Chapter 6

Inheritance

6.2 Cell Division and Genetic Diversity

You have learned that some cells reproduce through a type of cell division called mitosis. In mitosis, one cell divides into two daughter cells, each of which contains the same genetic information as the original cell. **Meiosis** is another type of cell division. Meiosis is used to make haploid cells, such as eggs and sperm. In meiosis, one diploid cell, with two of each kind of chromosome, divides into four haploid cells, each with only one of each kind of chromosome. The normal diploid chromosome number is restored during sexual reproduction when sperm and egg fuse at fertilization (Figure 6.5).

When meiosis begins, the diploid cell has already copied its DNA. Meiosis takes place in two steps: *meiosis I* and *meiosis II* (Figure 6.6). During meiosis I, the original cell divides into two cells. During meiosis II, these two cells divide again to produce four haploid cells.

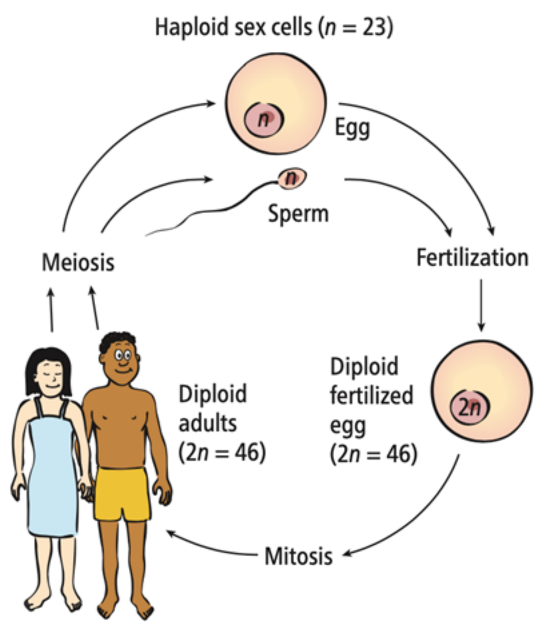
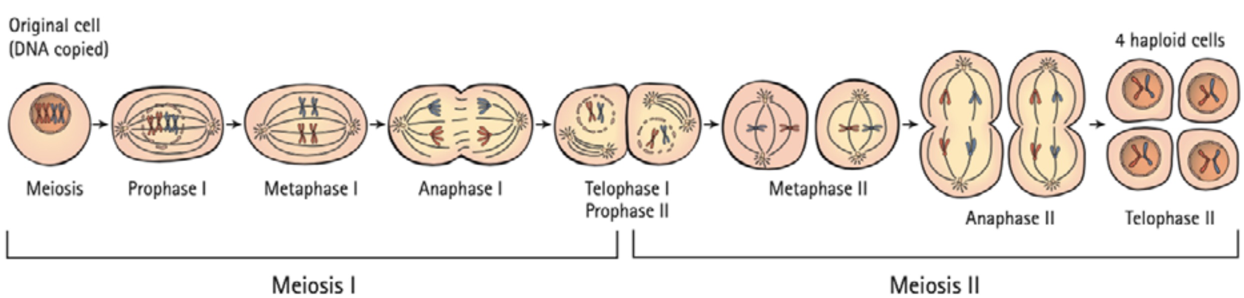


FIGURE 6.5

Sperm and eggs are haploid cells produced during meiosis. At fertilization, sperm and egg fuse to make a diploid cell. This diploid cell develops into a diploid individual (right).

FIGURE 6.6

Meiosis produces four haploid cells (below).

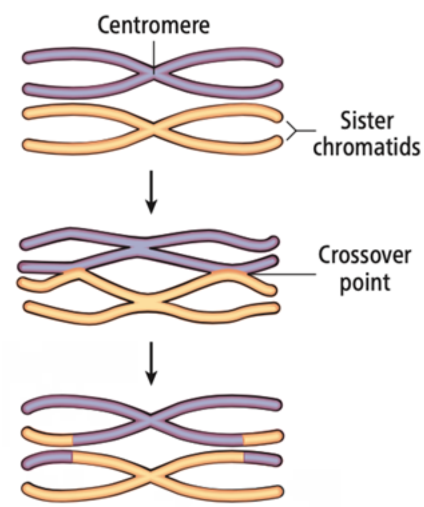


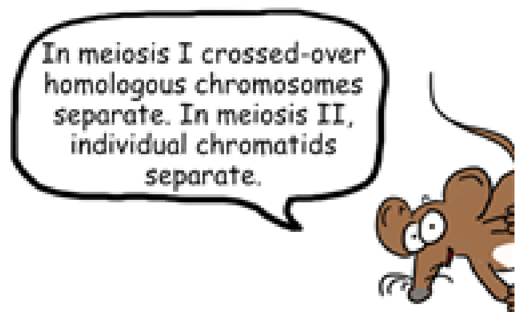
Meiosis I begins with prophase I. During *prophase I*, the chromosomes condense and the membranes of the nucleus break down. As in mitosis, each chromosome includes two identical sister chromatids. Homologous chromosomes then line up with each other, and a process known as *crossing over* occurs. In crossing over, a chromosome exchanges parts with its homologous chromosome (Figure 6.7). As a result, the chromosomes in the dividing cell are no longer identical to the ones in the original cell. Instead, many chromosomes now include parts of *each* of the two original homologous chromosomes. On a genetic level, crossing over results in **recombination**, the production of new combinations of genes different from those found in the original chromosomes. We'll see why this is important when we consider how meiosis produces genetic diversity.

