Reproduction

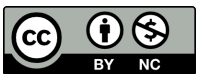
Say Thanks to the Authors
Click http://www.ck12.org/saythanks
(No sign in required)

To access a customizable version of this book, as well as other interactive content, visit www.ck12.org

CK-12 Foundation is a non-profit organization with a mission to reduce the cost of textbook materials for the K-12 market both in the U.S. and worldwide. Using an open-content, web-based collaborative model termed the **FlexBook®**, CK-12 intends to pioneer the generation and distribution of high-quality educational content that will serve both as core text as well as provide an adaptive environment for learning, powered through the **FlexBook Platform®**.

Printed: August 11, 2014

flexbook
next generation textbooks



CHAPTER 1

Reproduction

Lesson Objectives

- Name the types of asexual reproduction.
- Explain the advantage of sexual reproduction.
- List the stages of meiosis and explain what happens in each stage.

Check Your Understanding

- Can something that does not reproduce still be considered living?
- What stores the genetic information that is passed on to offspring?
- How many chromosomes are in the human nucleus?

Vocabulary

- allele
- asexual reproduction
- binary fission
- crossing-over
- cross-pollination
- diploid
- external fertilization
- gamete
- gonad
- haploid
- internal fertilization
- meiosis
- ovaries
- parthenogenesis
- sexual reproduction
- testes
- zygote

What is Reproduction?

What does reproduction mean? Can an organism be considered alive if it cannot make the next generation? Since individuals cannot live forever, they must reproduce for the species to survive. Reproduction is the ability to make the next generation.

Two methods of reproduction are:

1. **Asexual reproduction**, or the process of forming a new individual from a single parent.
2. **Sexual reproduction**, or the process of forming a new individual from two parents.

There are advantages and disadvantages to each method, but the result is always the same: a new life begins.

Asexual Reproduction

For humans to reproduce, DNA must be passed from the mother and father to the child. Humans cannot reproduce with just one parent, but it is possible in other organisms, like bacteria, some insects and some fish. These organisms can reproduce asexually, meaning that the offspring (children) have a single parent and share the exact same genetic material as the parent. This is very different from humans.

The advantage of asexual reproduction is that it can be very quick and does not require the meeting of a male and female organism. The disadvantage of asexual reproduction is that organisms cannot mix beneficial traits from both parents. An organism that is born through asexual reproduction only has the DNA from the one parent, and it is the exact copy of that parent. This can cause problems for the individual. For example, if the parent organism has a gene that causes cancer, the offspring will also have the gene that causes cancer. Organisms produced sexually may or may not inherit the cancerous gene because there are two parents mixing up their genes.

Types of organisms that reproduce asexually include:

1. Prokaryotic organisms, like bacteria. Bacteria reproduce through **binary fission,** where they grow and divide in half (**Figure** 1.1). First, their chromosome replicates (bacteria only have one chromosome) and the cell enlarges. After cell division, the two new cells each have one identical chromosome (mitosis is not necessary because bacteria do not have nuclei). Then, new membranes form to separate the two cells. This simple process allows bacteria to reproduce very rapidly.
2. Flatworms, an animal species. Flatworms divide in two, then each half regenerates into a new flatworm identical to the original.
3. Different types of insects, fish, and lizards. These organisms can reproduce asexually through a process called parthenogenesis (**Figure** 1.2). **Parthenogenesis** happens when an unfertilized egg cell grows into a new organism. The resulting organism has half the amount of genetic material of the parent. Parthenogenesis is common in honeybees. In a hive, the sexually produced eggs become workers, while the asexually produced eggs become drones.

Sexual Reproduction

During sexual reproduction, two parents are involved. Most animals are dioecious, meaning there is a separate male and female sex, with the male producing sperm and the female producing eggs. When a sperm and egg meet, a **zygote,** the first cell of a new organism, is formed (**Figure** 1.3). The zygote will divide and grow into the embryo.

