Topic 5.1

Meiosis

Learning Objectives

- Learn the important features of meiosis
- Understand the differences and similarities between mitosis and meiosis

Topic Questions

- What outcomes occur as a result of meiosis?
- What stages take place during meiosis and what events occur during these stages?
- In what ways are mitosis and meiosis different, and in what ways are they similar?

5.1.01 Features of Meiosis

[IST-1.F.1]

The ability to reproduce is a characteristic of all types of living organisms. Because all organisms are made up of one or more cells, organism reproduction is based on **cell division**. In eukaryotic organisms, cell division takes place by either mitosis (as described in Sub-Topics 4.6.03 and 4.6.04) or **meiosis**.

Asexual reproduction, which requires only one parent and does not involve the joining of gametes, takes place by mitosis in eukaryotes. **Sexual reproduction**, which typically involves two parents, always requires the joining of gametes (ie, fertilization). Sexual reproduction is dependent on meiosis because meiosis produces **daughter cells** that have half the number of chromosomes as the parent cell (see Figure 5.1).

Most eukaryotes are **diploid (2*n*)**, which means that each of their cells has two complete sets of chromosomes (ie, two copies of each different chromosome). Gametes, which are produced by meiosis, are **haploid (1*n*)** (ie, have one complete set of chromosomes). Gametes join during fertilization to form a diploid cell called a zygote. In most eukaryotes, the diploid zygote divides by mitosis to form a multicellular adult organism with diploid cells. Because DNA replication occurs before mitotic and meiotic cell division, both diploid and haploid cells can have chromosomes made up of one or two chromatids, depending on the cell's position in its life cycle.

