11–4 Meiosis

Gregor Mendel did not know where the genes he had discovered were located. Fortunately, his predictions of how genes should behave were so specific that it was not long before biologists were certain they had found them—on the chromosomes. The chromosomal theory of inheritance states that genes are located in specific positions on chromosomes.

Mendel's principles of genetics require at least two things. First, each organism must inherit a single copy of every gene from each of its "parents." A single copy of every chromosome is indeed passed along from parent to offspring in this way. Second, when an organism produces its own gametes, those two sets of genes must be separated so that each gamete contains just one set of genes. Chromosomes are separated in exactly this way during gamete formation, just as the chromosomal theory of inheritance would predict.

Guide for Reading

Key Concepts
- What happens during the process of meiosis?
- How is meiosis different from mitosis?

Vocabulary
homologous
diploid
haploid
meiosis
tetrad
crossing-over

Reading Strategy: Using Visuals Before you read, preview **Figure 11–15.** As you read, note what happens at each stage of meiosis.

Chromosome Number

As an example of how chromosomal inheritance works, let's consider the fruit fly, *Drosophila.* A body cell in an adult fruit fly has 8 chromosomes, as shown in **Figure 11–14.** Four of the chromosomes came from the fruit fly's male parent, and 4 came from its female parent. These two sets of chromosomes are **homologous** (hoh-MAHL-uh-guhs), meaning that each of the 4 chromosomes that came from the male parent has a corresponding chromosome from the female parent.

A cell that contains both sets of homologous chromosomes is said to be **diploid,** which means "two sets." The number of chromosomes in a diploid cell is sometimes represented by the symbol 2N. Thus for *Drosophila,* the diploid number is 8, which can be written 2N = 8. Diploid cells contain two complete sets of chromosomes and two complete sets of genes. This agrees with Mendel's idea that the cells of an adult organism contain two copies of each gene.

By contrast, the gametes of sexually reproducing organisms, including fruit flies and peas, contain only a single set of chromosomes, and therefore only a single set of genes. Such cells are said to be **haploid,** which means "one set." For *Drosophila,* this can be written as N = 4, meaning that the haploid number is 4.

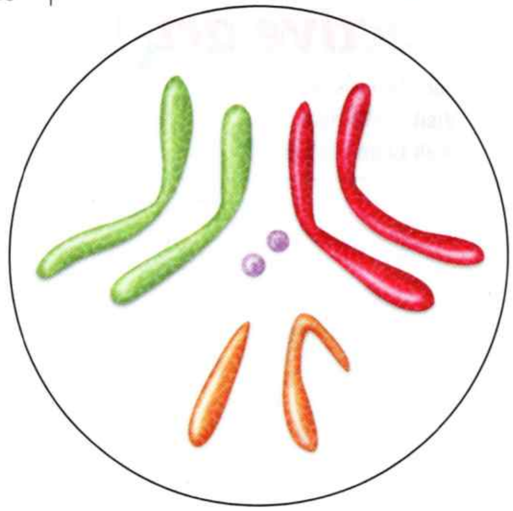


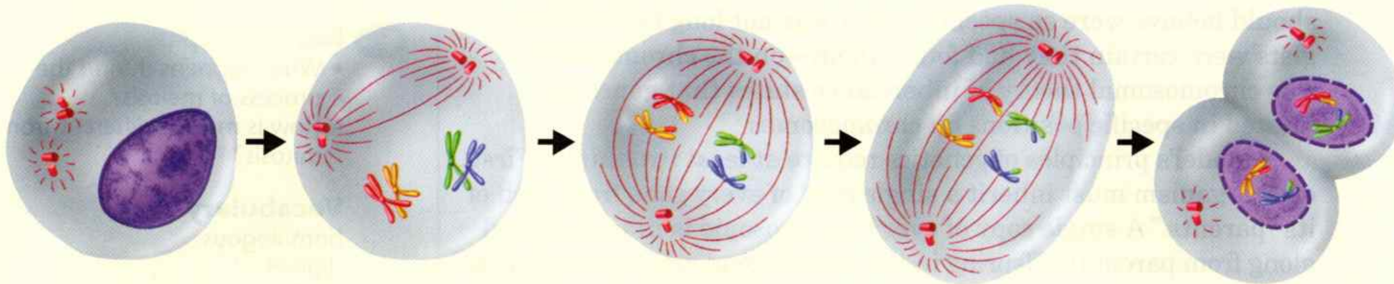
Figure 11–14 These chromosomes are from a fruit fly. Each of the fruit fly's body cells has 8 chromosomes.

