an organism with the recessive phenotype. If the organism with the unknown genotype is homozygous dominant, the offspring will all have the dominant phenotype. If it is heterozygous, half the offspring will have the dominant phenotype, and half will have the recessive phenotype.

A dihybrid cross is used when studying the inheritance of two traits. Mendel’s dihybrid crosses helped him develop the law of independent assortment, which basically states that different traits are inherited separately. When two organisms that are heterozygous for both traits are crossed, the resulting phenotypic ratio is 9:3:3:1.

Probability is the likelihood that a particular event, such as the inheritance of a particular allele, will happen. The events of meiosis and fertilization are random, so hereditary patterns can be calculated with probability.

On a separate sheet of paper, draw a Punnett square for a cross between organisms that have the genotypes Bb and bb. Use the Punnett square to answer the following questions.

1. Is this a monohybrid cross or a dihybrid cross?

2. What is the genotypic ratio of the offspring?

3. What is the phenotypic ratio of the offspring?
** KEY CONCEPT ** Independent assortment and crossing over during meiosis result in genetic diversity.

In organisms that reproduce sexually, the independent assortment of chromosomes during meiosis and the random fertilization of gametes creates a lot of new genetic combinations. In humans, for example, there are over 64 trillion different possible combinations of chromosomes. Sexual reproduction creates genetically unique offspring that have a combination of both parents’ traits. This uniqueness increases the likelihood that some organisms will survive or even flourish in changing conditions.

Genetic diversity is further increased through crossing over. Crossing over is the exchange of segments of chromosomes between homologous chromosomes. It happens during prophase I of meiosis I when homologous chromosomes pair up with each other and come into very close contact. At this stage, the chromosomes have already been duplicated. Part of a chromatid from each homologous chromosome may break off and reattach to the other chromosome.

Crossing over is more likely to occur between genes that are far apart from each other on a chromosome. The likelihood that crossing over will happen is much less if two genes are located close together. Thus, genes that are located close together on a chromosome have a tendency to be inherited together, which is called genetic linkage. Most of the traits that Mendel studied were located on separate chromosomes, and so they assorted independently. When genes are on the same chromosome, however, their distance from each other is a large factor in how they assort. If they are far apart, crossing over is likely to occur between them and so they will assort independently. If they are close together, they are unlikely to be separated by crossing over and so they will not assort independently.

1. What factors contribute to genetic diversity?

2. What is crossing over?

3. If two genes are located close together on the same chromosome, are they likely to follow Mendel’s law of independent assortment? Explain.