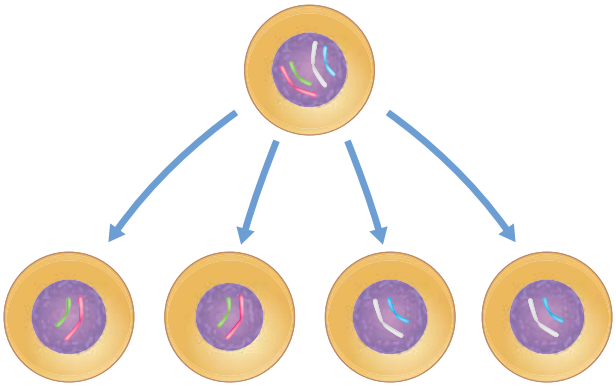
# The Process of Meiosis

Recall that body cells reproduce during part of the cell cycle. During mitosis and cytokinesis, the nucleus and cytoplasm divide, resulting in daughter cells that are genetically identical to the parent cell. Germ cells in your reproductive organs undergo the process of meiosis to form gametes. Meiosis is a form of nuclear division that divides one diploid cell into four haploid cells. There are two rounds of cell division—meiosis I and meiosis II. This process divides the DNA and reduces each resulting cell's chromosome number by half.

**FIGURE 6:** Meiosis has many stages and produces four haploid cells from one diploid cell.



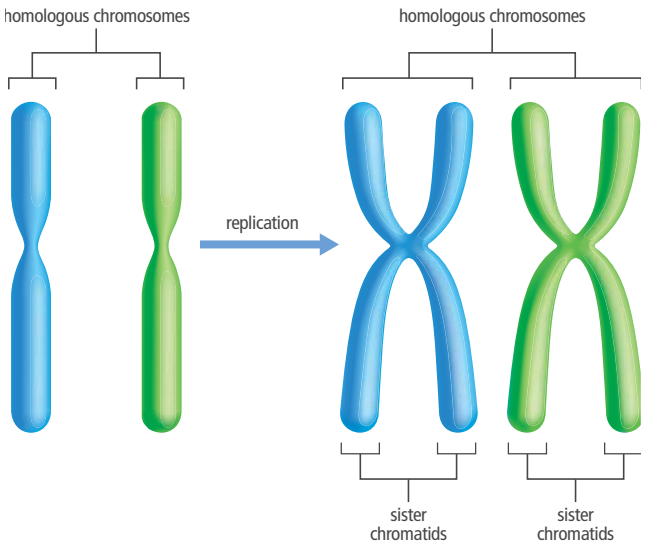
**Predict** Meiosis divides one cell into four cells, but each resulting cell has half the amount of DNA as compared to the original cell. How do you think this is possible?

## Chromosomes and Replication

To understand meiosis, it is necessary to distinguish between homologous chromosomes and sister chromatids. As Figure 7 shows, homologous chromosomes are two separate chromosomes, one from your mother and one from your father. Homologous chromosomes are similar to each other because they are the same length and carry the same genes. However, they are not exact copies of each other. In contrast, a chromatid is one half of a duplicated chromosome. Sister chromatids refers to the duplicated chromosomes that remain attached (by the centromere). Homologous chromosomes divide during meiosis I, and sister chromatids are split and separated into new gametes during meiosis II.

**Analyze** What is the difference between the genetic material on two sister chromatids and the genetic material on homologous chromosomes?

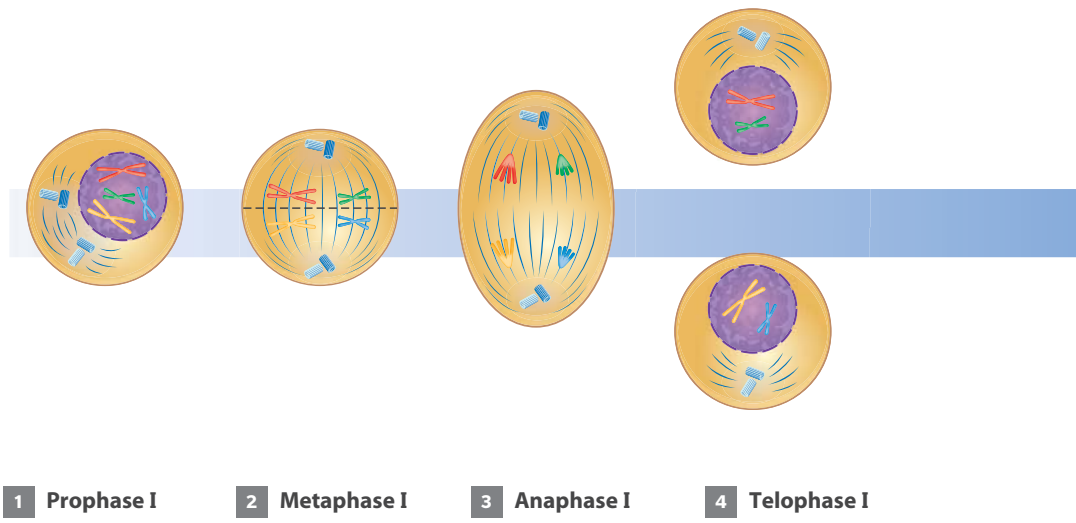
**FIGURE 7:** Homologous chromosomes are two separate chromosomes, while sister chromatids are duplicated chromosomes that remain attached to one another.