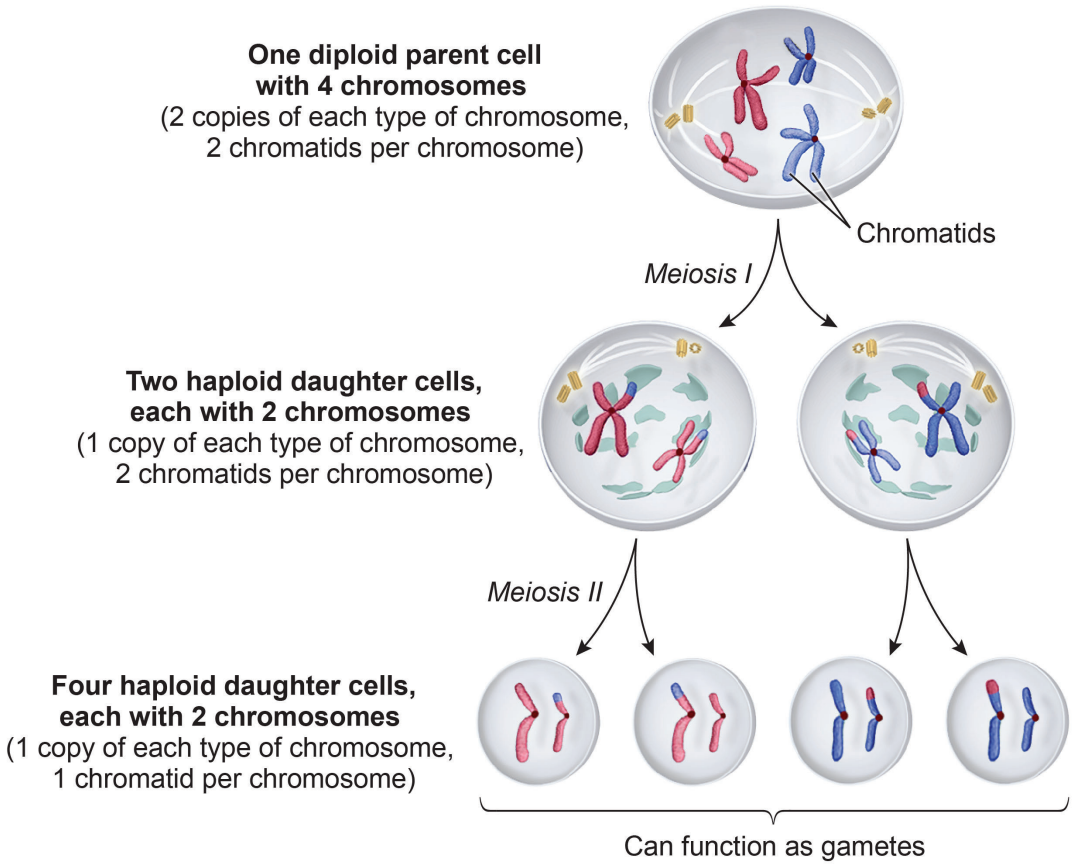

Figure 5.1 Production of haploid daughter cells by meiosis.

Meiosis takes place in two main stages, **meiosis I** and **meiosis II**, both of which involve cell division. These stages happen after DNA replication (ie, chromosome duplication). Specifically, DNA replication happens prior to meiosis I (ie, during S phase of interphase) but does *not* happen between meiosis I and meiosis II. Because chromosomes are duplicated only *once* before meiosis begins and meiosis involves *two* rounds of cell division, meiosis is a type of cell division that reduces daughter cell chromosome number to half of the parent cell chromosome number. Therefore, meiosis is sometimes called **reduction division**.

Meiosis I results in the formation of two haploid daughter cells that contain duplicated chromosomes (ie, chromosomes made up of two sister chromatids attached at the centromere). The phases of meiosis I (see Figure 5.2) are as follows:

- **Prophase I** includes chromosome condensation (ie, tighter wrapping of DNA within the chromosomes), nuclear envelope breakdown, spindle fiber formation, homologous chromosome pairing, and **crossing over** (ie, genetic recombination), which is discussed in detail in Topic 5.2.
- **Metaphase I** involves alignment of the homologous pairs of chromosomes at the cell's equator (ie, middle), with the members of each pair facing opposite poles (ie, ends) of the cell.
- **Anaphase I** involves the separation of homologous pairs of chromosomes (ie, one member of each homologous pair pulled toward each pole by spindle fibers).
- **Telophase I** includes separated chromosomes reaching opposite poles of the cell and new nuclei forming. **Cytokinesis** (ie, division of the cytoplasm) typically occurs at the same time as telophase and results in the formation of two haploid daughter cells (the chromosomes of which still have two sister chromatids attached to each other).