Let's explore how animals, plants, and fungi reproduce sexually:

- Animals often have **gonads,** organs that produce eggs or sperm. The male gonads are the **testes,** which produce the sperm, and the female gonads are the **ovaries,** which produce the eggs. Sperm and egg, the two sex cells, are known as **gametes**, and can combine two different ways:

1. Fish and other aquatic animals release their gametes in the water, which is called **external fertilization.** These gametes will combine by chance (**Figure** 1.4).

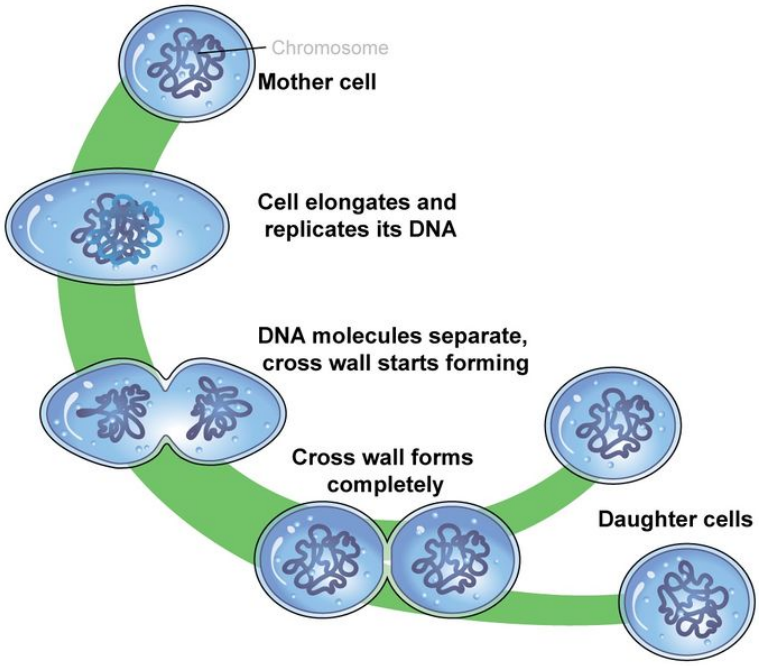


FIGURE 1.1

Bacteria reproduce by binary fission. Shown is one bacterium reproducing and becoming two bacteria.

FIGURE 1.2

This Komodo dragon was born by parthenogenesis.

2. Animals that live on land reproduce by **internal fertilization**. Typically males have a penis that deposits sperm into the vagina of the female. Birds do not have penises, but they do have a chamber called the cloaca that they place close to another bird's cloaca to deposit sperm.

FIGURE 1.3

During sexual reproduction, a sperm fertilizes an egg.

FIGURE 1.4

This fish guards her eggs, which will be fertilized externally.

- Plants can also reproduce sexually, but their reproductive organs are different from animals' gonads. Plants that have flowers have their reproductive parts in the flower. The sperm is contained in the pollen, while the egg is contained in the ovary, deep within the flower. The sperm can reach the egg two different ways:

1. In self-pollination, the egg is fertilized by the pollen of the same flower.
2. In **cross-pollination**, sperm from the pollen of one flower fertilizes the egg of another flower. Like other types of sexual reproduction, cross-pollination allows new combinations of traits. Cross-pollination occurs when pollen is carried by the wind to another flower. It can also occur when animal pollinators, like honeybees, or butterflies (**Figure** 1.5) carry the pollen from flower to flower.

- Fungi can also reproduce sexually, but instead of female and male sexes, they have (+) and (-) strains. When the filaments of a (+) and (-) fungi meet, the zygote is formed. Just like in plants and animals, each zygote

receives DNA from two parent strains.

FIGURE 1.5

Butterflies receive nectar when they deposit pollen into flowers, resulting in cross-pollination.

Meiosis and Gametes

Meiosis is a process of cell division that produces sex cells, or gametes. Gametes are reproductive cells, such as sperm and egg. As gametes are produced, the number of chromosomes must be reduced by half. Why? The zygote must contain information from the mother and from the father, so the gametes must contain half of the chromosomes found in normal body cells.

In humans, our cells have 23 pairs of chromosomes, and each chromosome within a pair is called a **homologous chromosome.** For each of the 23 chromosome pairs, you received one chromosome from your father and one chromosome from your mother. The homologous chromosomes are separated when gametes are formed. Therefore, gametes have only 23 chromosomes, not 23 pairs.

