3.1 Meiosis

LEARNING TIP

Scan the titles, headings, and subheadings, as well as the words in bold type. Make predictions about what you expect to learn in Chapter 3.

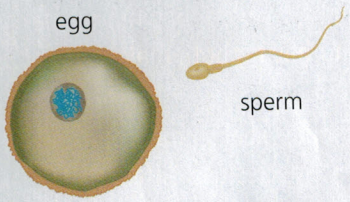


Figure 1 Sperm cells are much smaller than egg cells and have a very different shape.

In Chapter 2, you learned that the offspring of parents that reproduce asexually are genetically identical to each other and to the parents. You also learned that asexual reproduction involves cell division and sexual reproduction involves sex cells joining to produce a zygote. In this section, you will find out how the sex cells are formed.

Multicellular organisms that reproduce sexually have two types of cells: somatic cells and sex cells. **Somatic cells**, also called body cells, reproduce by cell division and make up the vast majority of an organism's cells. Human somatic cells have 23 pairs of chromosomes, for a total of 46 chromosomes. The sex cells are also called **gametes**. Gametes have half the chromosomes of the parent cell. Gametes make up an extremely tiny fraction of an organism's cells. Male gametes are called **sperm**, and female gametes are called **eggs** or **ova** (singular: ovum) (Figure 1).

Chromosome Numbers

In general, individuals of the same species have the same number of chromosomes. Goldfish have 94 chromosomes, fruit flies have 8, and humans have 46. If sexual reproduction involves the fusing of genetic material from two individuals, then why doesn't the resulting offspring contain twice the number of chromosomes as the parents? To maintain the same number of chromosomes from generation to generation, there needs to be a way to reduce the number of chromosomes that are passed on from each parent. The process that produces gametes, which have half the number of chromosomes as the parent, is called **meiosis**.

Meiosis happens only in the cells that produce gametes. These cells are called reproductive cells. Meiosis is sometimes called "reduction division" because it reduces the chromosome number by half. Each fruit fly gamete (Figure 2) contains four chromosomes—half of the genetic material of the parent. Cells with half the chromosome number of the parent are called **haploid**, symbolized with a single *n*. Cells that have a complete set of chromosomes are called **diploid**, symbolized as 2*n*.

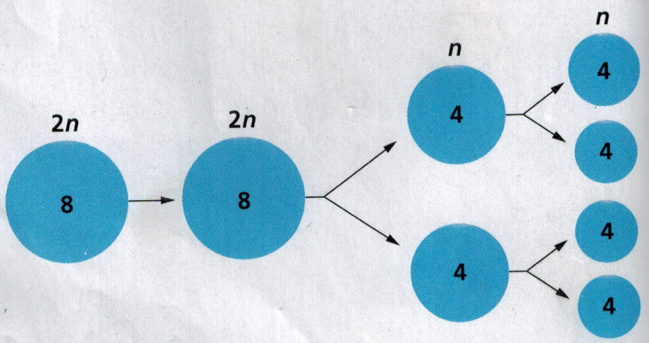


Figure 2 Fruit fly somatic cells have eight chromosomes (diploid or 2*n*) and are produced by mitosis. Fruit fly gametes have four chromosomes (haploid or *n*) and are produced by meiosis.

Homologous Chromosomes

Diploid ($2n$) somatic cells have their chromosomes arranged in pairs. Each chromosome has a corresponding chromosome, forming a pair. The pairs of corresponding chromosomes are called **homologous chromosomes** (Figure 3). The genes on one of the chromosomes in the pair correspond to the genes on the other chromosome in the pair. In fruit flies, for example, one chromosome has a gene for eye colour. The corresponding chromosome also has a gene for eye colour in the same location. Homologous chromosomes come from the parents. Each parent contributes one half (n) of the chromosomes. Each fruit fly parent contributes four chromosomes to the offspring.

