

6.1 Chromosomes and Meiosis

VOCABULARY

somatic cell
gamete
homologous chromosome
autosome
sex chromosome
sexual reproduction
fertilization
diploid
haploid
meiosis

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

MAIN IDEAS

- ▶ You have body cells and gametes.
- ▶ Your cells have autosomes and sex chromosomes.
- ▶ Body cells are diploid; gametes are haploid.

Connect to Your World

Perhaps you are familiar with the saying, “Everything old is new again.” This phrase usually indicates that a past style is again current. However, it applies equally well to you. The fusion of a single egg and sperm cell resulted in the complex creature that is you. There’s never been anyone quite like you. And yet the DNA that directs your cells came from your mother and father. And their DNA came from their mother and father, and so on and so on. In this chapter, you will examine the processes that went into making you who you are.

▶ MAIN IDEA

You have body cells and gametes.

You have many types of specialized cells in your body, but they can be divided into two major groups: somatic cells and germ cells. **Somatic cells** (soh-MAT-ihk), also called body cells, make up most of your body tissues and organs. For example, your spleen, kidneys, and eyeballs are all made entirely of body cells. DNA in your body cells is not passed on to your children. Germ cells, in contrast, are cells in your reproductive organs, the ovaries or the testes, that develop into gametes. **Gametes** are sex cells—ova, or eggs, in the female, and spermatozoa, or sperm cells, in the male. DNA in your gametes can be passed on to your children.

Each species has a characteristic number of chromosomes per cell. This number is typically given for body cells, not for gametes. Chromosome number does not seem to be related to the complexity of an organism. For example, yeast have 32 chromosomes, which come in 16 pairs. The fruit flies commonly used in genetic experiments have 8 chromosomes, which come in 4 pairs. A fern holds the record for the most chromosomes—more than 1200. Each of your body cells contains a set of 46 chromosomes, which come in 23 pairs. These cells are genetically identical to each other unless mutations have occurred. As you have learned, cells within an organism differ from one another because different genes are expressed, not because they have different genes.

Identify Which cell type makes up the brain?

READING TOOLBOX

TAKING NOTES

Make a two-column table to keep track of the vocabulary in this chapter.

Term	Definition
somatic cell	
gamete	

MAIN IDEA

Your cells have autosomes and sex chromosomes.

Suppose you had 23 pairs of gloves. You would have a total of 46 gloves that you could divide into two sets, 23 right and 23 left. Similarly, your body cells have 23 pairs of chromosomes for a total of 46 that can be divided into two sets: 23 from your mother and 23 from your father. Just as you use both gloves when it's cold outside, your cells use both sets of chromosomes to function properly.

Together, each pair of chromosomes is referred to as a homologous pair. In this context, *homologous* means “having the same structure.” **Homologous chromosomes** are two chromosomes—one inherited from the mother, one from the father—that have the same length and general appearance. More importantly, these chromosomes have copies of the same genes, although the two copies may differ. For example, if you have a gene that influences blood cholesterol levels on chromosome 8, you will have one copy from your mother and one copy from your father. It is possible that one of these copies is associated with high cholesterol levels, while the other is associated with low cholesterol levels. For convenience, scientists have assigned a number to each pair of homologous chromosomes, ordered from largest to smallest. As **FIGURE 1.1** shows, the largest pair of chromosomes is number 1, the next largest pair is number 2, and so forth.

Collectively, chromosome pairs 1 through 22 make up your **autosomes**, chromosomes that contain genes for characteristics not directly related to the sex of an organism. But what about the 23rd chromosome pair?

Most sexually reproducing species also have **sex chromosomes** that directly control the development of sexual characteristics. Humans have two very different sex chromosomes, X and Y. How sex is determined varies by species. In all mammals, including humans, an organism's sex is determined by the XY system. An organism with two X chromosomes is female. An organism with one X and one Y chromosome is male. Sex chromosomes make up your 23rd pair of chromosomes. Although the X and Y chromosomes pair with each other, they are not homologous. The X chromosome is the larger sex chromosome and contains numerous genes, including many that are unrelated to sexual characteristics. The Y chromosome is the sex chromosome that contains genes that direct the development of the testes and other male traits. It is the smallest chromosome and carries the fewest genes.

Summarize Are homologous chromosomes identical to each other? Explain.