Alleles are alternate forms of genes found on chromosomes. Since the separation of chromosomes into gametes is random, it results in different combinations of chromosomes (and alleles) in each gamete. With 23 pairs of chromosomes, there is a possibility of over 8 million different combinations of chromosomes in a gamete.

Haploid vs. Diploid

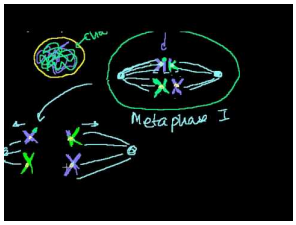
A cell with two sets of chromosomes is **diploid**, referred to as $2n$, where n is the number of sets of chromosomes. Most of the cells in a human body are diploid. A cell with one set of chromosomes, such as a gamete, is **haploid,** referred to as n. Sex cells are haploid. When a haploid sperm (n) and a haploid egg (n) combine, a diploid zygote will be formed ($2n$). In short, when a diploid zygote is formed, half of the DNA comes from each parent.

Meiosis

Before meiosis begins, DNA replication occurs, so each chromosome contains two sister chromatids that are identical to the original chromosome.

Meiosis is divided into two divisions: Meiosis I and Meiosis II. Each division is similar to mitosis and can be divided into the same phases: prophase, metaphase, anaphase, and telophase. Between the two divisions, DNA replication does not occur. Through this process, one diploid cell will divide into four haploid cells.

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



MEDIA

Click image to the left for more content.

Meiosis I

During meiosis I, the pairs of homologous chromosomes are separated from each other.

1. Prophase I: The homologous chromosomes line up together. During this time, a process that only happens in meiosis can occur. This process is called **crossing-over** (**Figure** 1.6), which is the exchange of DNA between homologous chromosomes. Crossing-over increases the new combinations of alleles in the gametes. Without crossing-over, the offspring would always inherit all of the many alleles on one of the homologous chromosomes. Also during prophase I, the spindle forms, the chromosomes condense as they coil up tightly, and the nuclear envelope disappears.
2. Metaphase I: The homologous chromosomes line up in pairs in the middle of the cell. Chromosomes from the mother or from the father can each attach to either side of the spindle. Their attachment is random, so all of the chromosomes from the mother or father do not end up in the same gamete. The gamete will contain some chromosomes from the mother and some chromosomes from the father.
3. Anaphase I: The homologous chromosomes separate.
4. Telophase I: The spindle fibers dissolves, but a new nuclear envelope does not need to form. This is because the nucleus will divide again. No DNA replication happens between meiosis I and meiosis II because the chromosomes are already duplicated.

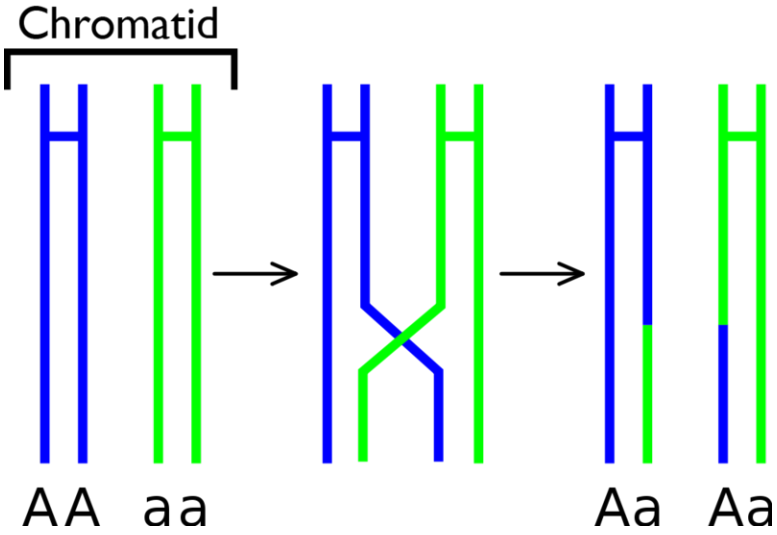


FIGURE 1.6

During crossing-over, segments of DNA are exchanged between non-sister chromatids of homologous chromosomes. Notice how this can result in an allele (A) on one chromatid being moved onto the other non-sister chromatid.