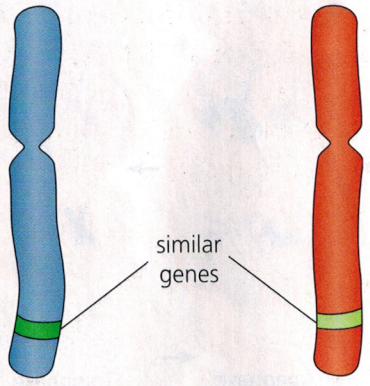


Figure 3 Both chromosomes in a pair of homologous chromosomes carry genes that code for the same characteristic. One chromosome in the pair comes from the female parent, and the other chromosome comes from the male parent.

Did You KNOW?

Polyploidy

Have you noticed that some blueberries in fruit markets are almost twice as big as those found in the wild? Cultivated blueberries have four copies of each chromosome instead of the usual two copies. This $4n$ condition is called polyploidy. Polyploidy produces larger plants and larger fruits. Other food plants, such as wheat, plums, and grapes, can also have more than the usual $2n$ chromosome number.

The Stages of Meiosis

Meiosis is actually composed of two phases, meiosis I and meiosis II, and produces four haploid gametes (Figure 4 on the next page).

The first phase, **meiosis I** (Figure 4(b)), is similar to mitosis (Figure 4(a)) during interphase and prophase. During interphase, the chromosomes replicate to form joined sister chromatids. During prophase, the chromosomes shorten and thicken, and become visible with a light microscope. The chromosomes behave differently than in mitosis, however, during metaphase and anaphase. Recall that during metaphase, in mitosis, the sister chromatids line up along the middle, or equator, of the cell. During anaphase, the sister chromatids separate and are pulled to opposite ends, or poles. In meiosis I, the homologous chromosomes (each joined to its sister chromatid) pair up along the equator. Then, during anaphase in meiosis I, the pairs of homologous chromosomes separate and move to opposite poles along with their sister chromatids. The sister chromatids do not separate in meiosis I. Meiosis I results in two daughter cells, but each has only one of the homologous chromosomes, with its sister chromatid still attached.

LEARNING TIP

Active readers adjust their reading to fit the difficulty of the text. If you find a topic difficult to understand, divide the reading task into smaller chunks, read more slowly, and reread. Reread the section on meiosis as many times as you need to before you move on.