## Meiosis I

Before meiosis begins, DNA is copied during S phase. Meiosis I separates homologous chromosomes, producing two haploid cells with duplicated chromosomes. Meiosis I can be described in distinct phases, each of which is a series of gradual changes.

**FIGURE 8:** Meiosis I and meiosis II are each made up of four phases.

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**Modeling Meiosis**

Make a model to illustrate how the arrangement and separation of chromosomes during meiosis causes an increase in genetic diversity.

**1. Prophase I** During this first phase of meiosis, the nuclear membrane breaks down, the centrosomes and centrioles move to opposite sides of the cell, and spindle fibers start to assemble. The duplicated chromosomes condense, and homologous chromosomes pair up. They appear to pair up precisely, gene for gene, down their entire length. The sex chromosomes also pair with each other, and some regions of their DNA appear to line up as well.

**2. Metaphase I** The homologous chromosome pairs randomly line up along the middle of the cell, or the cell equator, attached to spindle fibers. The result is that 23 chromosomes—some from the father, some from the mother—are lined up along each side of the cell equator. This arrangement mixes up the chromosomal combinations and helps make and maintain genetic diversity.

**3. Anaphase I** Next, the paired homologous chromosomes separate from each other and move toward opposite sides of the cell. The sister chromatids remain together during this step and throughout meiosis I.

**4. Telophase I** The cell undergoes cytokinesis.

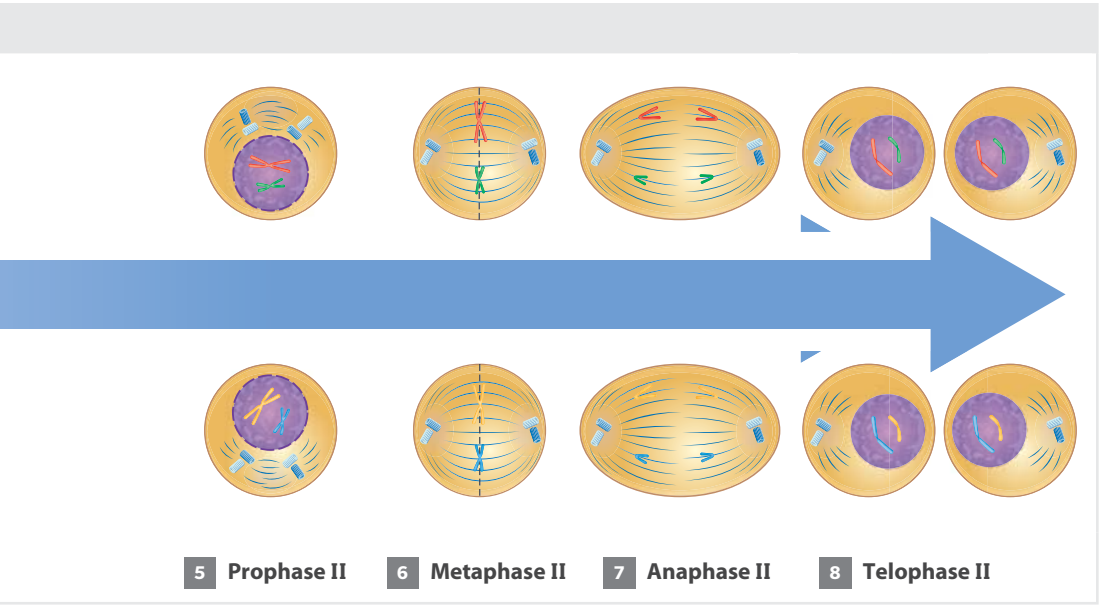
After telophase I, the nuclear membrane forms again in some species, and the spindle fibers disassemble. These steps occur during a period between meiosis I and meiosis II.

**Analyze** Observe the model of meiosis I in Figure 8. Use this model to answer the following questions:

1. What are the products of meiosis I? Explain in terms of number of cells and the genetic material contained in those cells.
2. Describe the arrangement of chromosomes in metaphase I. Why do you think chromosomes are arranged in this way?
3. What are some of the strengths and limitations of this model?

## Meiosis II

Meiosis II separates sister chromatids, which results in chromosomes that are not doubled. The diagram of this process applies to both of the cells produced in meiosis I. It's important to note that DNA is not copied between meiosis I and meiosis II.




**5. Prophase II** The nuclear membrane breaks down, centrosomes and centrioles move to opposite sides of the cell, and spindle fibers assemble.

**6. Metaphase II** Spindle fibers align the 23 chromosomes at the cell equator. Each chromosome still has two sister chromatids at this stage.

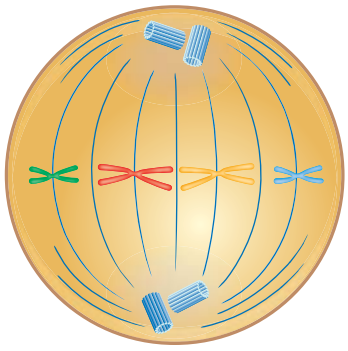
**7. Anaphase II** Next, the sister chromatids are pulled apart from each other and move to opposite sides of the cell.