Meiosis II

During meiosis II, the sister chromatids are separated and the gametes are generated.

The steps are outlined below:

1. Prophase II: The chromosomes condense.
2. Metaphase II: The chromosomes line up one on top of the next along the middle of the cell.
3. Anaphase II: The sister chromatids separate.
4. Telophase II: Nuclear envelopes form around the chromosomes in all four cells.

After cytokinesis, each cell has divided again. Therefore, meiosis results in four daughter cells with half the DNA of the parent cell (**Figure** 1.7). In human cells, the parent cell has 46 chromosomes, so the cells produced by meiosis have 23 chromosomes. These cells will become gametes.

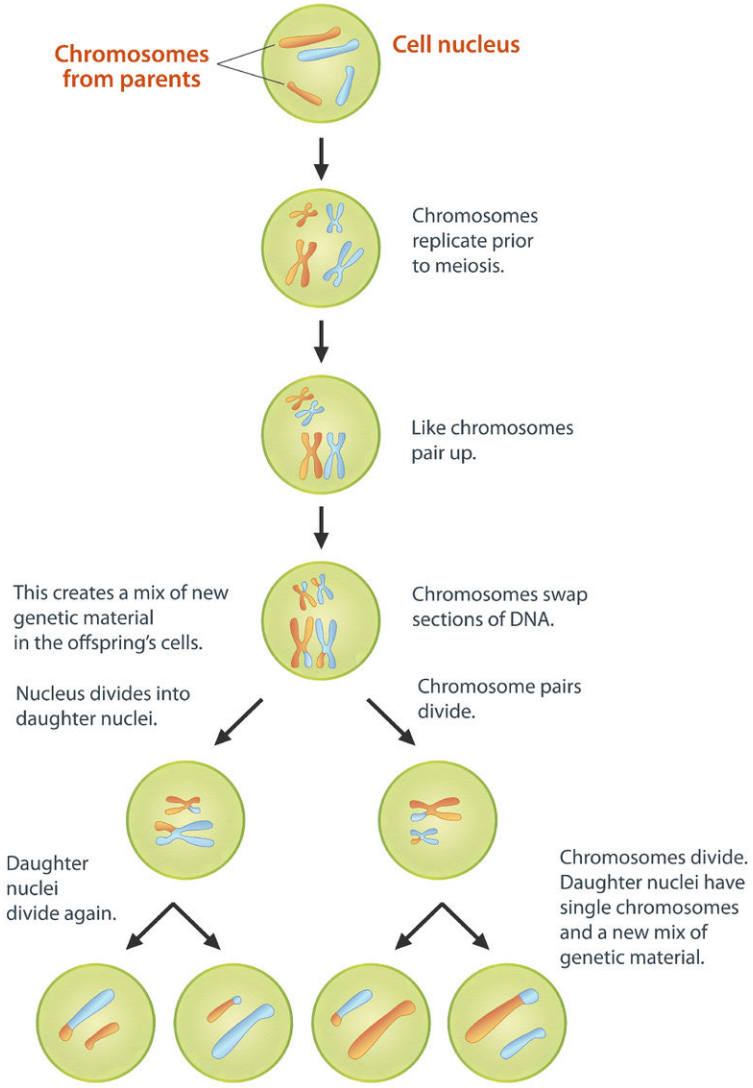


FIGURE 1.7
An overview of meiosis.

Mitosis vs. Meiosis: A Comparison

Mitosis, meiosis and sexual reproduction are discussed at http://www.youtube.com/watch?v=kaSIjIzAtYA (18:23).

MEDIA

Click image to the left for more content.

Figure 1.8 is a comparison between binary fission, mitosis, and meiosis. Mitosis and meiosis are also compared in **Table** 1.1.

