Reproduction and Meiosis

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CHAPTER 1 Reproduction and Meiosis

Lesson Objectives

- Compare and contrast asexual and sexual reproduction.
- Give an overview of sexual reproduction, and outline the phases of meiosis.
- Explain why sexual reproduction leads to variation in offspring.
- Define life cycle, and identify different types of sexual life cycles.

Vocabulary

- asexual reproduction
- crossing-over
- diploid
- egg
- fertilization
- gamete
- gametogenesis
- haploid
- independent assortment
- life cycle
- meiosis
- sexual reproduction
- sperm
- zygote

Introduction

Cell division is how organisms grow and repair themselves. It is also how they produce offspring. Many single-celled organisms reproduce by binary fission. The parent cell simply divides to form two daughter cells that are identical to the parent. In many other organisms, two parents are involved, and the offspring are not identical to the parents. In fact, each offspring is unique. Look at the family in **Figure** 1.1. The children resemble their parents, but they are not identical to them. Instead, each has a unique combination of characteristics inherited from both parents. In this lesson, you will learn how this happens.

Reproduction: Asexual vs. Sexual

Reproduction is the process by which organisms give rise to offspring. It is one of the defining characteristics of living things. There are two basic types of reproduction: asexual reproduction and sexual reproduction.

FIGURE 1.1

Family Portrait: Mother, Daughter, Father, and Son. Children resemble their parents, but they are never identical to them. Do you know why this is the case?

Asexual Reproduction

Asexual reproduction involves a single parent. It results in offspring that are genetically identical to each other and to the parent. All prokaryotes and some eukaryotes reproduce this way. There are several different methods of asexual reproduction. They include binary fission, fragmentation, and budding.

- Binary fission occurs when a parent cell splits into two identical daughter cells of the same size (**Figure** 1.2). This process was described in detail in the lesson "Cell Division and the Cell Cycle."

- Fragmentation occurs when a parent organism breaks into fragments, or pieces, and each fragment develops into a new organism. Starfish, like the one in **Figure** 1.3, reproduce this way. A new starfish can develop from a single ray, or arm.

- Budding occurs when a parent cell forms a bubble-like bud. The bud stays attached to the parent cell while it grows and develops. When the bud is fully developed, it breaks away from the parent cell and forms a new organism. Budding in yeast is shown in **Figure** 1.4.

Asexual reproduction can be very rapid. This is an advantage for many organisms. It allows them to crowd out other organisms that reproduce more slowly. Bacteria, for example, may divide several times per hour. Under ideal conditions, 100 bacteria can divide to produce millions of bacterial cells in just a few hours! However, most bacteria do not live under ideal conditions. If they did, the entire surface of the planet would soon be covered with them. Instead, their reproduction is kept in check by limited resources, predators, and their own wastes. This is true of most other organisms as well.

Sexual Reproduction

Sexual reproduction involves two parents. As you can see from **Figure** 1.5, in sexual reproduction, parents produce reproductive cells—called **gametes**—that unite to form an offspring. Gametes are **haploid** cells. This means they contain only half the number of chromosomes found in other cells of the organism. Gametes are produced by a type of cell division called meiosis, which is described in detail below. The process in which two gametes unite is called **fertilization**. The fertilized cell that results is referred to as a **zygote**. A zygote is **diploid** cell, which means that it has twice the number of chromosomes as a gamete.

Mitosis, Meiosis, and Sexual Reproduction is discussed at http://www.youtube.com/watch?v=kaSIjIzAtYA .

