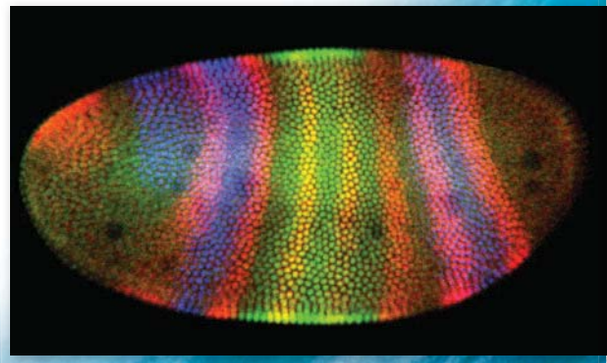
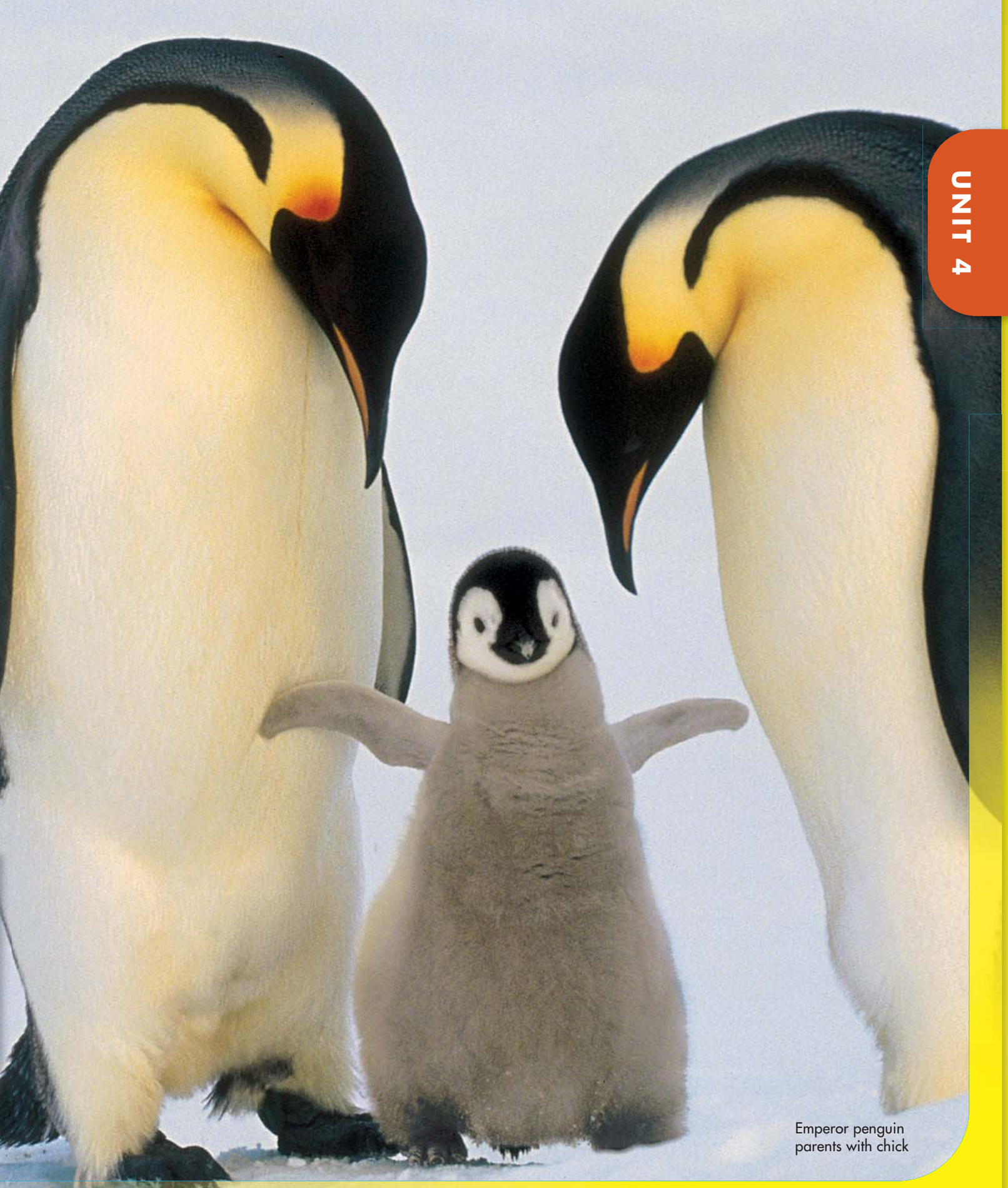
UNIT 4 Heredity