Phases of Meiosis

How are haploid (N) gamete cells produced from diploid (2N) cells? That's where **meiosis** (my-OH-sis) comes in. **Meiosis is a process of reduction division in which the number of chromosomes per cell is cut in half through the separation of homologous chromosomes in a diploid cell.**

Meiosis

Figure 11–15 During meiosis, the number of chromosomes per cell is cut in half through the separation of the homologous chromosomes. The result of meiosis is 4 haploid cells that are genetically different from one another and from the original cell.



MEIOSIS I

Interphase I
Cells undergo a round of DNA replication, forming duplicate chromosomes.

Prophase I
Each chromosome pairs with its corresponding homologous chromosome to form a tetrad.

Metaphase I
Spindle fibers attach to the chromosomes.

Anaphase I
The fibers pull the homologous chromosomes toward opposite ends of the cell.

Telophase I and Cytokinesis
Nuclear membranes form. The cell separates into two cells.

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Meiosis usually involves two distinct divisions, called meiosis I and meiosis II. By the end of meiosis II, the diploid cell that entered meiosis has become 4 haploid cells. **Figure 11–15** shows meiosis in an organism that has a diploid number of 4 (2N = 4).

Meiosis I Prior to meiosis I, each chromosome is replicated. The cells then begin to divide in a way that looks similar to mitosis. In mitosis, the 4 chromosomes line up individually in the center of the cell. The 2 chromatids that make up each chromosome then separate from each other.

In prophase of meiosis I, however, each chromosome pairs with its corresponding homologous chromosome to form a structure called a **tetrad.** There are 4 chromatids in a tetrad. This pairing of homologous chromosomes is the key to understanding meiosis.

As homologous chromosomes pair up and form tetrads in meiosis I, they exchange portions of their chromatids in a process called **crossing-over.** Crossing-over, shown in **Figure 11–16,** results in the exchange of alleles between homologous chromosomes and produces new combinations of alleles.

What happens next? The homologous chromosomes separate, and two new cells are formed. Although each cell now has 4 chromatids (as it would after mitosis), something is different.