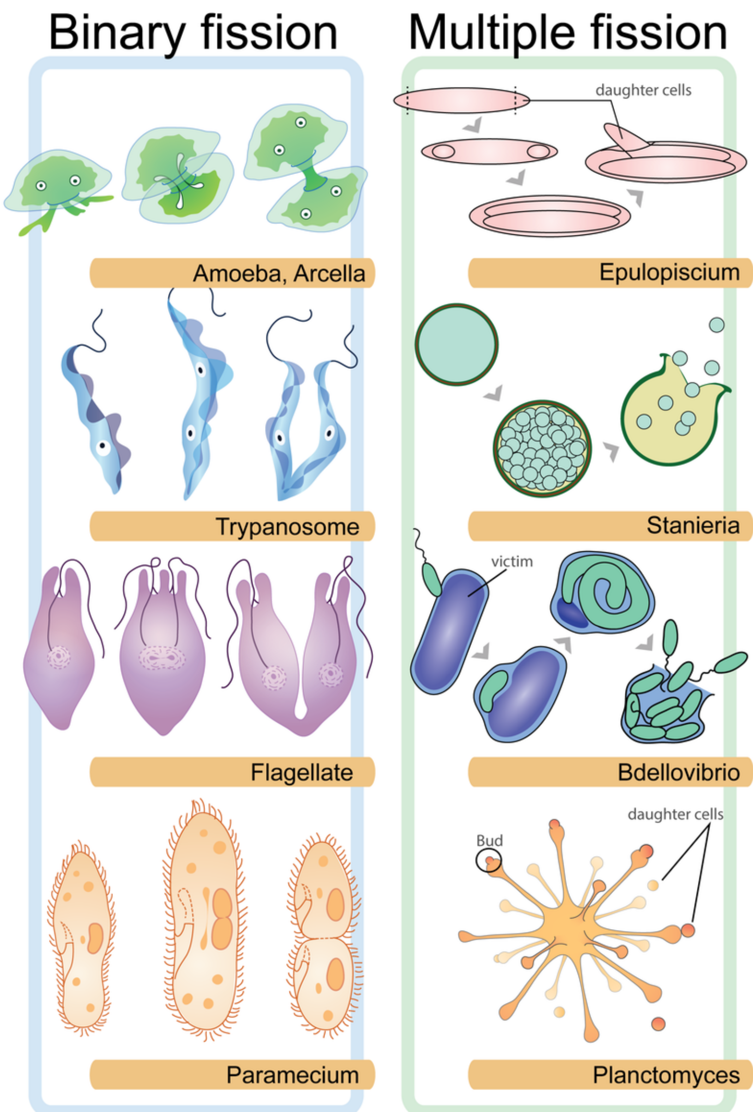
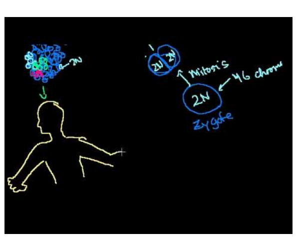


FIGURE 1.2
Binary fission in various single-celled organisms (left). Cell division is a relatively simple process in many single-celled organisms. Eventually the parent cell will pinch apart to form two identical daughter cells. In multiple fission (right), a multinucleated cell can divide to form more than one daughter cell. Multiple fission is more often observed among protists.

FIGURE 1.3
Starfish reproduce by fragmentation. Starfish, however, are also capable of sexual reproduction.



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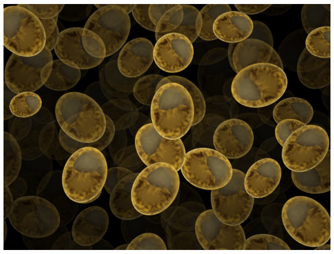


FIGURE 1.4
Yeast reproduces by budding. Both are types of asexual reproduction.

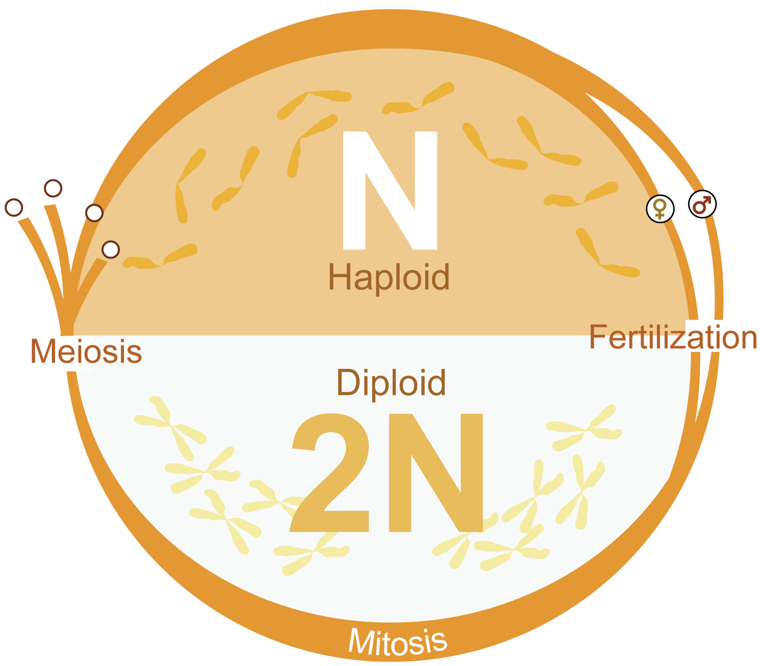


FIGURE 1.5
Cycle of Sexual Reproduction. Sexual reproduction involves the production of haploid gametes by meiosis. This is followed by fertilization and the formation of a diploid zygote. The number of chromosomes in a gamete is represented by the letter n. Why does the zygote have 2n, or twice as many, chromosomes?