Eggs of the red-eyed tree frog stuck to the underside of a leaf



Fruit fly embryo, marked to show pattern of genes being expressed



Emperor penguin parents with chick

DISCOVERIES IN SCIENCE

Heredity and Genetics

1865

Gregor Mendel publishes the results of his studies of genetic inheritance in pea plants. Although his work is not widely known until much later, Mendel is remembered as the founder of the science of genetics.

Gregor Mendel

1879

After staining cells with Perkins dye and viewing them under a microscope, Walter Fleming identifies chromatin in cells. Soon after, he observes and describes all stages of mitosis, using terms such as *metaphase, anaphase and telophase.*

1905

Nettie Maria Stephens describes how human gender is determined by the X and Y chromosomes.

Nettie Stevens

1909

The Elements of Heredity, by Wilhelm Johannsen, a Danish biologist, is revised and translated into German. In the book, Johannsen develops many of the concepts of modern genetics, particularly phenotype and genotype. This book becomes a founding text of genetics.

1913

Alfred Henry Sturtevant, an undergraduate student at Columbia University, determines the relative location of genes on a fruit fly chromosome. He publishes a genetic map showing the order of genes and their relative distance from each other.

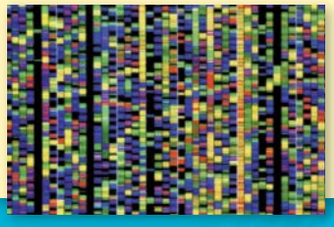
1915

Thomas Hunt publishes the book *Mechanism of Mendelian Heredity,* which explains the phenomenon of sex-linked traits observed in fruit flies.

***Drosophila melanogaster* (fruit fly)**

1989

Francis Collins and Lap-Chee Tsui identify a mutant version of a gene on chromosome 7 that causes cystic fibrosis. Discovery of the gene leads to the development of tests that can determine whether potential parents are carriers of the gene.

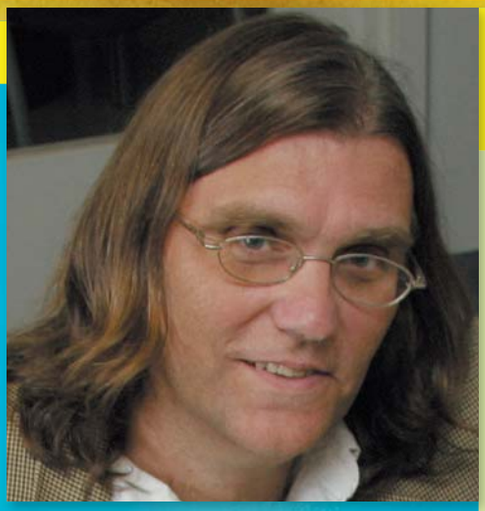


Genetic sequences on a computer screen

2003

The Human Genome Project is completed. Research teams around the world collaborated to identify all genes and decode the sequence of all DNA in human cells.

Albino peacock



BIOLOGY CAREER

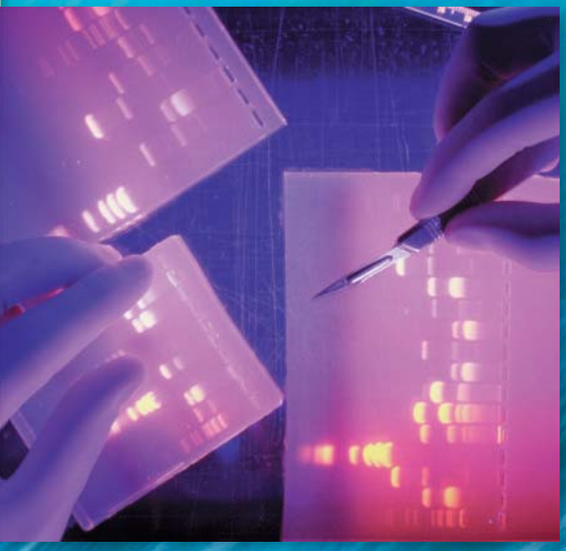
Genetics Researcher

Rob Desalle

Rob DeSalle is a curator in the Division of Invertebrate Zoology at the American Museum of Natural History in New York City. His current research focuses on molecular evolution in a variety of organisms, including pathogenic bacteria and insects.