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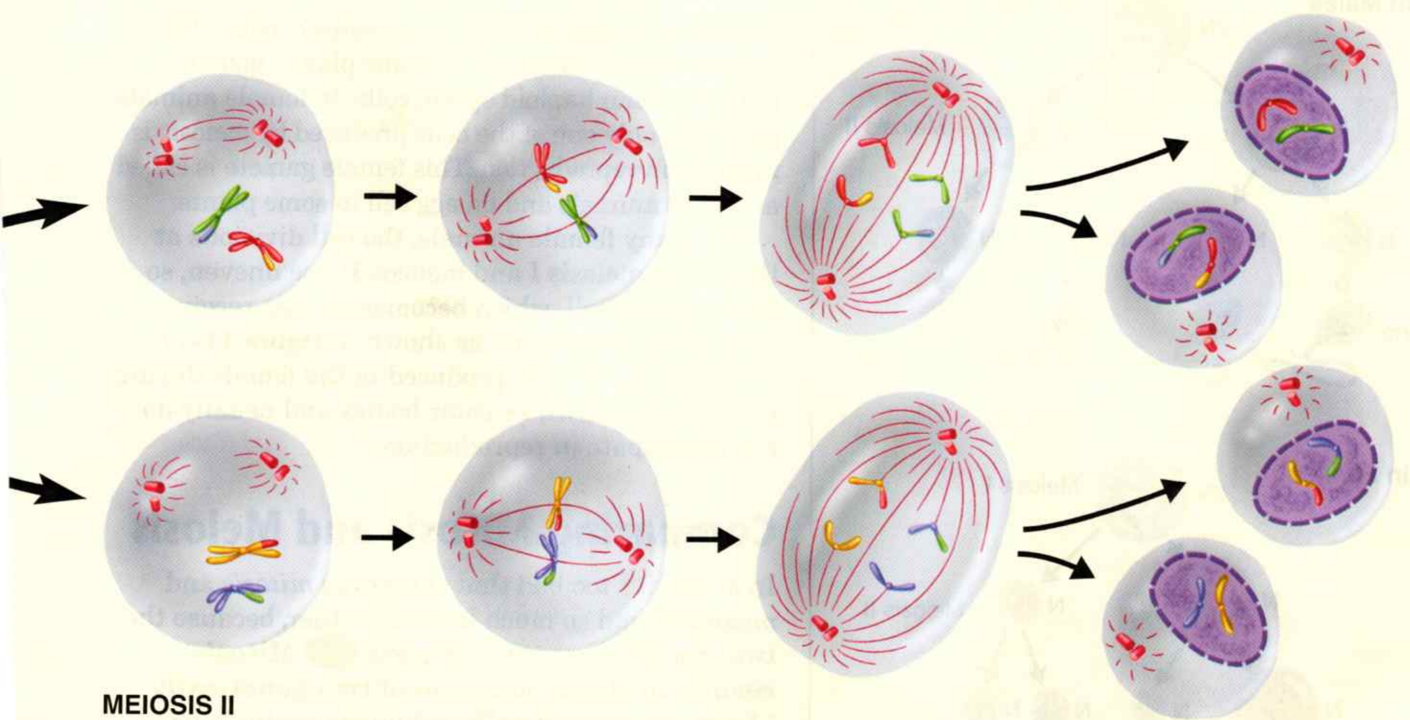


MEIOSIS II

Prophase II
Meiosis I results in two haploid (N) daughter cells, each with half the number of chromosomes as the original cell.

Metaphase II
The chromosomes line up in a similar way to the metaphase stage of mitosis.

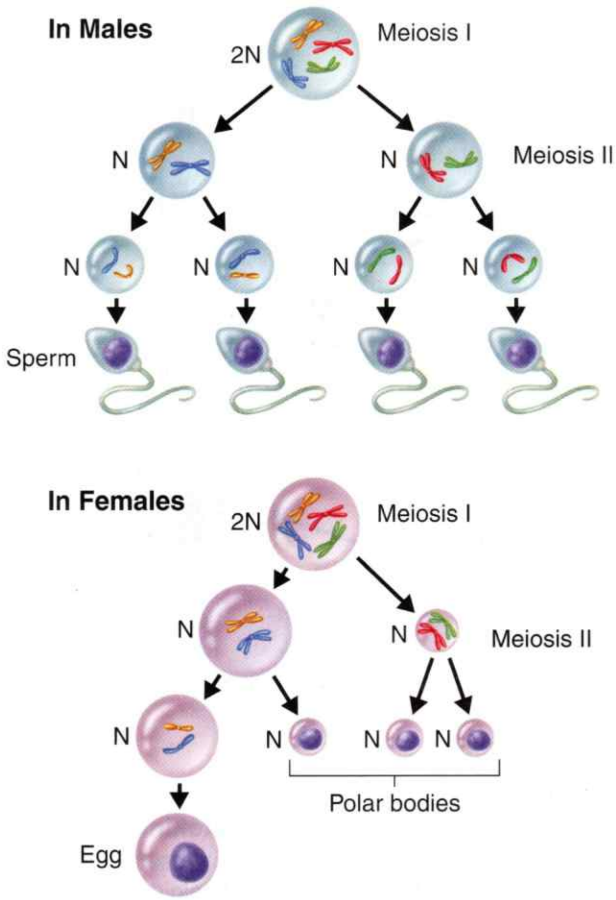
Anaphase II
The sister chromatids separate and move toward opposite ends of the cell.