Meiosis

The process that produces haploid gametes is meiosis (see **Figure** 1.5). **Meiosis** is a type of cell division in which the number of chromosomes is reduced by half. It occurs only in certain special cells of the organisms. During meiosis, homologous chromosomes separate, and haploid cells form that have only one chromosome from each pair. Two cell divisions occur during meiosis, and a total of four haploid cells are produced. The two cell divisions are called meiosis I and meiosis II. The overall process of meiosis is summarized in **Figure** 1.6. It is also described in detail below. You can watch an animation of meiosis at this link: http://www.youtube.com/watch?v=D1_-mQS_FZ0 .

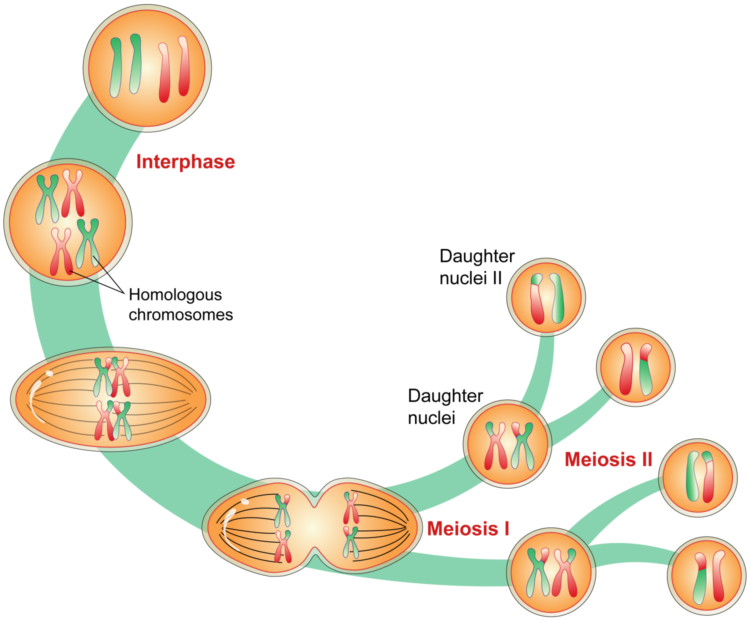


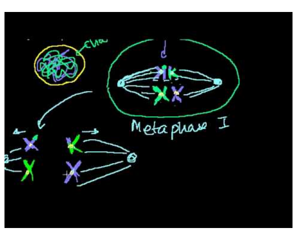
FIGURE 1.6

Overview of Meiosis. During meiosis, homologous chromosomes separate and go to different daughter cells. This diagram shows just the nuclei of the cells. Notice the exchange of genetic material that occurs prior to the first cell division.

Phases of Meiosis

Meiosis I begins after DNA replicates during interphase. In both meiosis I and meiosis II, cells go through the same four phases as mitosis. However, there are important differences between meiosis I and mitosis. The flowchart in **Figure** 1.7 shows what happens in both meiosis I and II. You can follow the changes in the flowchart as you read about them below.

The phases of meiosis are discussed at http://www.youtube.com/watch?v=ijLc52LmFQg (27:23).