DeSalle studies molecular evolution through comparative genomics, which is the study of similarities and differences between the genomes of various species or strains within species. Comparing the genomes of species can help determine how the species are related.

DeSalle also helped found the Conservation Genetics Program at the American Museum of Natural History. This program uses the tools of molecular genetics to help protect wildlife around the world. For example, DeSalle helped develop a genetic test to determine if caviar sold in the United States was illegally harvested from endangered species of sturgeon in the Caspian Sea.



Genetic analysis by gel electrophoresis

UNIT 4

Chapter Planner

11 Meiosis and Sexual Reproduction

		Standards	Teach Key Ideas
CHAPTER OPENER, pp. 244–245	15 min.	*National Science Education Standards*	
SECTION 1 Reproductio, pp. 247–249 › Asexual Reproduction › Sexual Reproduction › Chromosome Number	45 min.	LSCell 3, LSGene 2	**Bellringer Transparency** **Transparencies** B44 Chromosome Number of Various Organisms **Visual Concepts** Sexual Reproduction • Fertilization • Comparing Haploid and Diploid Cells
SECTION 2 Meiosis, pp. 250–255 › Stages of Meiosis › Comparing Mitosis and Meiosis › Genetic Variation	90 min.	LSCell 1, LSCell 2, LSCell 3, LSCell 6	**Bellringer Transparency** **Transparencies** B49 Stages of Meiosis • B51 Meiosis in Male and Female Animals **Visual Concepts** Tetrads and Crossing-over of Genetic Material • Independent Assortment • Formation of a Sperm • Formation of an Egg Cell • Comparing the Results of Meiosis and Mitosis • Comparing Meiosis and Mitosis
SECTION 3 Multicellular Life Cycles, pp. 256–259 › Diploid Life Cycle › Haploid Life Cycle › Alternation of Generations	60 min.	LSCell 4	**Bellringer Transparency** **Transparencies** B48 Diploid Life Cycle • F13 Haploid Life Cycle • G5 Alternation of Generations **Visual Concepts** Comparing Haploid and Diploid Cells • Alternation of Generations
			See also PowerPoint® Resources

Chapter Review and Assessment Resources

- SE Super Summary, p. 260
- SE Chapter Review, p. 261
- SE Standardized Test Prep, p. 263
- Review Resources
- Chapter Tests A and B
- Holt Online Assessment

CHAPTER FastTrack

Thorough instruction will require the times shown.

Basic Learners

- TE Advantages and Disadvantages, p. 248
- TE Crossing-Over, p. 253
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide* ■
- Note-taking Workbook*
- Special Needs Activities and Modified Tests*

Advanced Learners

- TE Genetic Variation, p. 253
- Critical Thinking Worksheets*
- Concept Mapping Worksheets*
- Science Skills Worksheets*
- Lab Datasheets, Level C*

Key

SE Student Edition
TE Teacher's Edition

Chapter Resource File
Workbook
Transparency

CD or CD-ROM
* Datasheet or blackline master available

■ Also available in Spanish

All resources listed below are also available on the Teacher's One-Stop Planner.