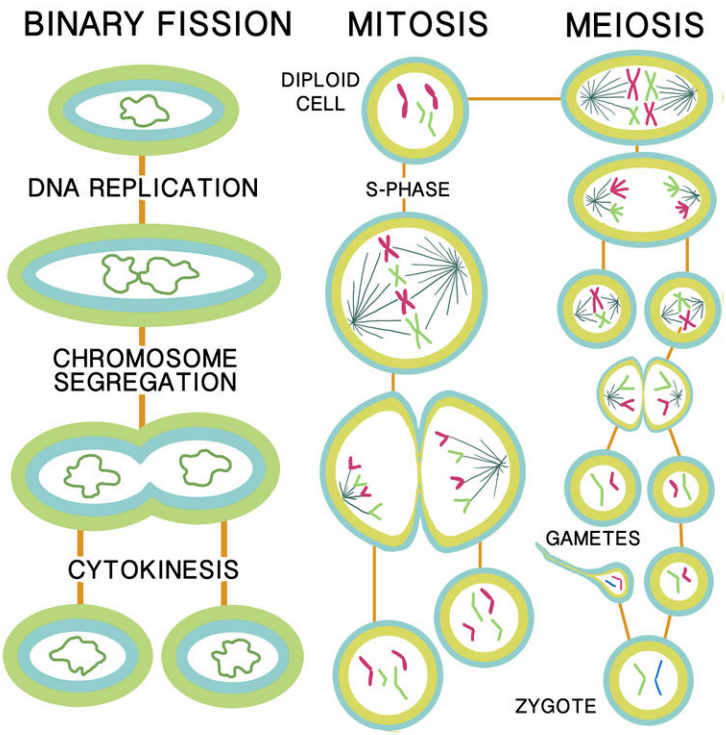


FIGURE 1.8

A comparison between binary fission, mitosis, and meiosis.

Animations of meiosis can be found at the following sites:

- http://www.cellsalive.com/meiosis.htm
- http://www.youtube.com/watch?v=MqaJqLL49a0

TABLE 1.1: Mitosis vs. Meiosis: A Comparison

	Mitosis	Meiosis
Purpose:	To produce new cells	To produce gametes
Number of cells produced:	2	4
Rounds of Cell Division:	1	2
Haploid or Diploid:	Diploid	Haploid
Daughter cells identical to parent cells?	Yes	No
Daughter cells identical to each other?	Yes	No

Lesson Summary

- Organisms can reproduce sexually or asexually.
- The gametes in sexual reproduction must have half the DNA of the parent.
- Meiosis is the process of nuclear division that forms gametes.

Review Questions

Recall

1. What is parthogenesis?
2. During what phase of meiosis do homologous chromosomes separate?
3. What is the purpose of meiosis?
4. In what phase of meiosis do homologous chromosomes pair up?

Apply Concepts

5. Explain how organisms reproduce asexually.
6. Explain how birds fertilize their eggs.
7. How do most plants reproduce sexually?
8. Compare and contrast the process of mitosis and the process of meiosis.

Critical Thinking

9. How would sexual reproduction in a lizard be different than in a fish?
10. What is the advantage of sexual reproduction over asexual reproduction?
11. If an organism has 12 chromosomes in its cells, how many chromosomes will be in its gametes?

Further Reading / Supplemental Links

- http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookmeiosis.html
- http://www.biology.arizona.edu/Cell_BIO/tutorials/meiosis/page3.html

Points to Consider

- What must be replicated prior to mitosis?
- How do you think DNA might be replicated?
- What might happen if there is a mistake during DNA replication?

References

1. Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation. CK-12 Foundation . CC BY-NC 3.0
2. Dale Harvey. http://www.flickr.com/photos/daleharvey/2718250378/ . CC BY 2.0
3. Zappy's. CK-12 Foundation . CC BY-NC 3.0
4. Chika Watanabe. http://www.flickr.com/photos/chikawatanabe/1888284871/ . CC BY 2.0
5. James Emery. http://www.flickr.com/photos/emeryjl/456175019/ . CC BY 2.0
6. User:Masur/Wikimedia Commons. http://commons.wikimedia.org/wiki/File:Crossing-over_scheme_PL.svg . Public Domain
7. Hana Zavadska. CK-12 Foundation . CC BY-NC 3.0
8. Laura Guerin. CK-12 Foundation . CC BY-NC 3.0