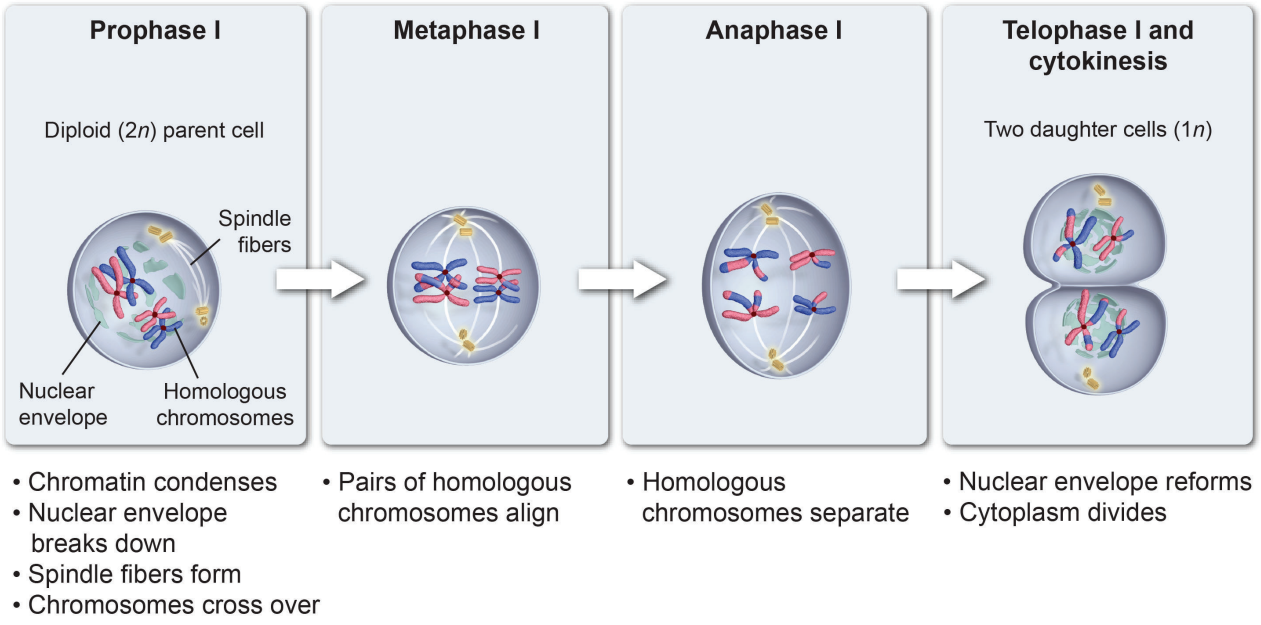

Figure 5.2 Events of meiosis I.

Meiosis II, which is very similar to mitosis, results in the formation of *four haploid* daughter cells whose chromosomes are made up of a single chromatid. The phases of meiosis II (see Figure 5.3) are as follows:

- **Prophase II** includes nuclear envelope breakdown and spindle fiber formation.
- **Metaphase II** involves alignment of individual chromosomes at the cell's equator, with the sister chromatids of each chromosome facing opposite poles of the cell.
- **Anaphase II** involves the separation of sister chromatids toward opposite poles of the cell by spindle fibers.
- **Telophase II** includes separated sister chromatids (which function as independent chromosomes) reaching opposite poles of the cell, nuclear envelopes reforming around each set of chromosomes to produce new nuclei, and division of the cytoplasm to produce new daughter cells (ie, cytokinesis).