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Meiosis I

1. Prophase I: The nuclear envelope begins to break down, and the chromosomes condense. Centrioles start moving to opposite poles of the cell, and a spindle begins to form. Importantly, homologous chromosomes pair up, which is unique to prophase I. In prophase of mitosis and meiosis II, homologous chromosomes do not form pairs in this way. During prophase I, crossing-over occurs (see below).
2. Metaphase I: Spindle fibers attach to the paired homologous chromosomes. The paired chromosomes line up along the equator of the cell. This occurs only in metaphase I. In metaphase of mitosis and meiosis II, it is sister chromatids that line up along the equator of the cell.
3. Anaphase I: Spindle fibers shorten, and the chromosomes of each homologous pair start to separate from each other. One chromosome of each pair moves toward one pole of the cell, and the other chromosome moves toward the opposite pole.
4. Telophase I and Cytokinesis: The spindle breaks down, and new nuclear membranes form. The cytoplasm of

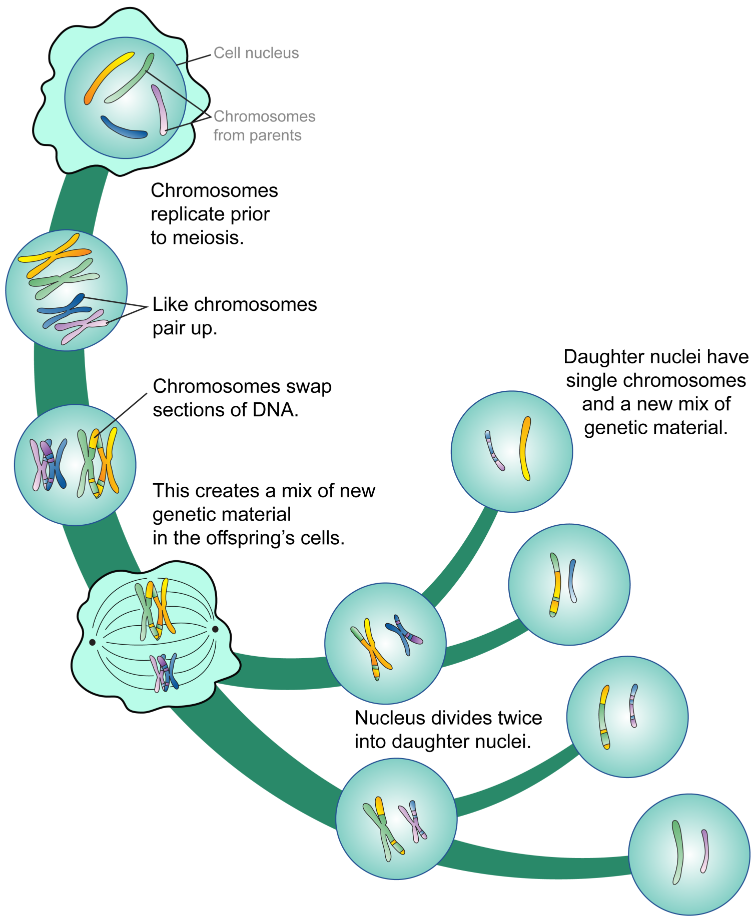


FIGURE 1.7

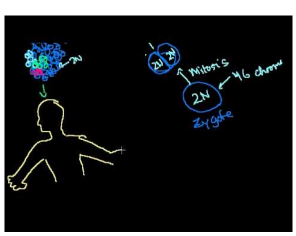
Phases of Meiosis. This flowchart of meiosis shows meiosis I in greater detail than meiosis II. Meiosis I—but not meiosis II—differs somewhat from mitosis. Compare meiosis I in this flowchart with the earlier figure featuring mitosis. How does meiosis I differ from mitosis?

the cell divides, and two haploid daughter cells result. The daughter cells each have a random assortment of chromosomes, with one from each homologous pair. Both daughter cells go on to meiosis II.

Meiosis II

1. Prophase II: The nuclear envelope breaks down and the spindle begins to form in each haploid daughter cell from meiosis I. The centrioles also start to separate.
2. Metaphase II: Spindle fibers line up the sister chromatids of each chromosome along the equator of the cell.
3. Anaphase II: Sister chromatids separate and move to opposite poles.
4. Telophase II and Cytokinesis: The spindle breaks down, and new nuclear membranes form. The cytoplasm of each cell divides, and four haploid cells result. Each cell has a unique combination of chromosomes.

Mitosis, Meiosis, and Sexual Reproduction is discussed at http://www.youtube.com/watch?v=kaSIjIzAtYA (18:23).



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Gametogenesis

At the end of meiosis, four haploid cells have been produced, but the cells are not yet gametes. The cells need to develop before they become mature gametes capable of fertilization. The development of haploid cells into gametes is called **gametogenesis**.