Why It Matters	Hands-On	Skills Development	Assessment
Build student motivation with resources about high-interest applications.	SE **Inquiry Lab** Pollen Up Close, p. 245* ■	TE **Reading Toolbox** Assessing Prior Knowledge, p. 244 SE **Reading Toolbox,** p. 246	
	Exploration Lab Karyotyping* **Skills Practice Lab** Laboratory Techniques: Staining DNA and RNA*	TE **Math Skills** Asexual Reproduction in Bacteria, p. 248 SE **Reading Toolbox** Key-Term Fold, p. 249 TE **Reading Toolbox** Key-Term Fold, p. 249	SE **Section Review** TE **Formative Assessment** **Spanish Assessment*** ■ **Section Quiz** ■
TE **Demonstration** Counting Chromosomes, p. 250 TE **Development in Eggs,** p. 252 SE **Girls, Girls, Girls,** p. 255	SE **Quick Lab** Crossing-Over Model, p. 253* ■ SE **Skills Practice Lab** Meiosis Model, p. 259* ■	SE **Reading Toolbox** Comparisons, p. 252 TE **Reading Toolbox** Comparisons, p. 252 TE **Reading Toolbox** Visual Literacy, p. 255	SE **Section Review** TE **Formative Assessment** **Spanish Assessment*** ■ **Section Quiz** ■
	SE **Quick Lab** Chromosome Combinations, p. 257* ■	SE **Reading Toolbox** Two-Column Notes, p. 258 TE **Reading Toolbox** Two-Column Notes, p. 258	SE **Section Review** TE **Formative Assessment** **Spanish Assessment*** ■ **Section Quiz** ■
	See also Lab Generator		**See also Holt Online Assessment Resources**

Resources for Differentiated Instruction

English Learners

TE Reading Organizer, p. 257
Directed Reading Worksheets*
Active Reading Worksheets*
Lab Manuals, Level A*
Study Guide* ■
Note-taking Workbook*
Multilingual Glossary

Struggling Readers

TE Counting Chromosomes, p. 251
Directed Reading Worksheets*
Active Reading Worksheets*
Lab Manuals, Level A*
Study Guide*
Note-taking Workbook*
Special Needs Activities and Modified Tests*

Special Education Students

TE Modeling Meiosis, p. 252
Directed Reading Worksheets*
Active Reading Worksheets*
Lab Manuals, Level A*
Study Guide* ■
Note-taking Workbook*
Special Needs Activities and Modified Tests*

Alternative Assessment

TE Modeling Life Cycles, p. 257
Science Skills Worksheets*
Section Quizzes* ■
Chapter Tests A, B, and C* ■

Chapter 11

Overview

The purpose of this chapter is to explain the different types of reproduction. In sexual reproduction, genes are rearranged in the process of meiosis, which results in genetic variation in a population. Organisms that reproduce sexually have diploid and haploid stages in their life cycles. Some organisms have a life cycle that alternates between haploid and diploid phases.