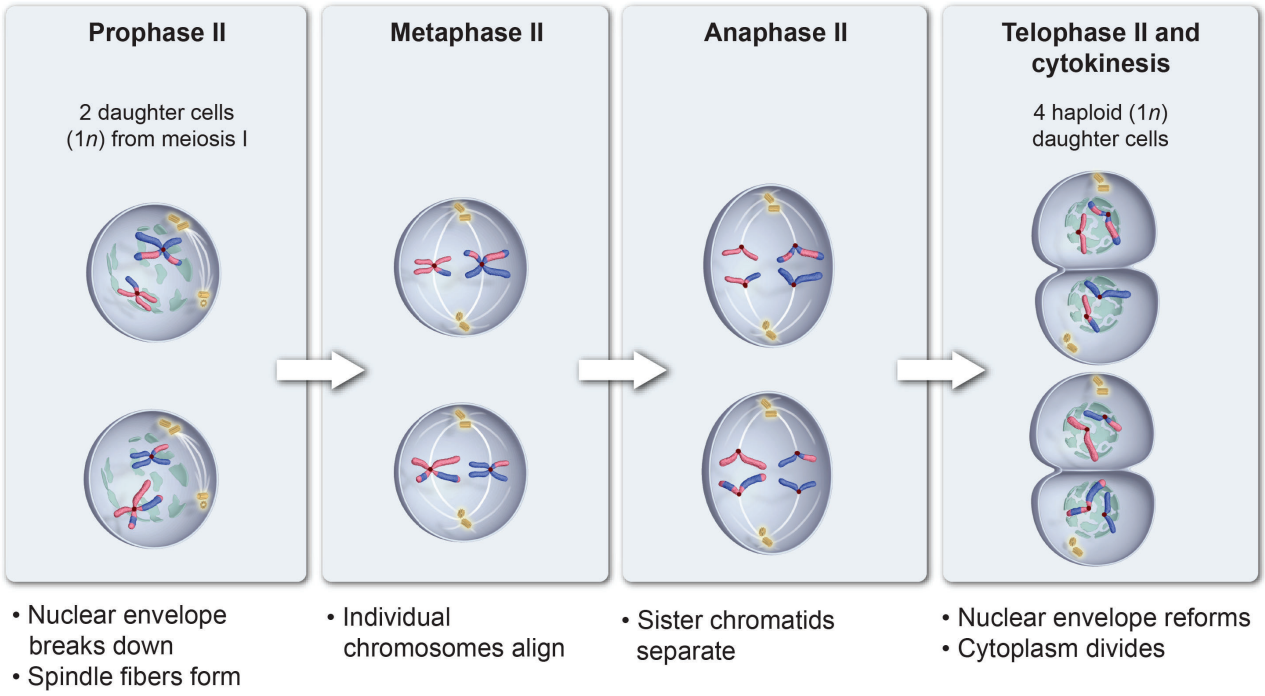

Figure 5.3 Events of meiosis II.

5.1.02 Differences and Similarities between Mitosis and Meiosis

[IST-1.G.1]

Eukaryotic cell division takes place through two processes, mitosis and meiosis, both of which involve passing genetic information (ie, chromosomes) from a parent cell to daughter cells. Although both mitosis and meiosis result in the production of new cells, there are important differences in the characteristics of these processes (Table 5.1).

A main difference between mitosis and meiosis is that mitosis produces daughter cells that are genetically identical to the parent cell (ie, same chromosome type and number, same genes), and meiosis produces daughter cells that are genetically different from each other and from the parent cell. This difference allows mitosis to be used for organism growth and repair, as well as for asexual reproduction, and allows meiosis to be used for sexual reproduction (ie, due to the production of haploid gametes). Another difference between mitosis and meiosis is that mitosis produces two daughter cells, whereas meiosis produces four daughter cells.

Table 5.1 Differences between mitosis and meiosis.

Characteristics	Mitosis	Meiosis
Number of daughter cells formed	2	4
Creates genetic differences among daughter cells	No	Yes
Number of chromosomes in daughter cells compared to parent cell	Same number	Half as many
Ploidy (number of sets of chromosomes) of parent cell	Diploid or haploid	Diploid only
Ploidy (number of sets of chromosomes) of daughter cells	Diploid or haploid (same as parent cell)	Haploid only
Purpose	Organism growth and repair, asexual reproduction	Production of gametes

Although the purposes and outcomes of mitosis and meiosis are different, both mitosis and meiosis require that DNA replication take place before these processes begin. Therefore, both processes start with parent cells whose chromosomes are made of two identical sister chromatids. Likewise, both mitosis and meiosis use spindle fibers to move chromosomes and segregate (ie, separate) sister chromatids into daughter cells, which are formed at the end of mitosis and meiosis II by cytokinesis. Figure 5.4 shows similarities between mitosis and meiosis.