Telophase II and Cytokinesis
Meiosis II results in four haploid (N) daughter cells.

Because each pair of homologous chromosomes was separated, neither of the daughter cells has the two complete sets of chromosomes that it would have in a diploid cell. Those two sets have been shuffled and sorted almost like a deck of cards. The two cells produced by meiosis I have sets of chromosomes and alleles that are different from each other and from the diploid cell that entered meiosis I.

Meiosis II The two cells produced by meiosis I now enter a second meiotic division. Unlike the first division, neither cell goes through a round of chromosome replication before entering meiosis II. Each of the cell's chromosomes has 2 chromatids. During metaphase II of meiosis, chromosomes line up in the center of each cell. In anaphase II, the paired chromatids separate. In this example, each of the four daughter cells produced in meiosis II receives 2 chromatids. Those four daughter cells now contain the haploid number (N)—just 2 chromosomes each.

Figure 11–16 Crossing-over occurs during meiosis. (1) Homologous chromosomes form a tetrad. (2) Chromatids cross over one another. (3) The crossed sections of the chromatids are exchanged. **Interpreting Graphics** *How does crossing-over affect the alleles on a chromatid?*



▲ **Figure 11–17** **Meiosis produces four genetically different haploid cells.** In males, meiosis results in four equal-sized gametes called sperm. In females, only one large egg cell results from meiosis. The other three cells, called polar bodies, usually are not involved in reproduction.

Gamete Formation

In male animals, the haploid gametes produced by meiosis are called sperm. In some plants, pollen grains contain haploid sperm cells. In female animals, generally only one of the cells produced by meiosis is involved in reproduction. This female gamete is called an egg in animals and an egg cell in some plants.

In many female animals, the cell divisions at the end of meiosis I and meiosis II are uneven, so that a single cell, which becomes an egg, receives most of the cytoplasm, as shown in **Figure 11–17.** The other three cells produced in the female during meiosis are known as polar bodies and usually do not participate in reproduction.

Comparing Mitosis and Meiosis

In a way, it's too bad that the words *mitosis* and *meiosis* sound so much like each other, because the two processes are very different. **Mitosis results in the production of two genetically identical diploid cells, whereas meiosis produces four genetically different haploid cells.**

A diploid cell that divides by mitosis gives rise to two diploid (2N) daughter cells. The daughter cells have sets of chromosomes and alleles that are identical to each other and to the original parent cell. Mitosis allows an organism's body to grow and replace cells. In asexual reproduction, a new organism is produced by mitosis of the cell or cells of the parent organism.

Meiosis, on the other hand, begins with a diploid cell but produces four haploid (N) cells. These cells are genetically different from the diploid cell and from one another. Meiosis is how sexually reproducing organisms produce gametes. In contrast, asexual reproduction involves only mitosis.

11–4 Section Assessment

1. **Key Concept** Describe the main results of meiosis.
2. **Key Concept** What are the principal differences between mitosis and meiosis?
3. What do the terms *diploid* and *haploid* mean?
4. What is crossing-over?
5. **Critical Thinking Applying Concepts** In human cells, 2N = 46. How many chromosomes would you expect to find in a sperm cell? In an egg cell? In a white blood cell? Explain.

Focus on the BIG Idea

Information and Heredity
In asexual reproduction, mitosis occurs, but not meiosis. Which type of reproduction—sexual or asexual—results in offspring with greater genetic variation? Explain your answer.