**8. Telophase II** Finally, nuclear membranes form around each set of chromosomes at opposite ends of the cell, the spindle fibers break apart, and the cell undergoes cytokinesis.

**Explain** According to this model, do all the gametes produced by an organism have the same genetic material? Use evidence to support your claim.

### Cause and Effect

**FIGURE 9:** Metaphase in Mitosis



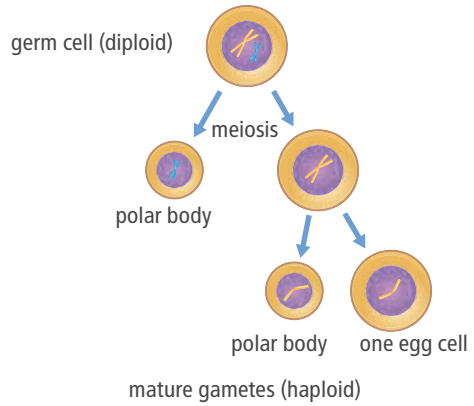
## Comparing Chromosome Arrangement

Mitosis, which occurs in body cells, produces two genetically identical cells. Like meiosis, mitosis includes metaphase. However, the alignment of chromosomes differs, which affects the genetic makeup of the final cells.

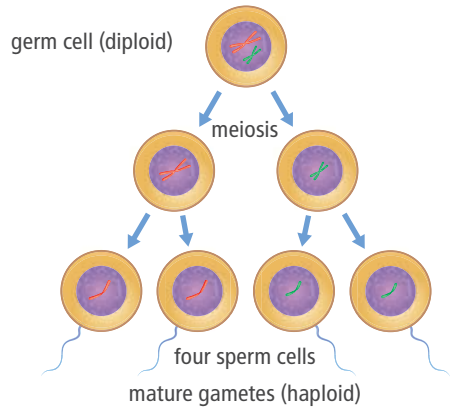
**Explain** Answer these questions about metaphase in meiosis and mitosis.

1. How do the arrangements of chromosomes in metaphase I and metaphase II of meiosis compare to each other and to the metaphase stage of mitosis?
2. What are the final products of mitosis and meiosis? How does the arrangement of chromosomes during metaphase affect the genetic makeup of the final products?

**FIGURE 10:** Gametogenesis (Cells are not to scale.)




a egg production




b sperm production

## Gametogenesis

The haploid cells produced by meiosis are not able to be fertilized until they go through additional changes to produce mature gametes. The final stages of this process, called gametogenesis, differ between the sexes. The formation of an egg, the female gamete, begins before birth, inside the developing body of a female embryo, and is not finished until a sperm fertilizes that egg many years later. Only one of the four cells produced by meiosis actually makes an egg. The other cells produced are called polar bodies and are not typically able to be fertilized. Nearly all of a zygote's cytoplasm and organelles come from the egg. Since mitochondria carry their own DNA, the mitochondrial DNA in the embryo is identical to the mother's.

The sperm cell, the male gamete, is much smaller than the egg. The sperm cell's main contribution to an embryo is DNA. Yet it must swim to an egg to fertilize it, so the ability to move is critical. Sperm formation starts with a round cell and ends by making a streamlined cell that can move rapidly. During this process, significant changes occur. DNA is tightly packed and much of the cytoplasm is lost, resulting in a compact head. The sperm cell develops a whip-like flagellum and a neck region with mitochondria that provide the energy needed to drive the cell's flagellum. Other changes, such as the addition of proteins to the cell membrane, also take place.

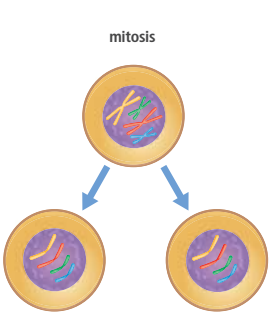
**Analyze** Make a Venn diagram to compare and contrast egg production and sperm production.

## Comparing Mitosis and Meiosis

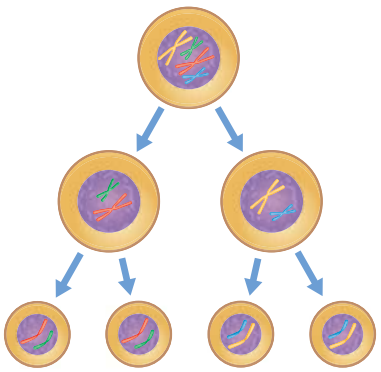
Mitosis is a process that occurs in body cells. It is essential for the growth and development of an organism. In contrast, meiosis occurs in germ cells.

**Explain** Make a table to compare mitosis and meiosis in terms of the number and type of cells produced, the genetic material in the cells, and the role of each process in the body. Does meiosis or mitosis occur more frequently in your body? Explain your answer.

**FIGURE 11:** Mitosis and meiosis produce different kinds of cells.




a Mitosis



b Meiosis