READING TOOLBOX

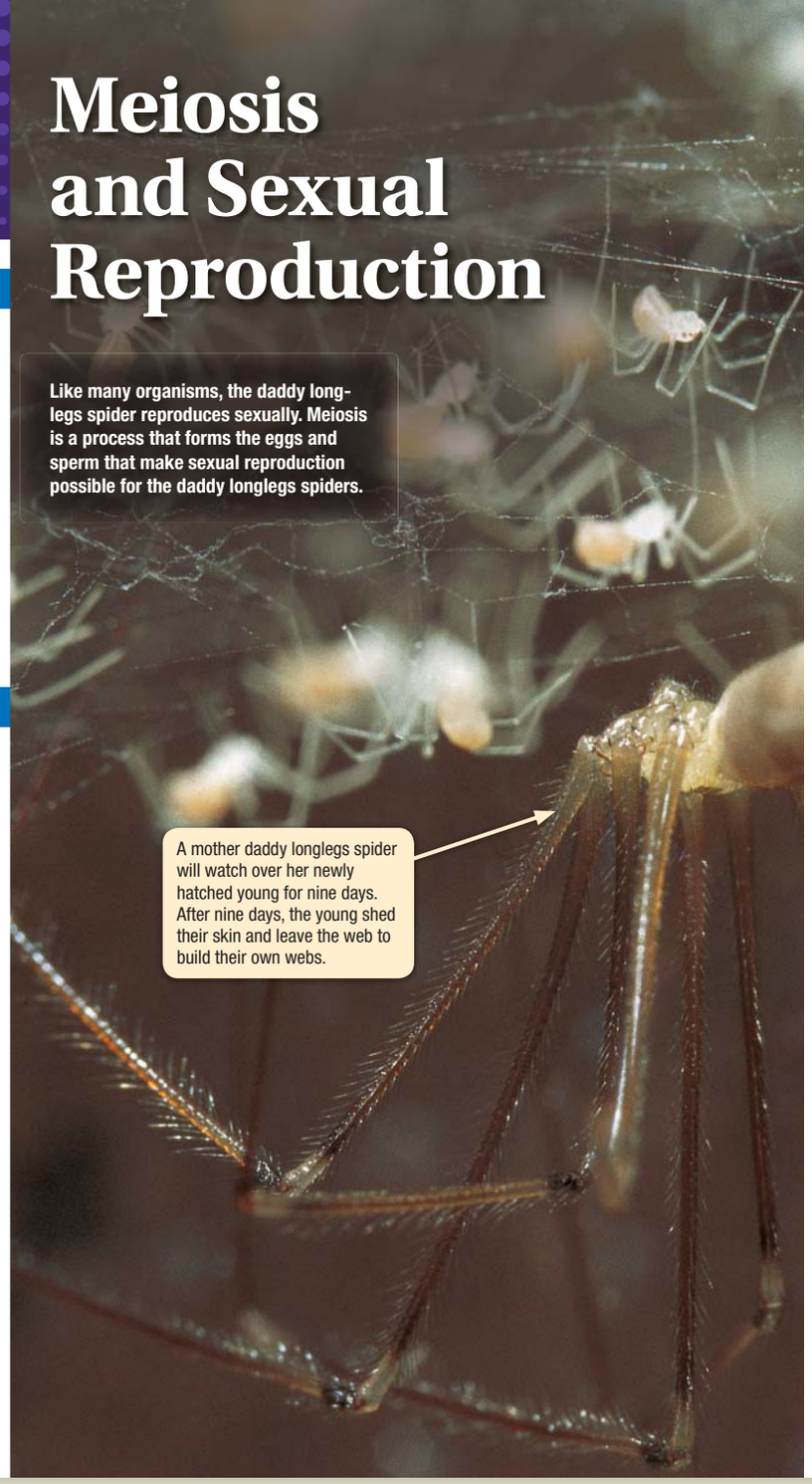
Assessing Prior Knowledge Students should understand the following concepts:

- sexual and asexual reproduction
- cellular structure
- DNA and genes
- mitosis

Visual Literacy Ask students to think of friends or acquaintances who look more like their mothers than their fathers (and vice versa). Ask them to also think about acquaintances who look like a blend of both parents. Have students look at the spider offspring in the photo. Do they look alike? (yes) Are they identical to their parents? (no) Ask students how they know that the offspring are different. (Their genes come from different mixtures of both parents' genes, so they cannot be identical.) LS Visual

Chapter 11

Meiosis and Sexual Reproduction



Like many organisms, the daddy longlegs spider reproduces sexually. Meiosis is a process that forms the eggs and sperm that make sexual reproduction possible for the daddy longlegs spiders.

A mother daddy longlegs spider will watch over her newly hatched young for nine days. After nine days, the young shed their skin and leave the web to build their own webs.

Preview

Why It Matters

You know that in sexual reproduction, an egg and a sperm combine to form a new organism. But how are eggs and sperm produced? In this chapter, you will learn about a special type of cell division called *meiosis*.

Chapter Correlations — *National Science Education Standards*

LSCell 1 Cells have particular structures that underlie their functions.

LSCell 2 Most cell functions involve chemical reaction.

LSCell 3 Cells store and use information to guide their functions.

LSCell 4 Cell functions are regulated.

LSCell 6 Cells can differentiate and form complete multicellular organisms.

LSGene 2 Most of the cells in a human contain two copies of each of 22 different chromosomes. In addition there is a pair of chromosomes that determine sex.

The newly hatched spiders, or *prenymphs,* may all look alike. However, because they formed from sexual reproduction, they are all genetically different.

InquiryLab

30 min

Pollen Up Close

Pollen is produced in the male reproductive part of a flower called the *anther*. Pollen develops from cells called *microspores*. The mature pollen grain encloses two nuclei. Each nucleus contains half of the number of chromosomes found in most cells of the mature, flower-producing plant.