Gametogenesis may differ between males and females. Male gametes are called **sperm**. Female gametes are called **eggs**. In human males, for example, the process that produces mature sperm cells is called spermatogenesis. During this process, sperm cells grow a tail and gain the ability to "swim," like the human sperm cell shown in **Figure** 1.8. In human females, the process that produces mature eggs is called oogenesis. Just one egg is produced from the four haploid cells that result from meiosis. The single egg is a very large cell, as you can see from the human egg in **Figure** 1.8.

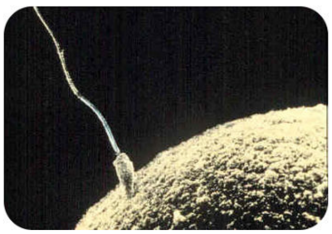

FIGURE 1.8
A human sperm is a tiny cell with a tail. A human egg is much larger. Both cells are mature haploid gametes that are capable of fertilization. What process is shown in this photograph?

Sexual Reproduction and Genetic Variation

Sexual reproduction results in offspring that are genetically unique. They differ from both parents and also from each other. This occurs for a number of reasons.

- When homologous chromosomes pair up during meiosis I, crossing-over can occur. **Crossing-over** is the exchange of genetic material between non-sister chromatids of homologous chromosomes. It results in new combinations of genes on each chromosome.
- When cells divide during meiosis, homologous chromosomes are randomly distributed to daughter cells, and different chromosomes segregate independently of each other. This called is called **independent assortment**. It results in gametes that have unique combinations of chromosomes.
- In sexual reproduction, two gametes unite to produce an offspring. But which two of the millions of possible gametes will it be? This is likely to be a matter of chance. It is obviously another source of genetic variation in offspring.

All of these mechanisms working together result in an amazing amount of potential variation. Each human couple, for example, has the potential to produce more than 64 trillion genetically unique children. No wonder we are all different!

Sexual Reproduction and Life Cycles

Sexual reproduction occurs in a cycle. Diploid parents produce haploid gametes that unite and develop into diploid adults, which repeat the cycle. This series of life stages and events that a sexually reproducing organism goes through is called its **life cycle**. Sexually reproducing organisms can have different types of life cycles. Three are described in the following sections.

Haploid Life Cycle

The haploid life cycle (**Figure** 1.9) is the simplest life cycle. It is found in many single-celled organisms. Organisms with a haploid life cycle spend the majority of their lives as haploid gametes. When the haploid gametes fuse, they form a diploid zygote. It quickly undergoes meiosis to produce more haploid gametes that repeat the life cycle.

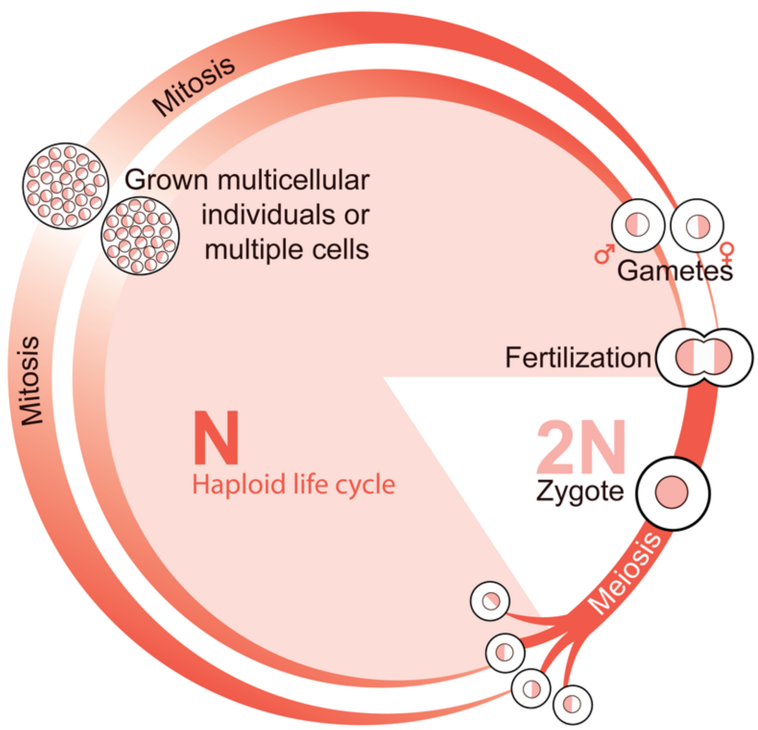

FIGURE 1.9
Haploid Life Cycle. The letter N indicates haploid stages of the life cycles, and 2N indicates diploid stages.