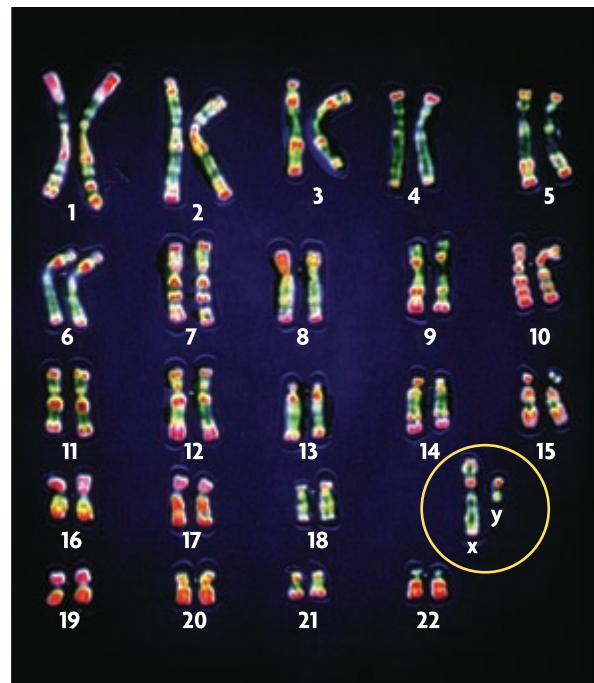
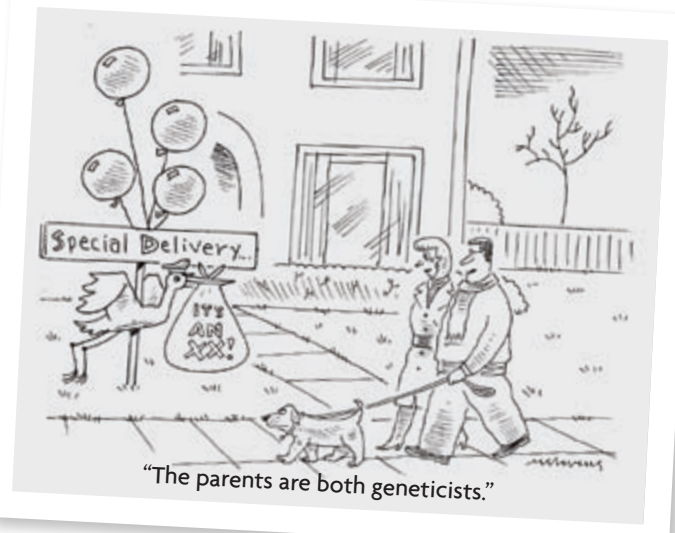


FIGURE 1.1 Human DNA is organized into two sets of 23 chromosomes. Each set contains 22 autosomes and 1 sex chromosome. Females have two X chromosomes. Males have an X and a Y chromosome (circled). (colored LM; magnification 4400×)



▶ MAIN IDEA

Body cells are diploid; gametes are haploid.

Sexual reproduction involves the fusion of two gametes, resulting in offspring that are a genetic mixture of both parents. The actual fusion of an egg and a sperm cell is called **fertilization**. When fertilization occurs, the nuclei of the egg and sperm cell fuse to form one nucleus. This new nucleus must have the correct number of chromosomes for a healthy new organism to develop. Therefore, both the egg and the sperm cell need only half the usual number of chromosomes—one chromosome from each homologous pair.

Diploid and Haploid Cells

Body cells and gametes have different numbers of chromosomes. Your body cells are diploid. **Diploid** (DIHP-LOYD) means that a cell has two copies of each chromosome: one copy from the mother, and one copy from the father. Diploid cells can be represented as $2n$. In humans, the diploid chromosome number is 46.

Gametes are not diploid cells; they are haploid cells, represented as n .

Haploid (HAP-LOYD) means that a cell has only one copy of each chromosome. Each human egg or sperm cell has 22 autosomes and 1 sex chromosome. In the egg, the sex chromosome is always an X chromosome. In the sperm cell, the sex chromosome can be an X chromosome or a Y chromosome. The reason for this difference will be discussed in the following sections.

Maintaining the correct number of chromosomes is important to the survival of all organisms. Typically, a change in chromosome number is harmful. However, increasing the number of sets of chromosomes can, on occasion, give rise to a new species. The fertilization of nonhaploid gametes has played an important role in plant evolution by rapidly making new species with more than two sets of chromosomes. For example, some plants have four copies of each chromosome, a condition called tetraploidy ($4n$). This type of event has occurred in many groups of plants, but it is very rare in animals.