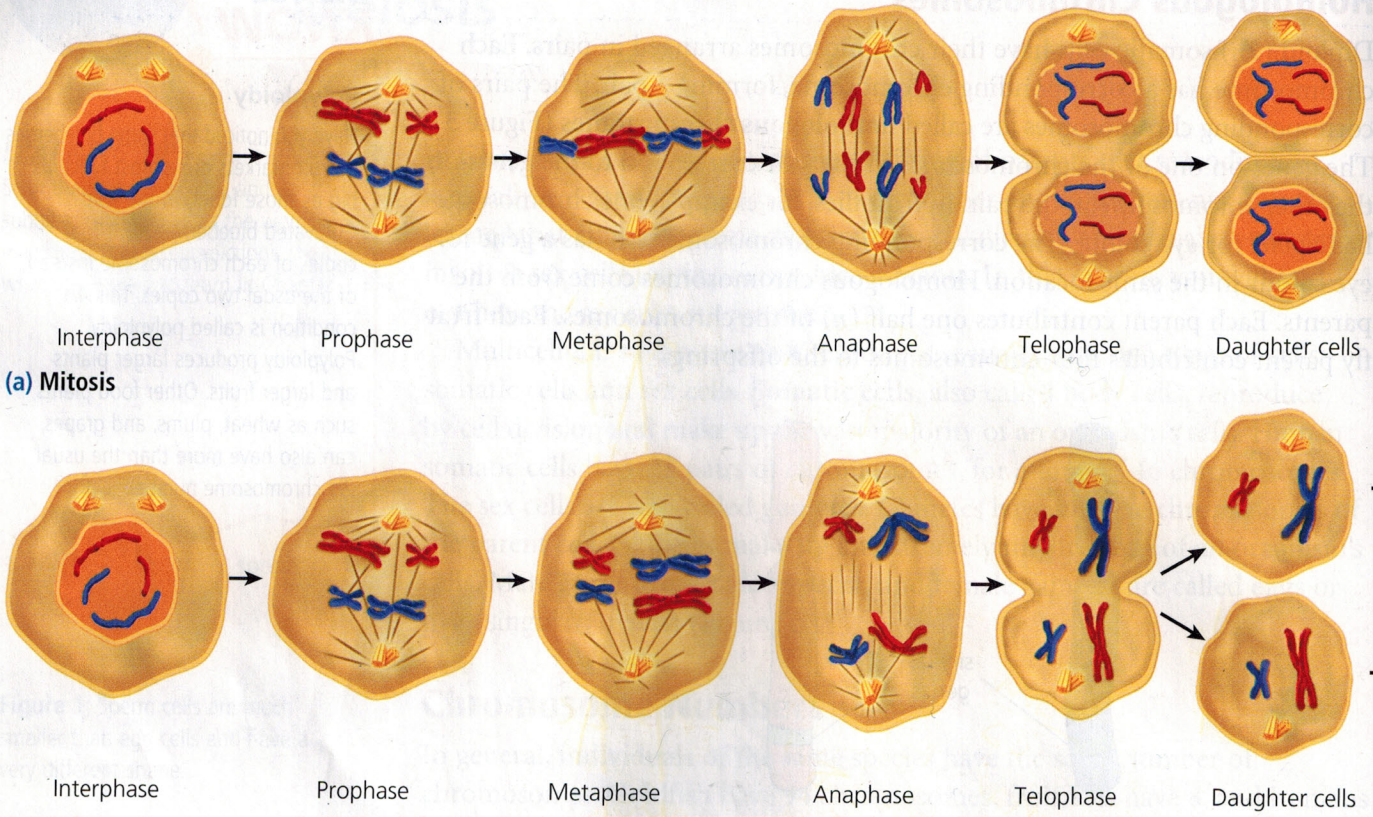


Figure 4 Mitosis (a) results in two diploid daughter cells with the same number of chromosomes as the parent cell. The sister chromatids have separated. Meiosis I (b) results in two daughter cells, each with half the chromosomes of the parent cell. Notice that the sister chromatids are still attached. These cells undergo meiosis II (c).

LEARNING TIP

Check that you understand the differences between mitosis and meiosis (summarized in Table 1) by explaining them to a partner.

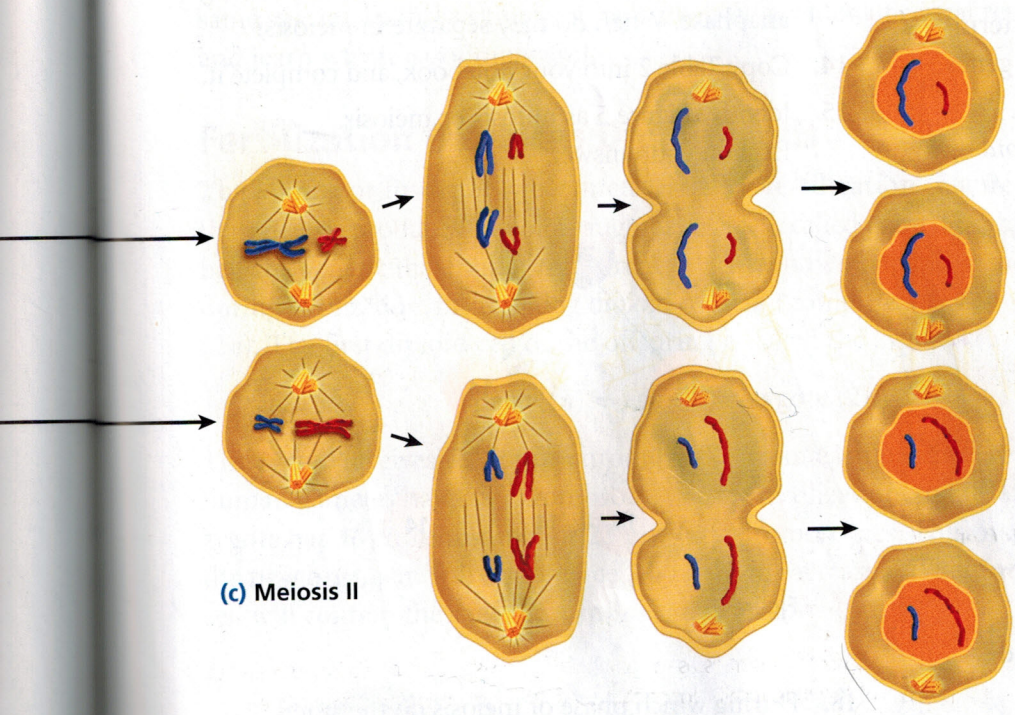
To learn more about meiosis, go to **www.science.nelson.com** GO

Recall that, in mitosis, the sister chromatids separate into two daughter cells, each with the same number of chromosomes as the parent cell.