Diploid Life Cycle

Organisms with a diploid life cycle (**Figure** 1.10) spend the majority of their lives as diploid adults. When they are ready to reproduce, they undergo meiosis and produce haploid gametes. Gametes then unite in fertilization and form a diploid zygote. The zygote develops into a diploid adult that repeats the life cycle. Can you think of an organism with a diploid life cycle? (*Hint:* What type of life cycle do humans have?)

Alternation of Generations

Organisms that have a life cycle with alternating generations (**Figure** 1.11) switch back and forth between diploid and haploid stages. Organisms with this type of life cycle include plants, algae, and some protists. These life cycles may be quite complicated. You can read about them in later chapters.

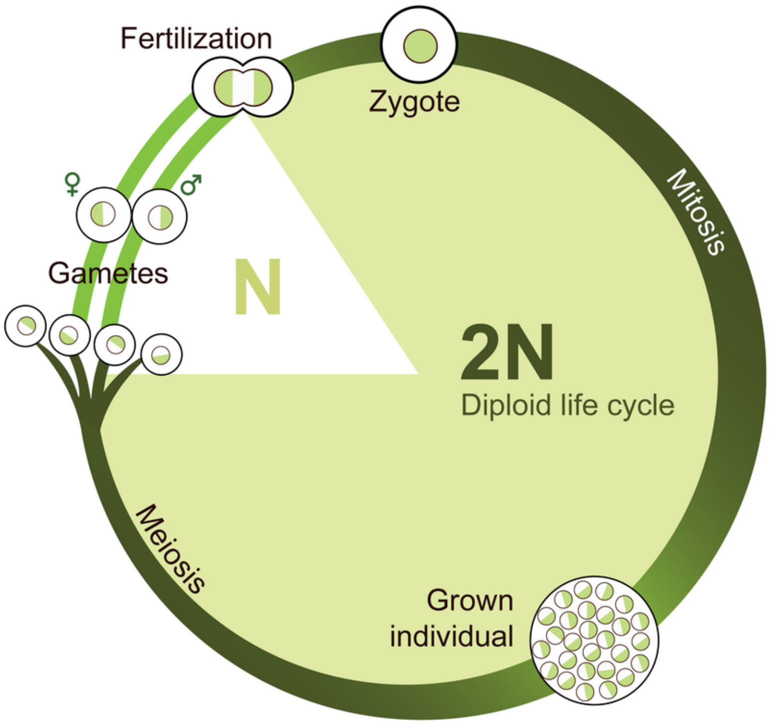

FIGURE 1.10
Diploid Life Cycle. The letter N indicates haploid stages of the life cycles, and 2N indicates diploid stages.

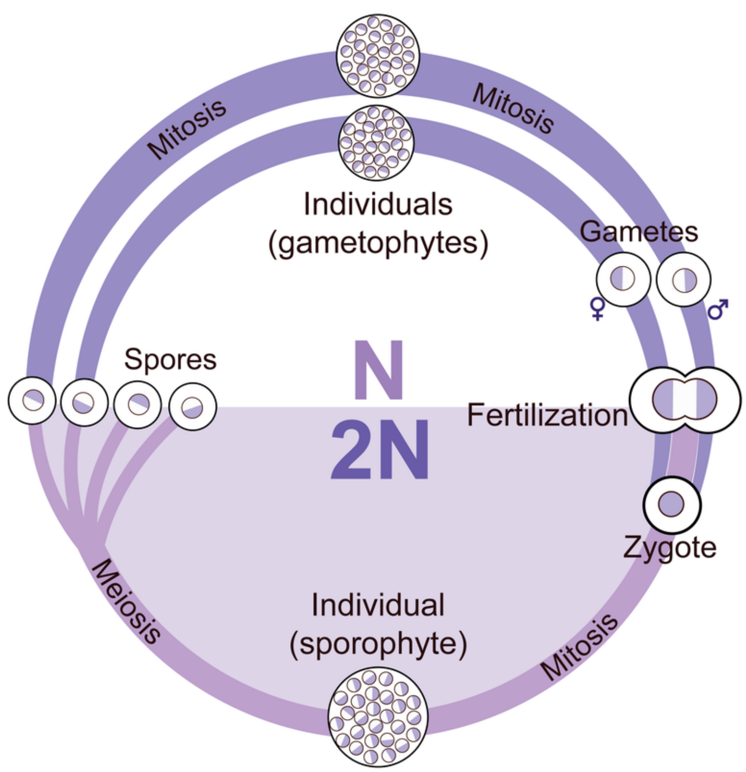

FIGURE 1.11
Alternation of Generations. The letter N indicates haploid stages of the life cycles, and 2N indicates diploid stages.