Meiosis

Germ cells in your reproductive organs undergo the process of meiosis to form gametes. **Meiosis** (my-OH-sihs) is a form of nuclear division that divides a diploid cell into haploid cells. This process is essential for sexual reproduction. The details of meiosis will be presented in the next section. **FIGURE 1.2** highlights some differences between mitosis and meiosis in advance to help you keep these two processes clear in your mind.

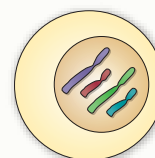
READING TOOLBOX

VOCABULARY

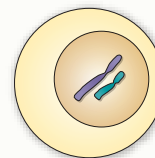
Diploid comes from the Greek word *diploous*, which means “double.” *Haploid* comes from the Greek word *haploous*, which means “single.”

VISUAL VOCAB

Diploid cells have two copies of each chromosome: one copy from the mother and one from the father.



Body cells are diploid ($2n$).



Gametes (sex cells) are haploid (n).

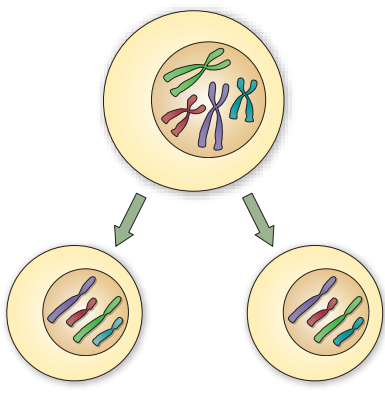
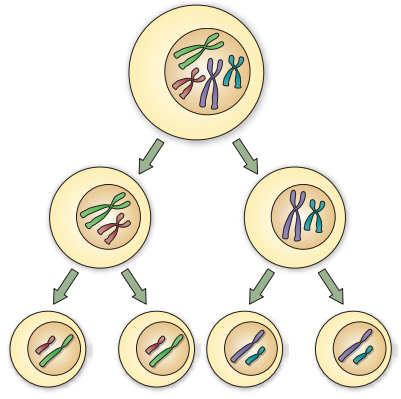
Haploid cells have only one copy of each chromosome.

CONNECT TO

PLANT LIFE CYCLES

As you will learn in **Plant Growth, Reproduction, and Response**, all plants complete their life cycle by alternating between two phases: diploid and haploid. During the diploid phase, plants make spores. During the haploid phase, plants make gametes.

FIGURE 1.2 Comparing Mitosis and Meiosis

MITOSIS		MEIOSIS	
	Produces genetically identical cells		Produces genetically unique cells
	Results in diploid cells		Results in haploid cells
	Takes place throughout an organism's lifetime		Takes place only at certain times in an organism's life cycle
	Involved in asexual reproduction		Involved in sexual reproduction

Compare Using the diagrams above, explain how you think the process of meiosis differs from mitosis.

You have already learned about mitosis, another form of nuclear division. Recall that mitosis is a process that occurs in body cells. It helps produce daughter cells that are genetically identical to the parent cell. In cells undergoing mitosis, DNA is copied once and divided once. Both the parent cell and the daughter cells are diploid. Mitosis is used for development, growth, and repair in all types of organisms. It is also used for reproduction in asexually reproducing eukaryotes.

In contrast, meiosis occurs in germ cells to produce gametes. This process is sometimes called a “reduction division” because it reduces a cell’s chromosome number by half. In cells undergoing meiosis, DNA is copied once but divided twice. Meiosis makes genetically unique haploid cells from a diploid cell. These haploid cells then undergo more processing in the ovaries or testes, finally forming mature gametes.

Apply Why is it important that gametes are haploid cells?

6.1 Formative Assessment

REVIEWING MAIN IDEAS

1. Where are germ cells located in the human body?
2. What is the difference between an **autosome** and a **sex chromosome**?
3. Is the cell that results from **fertilization** a **haploid** or **diploid** cell? Explain.

CRITICAL THINKING

4. **Infer** Does mitosis or **meiosis** occur more frequently in your body? Explain your answer.
5. **Analyze** Do you think that the Y chromosome contains genes that are critical for an organism’s survival? Explain your reasoning.

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PREMIUM CONTENT

CONNECT TO

TELOMERES

6. The ends of DNA molecules form telomeres that help keep the ends of chromosomes from sticking to each other. Why might this be especially important in germ cells, which go through meiosis and make haploid **gametes**?