Procedure

1. **CAUTION: Handle glass slides with care.** Place a prepared slide of a lily anther on the microscope stage. Examine the slide under low power.
2. Identify the large chambers called *pollen sacs*. How many can you find in your cross-sectional view? Are they whole or broken? Make a sketch of what you see.
3. Depending upon the stage of development, the pollen sacs will contain either clustered cells in various stages of division or mature grains of pollen. You can identify a pollen grain by its two stained nuclei and textured coat. Select several representative cells within the pollen sac. Make a sketch of each cell.

Analysis

1. **Describe** the structure of the lily anther.
2. **Determine** whether the observed pollen sacs contain dividing cells, pollen grains, or both.
3. **Describe** the appearance of the nuclei in either the dividing cells or the pollen grains.
4. **Explain** what advantage is achieved by halving the chromosome number in pollen nuclei.

InquiryLab

Teacher's Notes Prior to presenting this activity to students, preview all the prepared slides to ensure that each one offers an assortment of meiotic stages. You may also wish to display the male organs of a lily flower, so students may better understand the structure they are observing in the prepared cross-section. Explain to students that pollen is a male gamete produced by the process of meiosis. Explain to students that pollen is a male gamete produced by the process of meiosis.

Materials

- compound microscope
- prepared slides of lily anther

Answers to Analysis

1. The anther has several chambers. Each chamber contains pollen grains or the cells from which they will develop.
2. Answers will vary depending upon the slide examined.
3. The dividing cells are observed in clusters of up to four in various stages of division. The pollen grains have a textured coat and contain two distinct nuclei.
4. When the pollen fertilizes the egg, the union contains the chromosome number of the typical organism cell.

READING TOOLBOX

Using Words

1. Check students' work to make sure that they choose appropriate terms. The Chapter Summary page lists all of the key terms for this chapter.

Using Language

1. Meiosis and mitosis are being compared.
2. The Burmese python is being contrasted to other reptiles.

Taking Notes

1. Left-hand column: Tell students that key idea questions are answered in the bold-faced sentences. Example: An individual formed by asexual reproduction is genetically identical to its parent.
2. Right-hand column: Make sure students write notes in this column that correspond to the key ideas in the left column. Example: Organisms such as prokaryotes, starfish, amoebas, hydras, potatoes, and water fleas can reproduce this way. Tell students they may include drawings and diagrams in the right column.

READING TOOLBOX

These reading tools can help you learn the material in this chapter. For more information on how to use these and other tools, see **Appendix: Reading and Study Skills.**

Using Words

Key-Term Fold A key-term fold is a useful tool for studying definitions of key terms in a chapter. Each tab can contain a key term on one side and its definition on the other.

Your Turn Make a key-term fold for the terms of this chapter.

1. Fold a sheet of lined notebook paper in half from left to right.
2. Using scissors, cut along every third line from the right edge of the paper to the center fold to make tabs.

Using Language

Comparisons Comparing is a way of looking for the similarities between different things. Contrasting is a way of looking for the differences. Certain words and phrases can help you determine if things are being compared or contrasted. Comparison words include *and, like, just as,* and *in the same way.* Contrast words include *however, unlike, in contrast,* and *on the other hand.*

Your Turn In the following sentences, find the things that are being compared or contrasted.

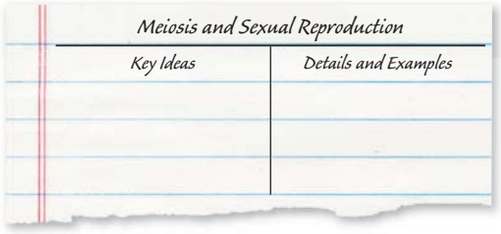
1. Like mitosis, meiosis is a process that reproduces new cells.
2. In contrast to many other reptiles, the Burmese python does not reproduce sexually.

Taking Notes

Two-Column Notes Two-column notes can help you summarize the key ideas of a topic, chapter, or process. The left column of the table contains key ideas. The right column contains details and examples of each main idea.

Your Turn As you read the chapter, create two-column notes that summarize the key ideas of this chapter.

1. Write the key ideas in the left-hand column. The key ideas are listed in the section openers. Include one key idea in each row.
2. As you read the section, add detailed notes and examples in the right-hand column. Be sure to put these details and examples in your own words.