Lesson Summary

- Asexual reproduction involves one parent and produces offspring that are genetically identical to each other and to the parent. Sexual reproduction involves two parents and produces offspring that are genetically unique.
- During sexual reproduction, two haploid gametes join in the process of fertilization to produce a diploid zygote. Meiosis is the type of cell division that produces gametes. It involves two cell divisions and produces four haploid cells.
- Sexual reproduction has the potential to produce tremendous genetic variation in offspring. This variation is due to independent assortment and crossing-over during meiosis and random union of gametes during fertilization.
- A life cycle is the sequence of stages an organisms goes through from one generation to the next. Organisms that reproduce sexually can have different types of life cycles, such as haploid or diploid life cycles.

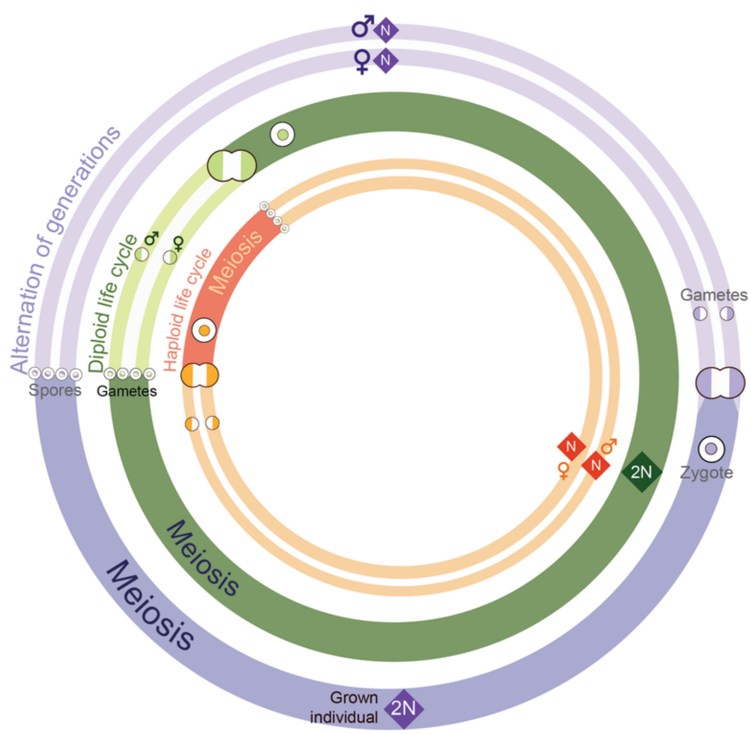

FIGURE 1.12
Summary of all three life cycles.

Lesson Review Questions

Recall

1. What are three types of asexual reproduction?
2. Define gamete and zygote. What number of chromosomes does each have?
3. What happens during fertilization?
4. Outline the phases of meiosis.

5. What is a life cycle?

6. What is gametogenesis, and when does it occur?

Apply Concepts

7. Create a diagram to show how crossing-over occurs and how it creates new gene combinations on each chromosome.

8. An adult organism produces gametes that quickly go through fertilization and form diploid zygotes. The zygotes mature into adults, which live for many years. Eventually the adults produce gametes and the cycle repeats. What type of life cycle does this organism have? Explain your answer.

Think Critically

9. Compare and contrast asexual and sexual reproduction.

10. Explain why sexual reproduction results in genetically unique offspring.

11. Explain how meiosis I differs from mitosis.

Points to Consider

In sexually reproducing organisms, parents pass a copy of each type of chromosome to their offspring by producing gametes. When gametes are fertilized and form offspring, each has a unique combination of chromosomes and genes from both parents. The inherited gene combination determines the characteristics of the offspring.

- Is it possible to predict possible gene combinations in offspring from the genes of their parents?
- Can the characteristics of offspring be predicted from the characteristics of their parents?

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