In *metaphase I*, homologous chromosomes line up in the middle of the cell. In *anaphase I*, the homologous chromosome pairs separate. In *telophase I*, the chromosomes move to opposite ends of the cell. Cytokinesis occurs, producing two cells.

FIGURE 6.7

During meiosis, homologous chromosomes exchange genetic material in a process called crossing over. The result of crossing over is that chromosomes end up with parts of each of the two original homologous chromosomes, as indicated in this illustration by the exchanged colors.





Meiosis II is similar to meiosis I, except for a few key differences. During *metaphase II*, the single, unpaired chromosomes (as opposed to homologous chromosome pairs) move to the center of the cell. In *anaphase II*, the sister chromatids separate. In *telophase II*, the sister chromatids move to opposite ends of the cell. Cytokinesis occurs, producing four haploid cells.

A mistake during meiosis can cause a sperm or egg to end up with the wrong number of chromosomes. In humans, embryos produced by these sex cells usually do not survive, but there are exceptions. One of the most common chromosomal abnormalities is having three copies of chromosome 21, which is called trisomy 21. Trisomy 21 causes Down syndrome, a condition characterized by mental retardation and defects of the heart and respiratory system.

How Meiosis and Sexual Reproduction Produce Genetic Diversity

Siblings often resemble each other, but they're not exactly alike. This is because the eggs and sperm of their parents are all different, and so the siblings receive different genes. Many different factors contribute to this genetic diversity.

First, crossing over during meiosis increases the genetic diversity of an individual's sperm or eggs. How? At the start of meiosis, our cells have two of each kind of chromosome—a maternal chromosome from our mother and a paternal chromosome from our father.

Every time meiosis occurs, crossing over takes place. But—here's the key—crossing over takes place at a different point along the chromosome every time. This means that each chromosome in our eggs and sperm is a unique mix of our maternal and paternal chromosomes.

Even without crossing over, though, all our sex cells would be different. This is because homologous chromosomes separate independently during meiosis I. One egg might get maternal chromosomes 1, 3, 4, 5, and so on and paternal chromosomes 2, 6, 7, 8, and so on. A second egg is almost certain to get different chromosomes, perhaps maternal chromosomes 2, 3, 5, 6, and so on and paternal chromosomes 1, 4, 7, 8, and so on (Figure 6.8). There are a huge number of possibilities!

Finally, during fertilization, when an egg and sperm join, genetic material is brought together in different ways. Each of the many different possible eggs can join with each of many different possible sperm.

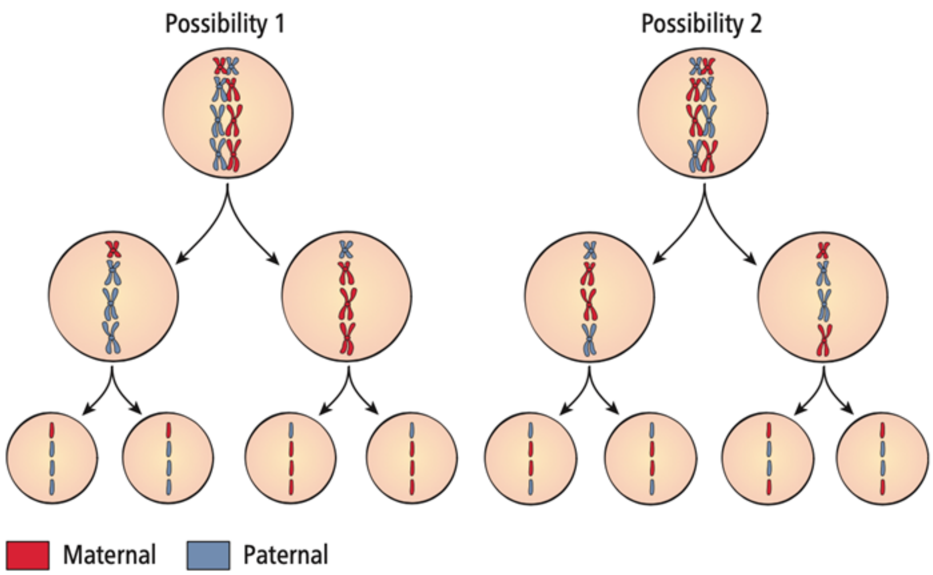


FIGURE 6.8

Each time meiosis occurs, the resulting cells receive different combinations of maternal and paternal chromosomes. This figure shows just two possibilities when meiosis occurs in an organism with 4 pairs of chromosomes. With the 23 pairs found in humans, the number of possibilities is exceedingly large.

Comparing Mitosis and Meiosis

There are three key differences between mitosis and meiosis: (1) Mitosis produces two cells; meiosis produces four cells. (2) Mitosis produces diploid cells; meiosis produces haploid cells. (3) The cells produced by mitosis are identical to one another and to the original cell; the cells produced by meiosis are all different.

READING CHECK

Name two ways in which meiosis contributes to genetic diversity in the eggs or sperm of an individual.

CHECK YOUR ANSWER

1. Crossing over during meiosis increases the genetic diversity of an individual's sperm or eggs. Because crossing over takes place at different points along the chromosome every time, chromosomes in eggs and sperm end up as unique mixes of maternal and paternal chromosomes.

2. Homologous chromosomes separate independently during meiosis I, so that every cell receives a different combination of maternal and paternal chromosomes.