During the second phase of meiosis, **meiosis II** (Figure 4(c)), the sister chromatids in the two daughter cells line up at the equator of the cell. Each chromatid is pulled to the opposite pole. The nuclear membranes reform, and cytokinesis occurs, resulting in four haploid daughter cells called gametes. This second phase is similar to mitosis, in which the sister chromatids separate. But since meiosis II starts with two daughter cells, which both divide in two, four daughter cells are produced. Mitosis and meiosis are compared in Table 1. GO

Table 1 A comparison of mitosis and meiosis

	Parent cell (chromosome number)	Sister chromatids …	Number of daughter cells	Number of chromosomes in daughter cells
mitosis	$2n$	separate during anaphase	2	$2n$
meiosis	$2n$	stay together in meiosis I, but separate in meiosis II	4	n



(c) Meiosis II

TRY THIS: Comparing Meiosis and Mitosis

Skills Focus: creating models, observing, communicating

Materials: craft materials, such as pipe cleaners, wool, modelling clay, twist ties, string, rubber bands, and paper clips

In Chapter 2, you built a model of mitosis to help you understand that it is a continuous process. Here you will build a model to illustrate the process of meiosis.

1. Work with a partner to build two models. One will show the stages of meiosis and the other, the stages of mitosis. Use two different colours or shapes to distinguish between the homologous chromosomes. To simplify your models, build only four chromosomes (two homologous pairs). Be sure that your models are large enough to allow the chromosomes enough room to be moved to the opposite poles of the cell. Also, be sure that you use enough materials to demonstrate both meiosis I and meiosis II.
2. Describe to your partner how meiosis I and meiosis II are different from mitosis.

A. What has to happen before meiosis begins? When does this occur? What are the structures called now?

B. What is the end product of meiosis?

C. What is the end product of mitosis?

3.1 CHECK YOUR Understanding

1. How do somatic cells and sex cells differ from each other? How are they similar?
2. Name the two types of gametes.
3. Describe homologous chromosomes in terms of the number of genes and the type of genes they have.
4. Explain how the terms *haploid* and *diploid* are related.
5. What types of cells are haploid? What type of cells are diploid?
6. A chicken has 78 chromosomes in each somatic cell. How many chromosomes are in one of its gametes?
7. How many pairs of homologous chromosomes are in a human somatic cell? How many pairs are in a fruit fly somatic cell?
8. If an organism has 18 chromosomes, how many homologous pairs does it have?
9. What are the two phases of meiosis called?
10. Why is meiosis sometimes called "reduction division"?
11. What are the end products of meiosis?
12. How are mitosis and meiosis similar? How are they different?
13. In mitosis, the sister chromatids separate during anaphase. When do they separate in meiosis?
14. Copy Table 2 into your notebook, and complete it.
15. Identify Figure 5 as mitosis or meiosis. Explain your answer.

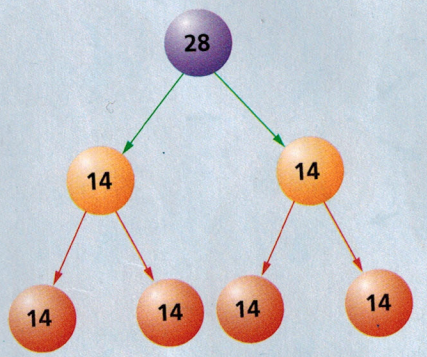


Figure 5

16. During which phase of meiosis do the sister chromatids form?
17. Why is meiosis necessary for sexual reproduction?

Table 2

Organism	Parent	Chromosome number			
		Diploid	Somatic cell	Haploid cell	Gametes
human		46			
chimpanzee				24	
cat			38		
guinea pig					32
horsetail	216				