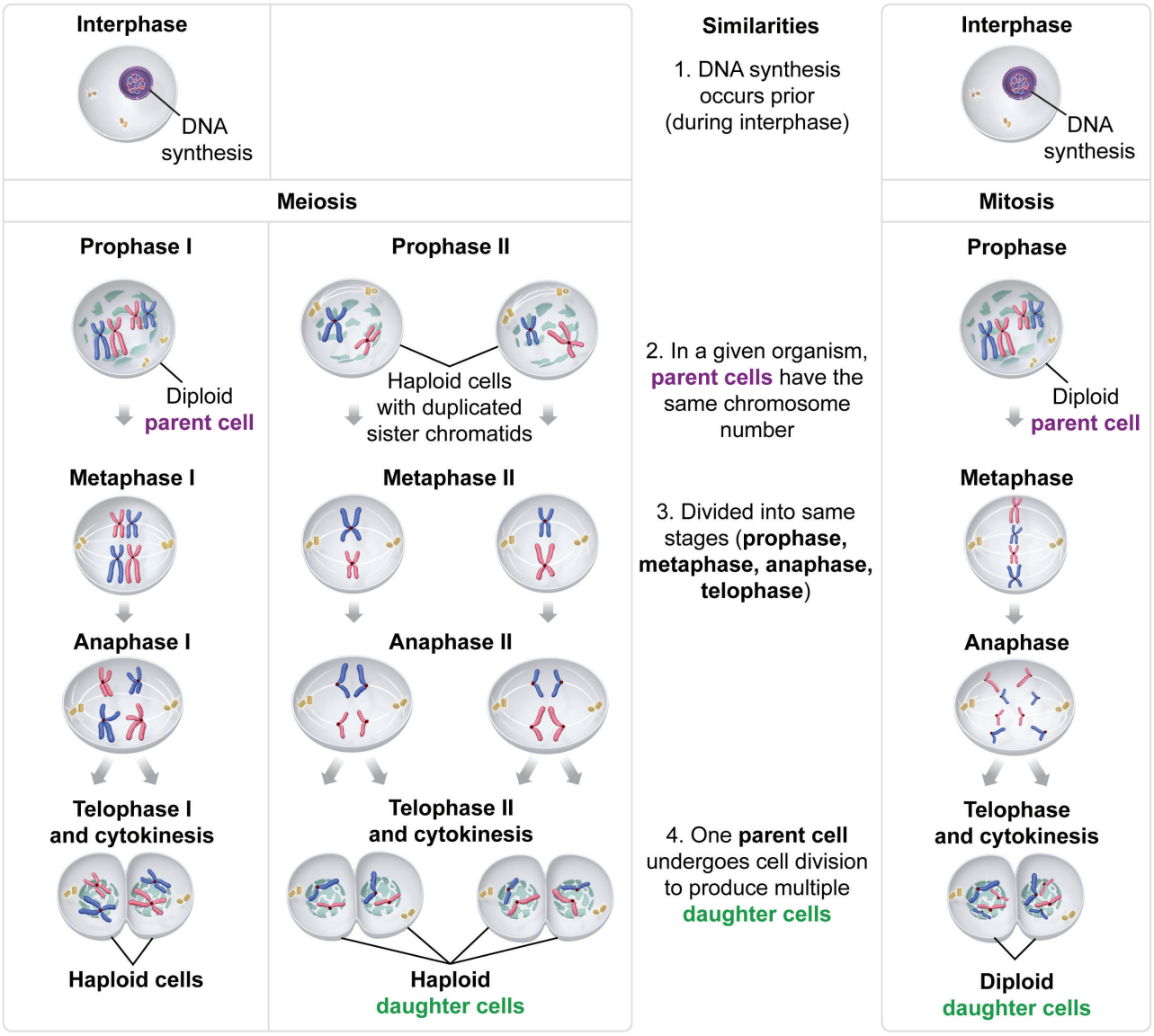

Figure 5.4 Similarities between mitosis and meiosis.

Topic 5.1 Meiosis

Check for Understanding Quiz

1. Which of the following best describes a characteristic of anaphase II?
   A. Individual chromosomes align at the cell's equator.
   B. The nuclear envelope breaks down and spindle fibers form.
   C. The cytoplasm divides to produce new daughter cells.
   D. Sister chromatids are separated by spindle fibers.

2. Which of the following best explains a way in which meiosis differs from mitosis?
   A. Meiosis produces two daughter cells; mitosis produces four daughter cells.
   B. Meiosis produces daughter cells that are genetically identical to the parent cell; mitosis produces genetically distinct daughter cells.
   C. Meiosis leads to the production of gametes; mitosis contributes to organism growth and repair.
   D. Meiosis generates daughter cells with the same ploidy as the parent cell; mitosis produces haploid daughter cells.

Note: Answers to this quiz are in the back of the book (appendix).