Section 1

Reproduction

Key Ideas	Key Terms	Why It Matters
❯ In asexual reproduction, how does the offspring compare to the parent? ❯ In sexual reproduction, how does the offspring compare to the parent? ❯ Why are chromosomes important to an organism?	gamete zygote diploid haploid homologous chromosomes	Living organisms produce offspring. How closely the offspring resemble their parents depends on how the organism reproduces.

Reproduction is the process of producing offspring. Some offspring are produced by two parents, and others are produced by just one parent. Some organisms look exactly like their parents, and others look very similar. Whether an organism is identical or similar to its parent is determined by the way that the organism reproduces.

Asexual Reproduction

In *asexual reproduction*, a single parent passes a complete copy of its genetic information to each of its offspring. ❯ **An individual formed by asexual reproduction is genetically identical to its parent.**

Prokaryotes reproduce asexually by a kind of cell division called *binary fission*. Many unicellular eukaryotes also reproduce asexually. Amoebas reproduce by splitting into two or more individuals of about equal size. Some multicellular eukaryotes, such as starfish, go through fragmentation. *Fragmentation* is a kind of reproduction in which the body breaks into several pieces. Some or all of these fragments regrow missing parts and develop into complete adults.

Other animals, such as the hydra shown in **Figure 1,** go through *budding*. In budding, new individuals split off from existing ones. Some plants, such as potatoes, can form whole new plants from parts of stems. Other plants can reproduce from roots or leaves. Some crustaceans, such as water fleas, reproduce by parthenogenesis. *Parthenogenesis* is a process in which a female makes a viable egg that grows into an adult without being fertilized by a male.

❯ **Reading Check** ***What is fragmentation? (See the Appendix for answers to Reading Checks.)***

Figure 1 This hydra is in the process of reproducing asexually. The smaller hydra budding from the parent is genetically identical to the parent.

Key Resources

Transparencies
B44 Chromosome Number of Various Organisms

Visual Concepts
Sexual Reproduction
Fertilization
Comparing Haploid and Diploid Cells

Section 1

❯ Focus

This section explains the differences between sexual and asexual reproduction and the advantages and disadvantages of each process to a species.

Bellringer
Use the Bellringer transparency to prepare students for this section.

❯ Teach

Teaching Key Ideas

Environmental Conditions Ask students to infer the advantage of asexual reproduction under ideal environmental conditions for a particular population. (Large numbers of offspring can be created that will also survive in the environment.) Ask students to infer the disadvantage of asexual reproduction in a changing environment. (If the organisms are not well adapted to survive the changes, the population will die out. Because all the organisms are genetically identical, no new varieties are produced that can adapt.) LS **Logical**

Teach, *continued*

Teaching Key Ideas

Hermaphroditism Students may be surprised to learn that in certain species, a single animal can sexually reproduce. For example, in some species of nematodes, the organism produces sperm, which are stored until eggs are produced. Egg production is followed by self-fertilization.

Math Skills

Asexual Reproduction in Bacteria Bacteria can reproduce asexually. The rate of reproduction (time required for a cell to divide) varies from minutes to hours. Have students use the rate of 15 minutes to calculate the number of bacteria produced from a single bacterium after each hour for 6 hours. (After hour 1, 16 bacteria; after hour 2, 256 bacteria; after hour 3, 4,096 bacteria; after hour 4, 65,536 bacteria; after hour 5, 1,048,576 bacteria; after hour 6, 16,777,216 bacteria) Tell students that at this rate, Earth would quickly be covered with bacteria. Ask students why this doesn't happen. (Ideal growth conditions for bacteria seldom occur in nature for very long.) LS Logical

Answers to Caption Questions

Figure 2: Germ cells produce gametes.

gamete (GAM eet) a haploid reproductive cell that unites with another haploid reproductive cell to form a zygote

zygote (ZIE GOHT) the cell that results from the fusion of gametes

diploid a cell that contains two haploid sets of chromosomes

haploid describes a cell, nucleus, or organism that has only one set of unpaired chromosomes

homologous chromosomes (hoh MAHL uh guhs) chromosomes that have the same sequence of genes, that have the same structure, and that pair during meiosis

SCILINKS
www.scilinks.org
Topic: Sexual and Asexual Reproduction
Code: HX81386

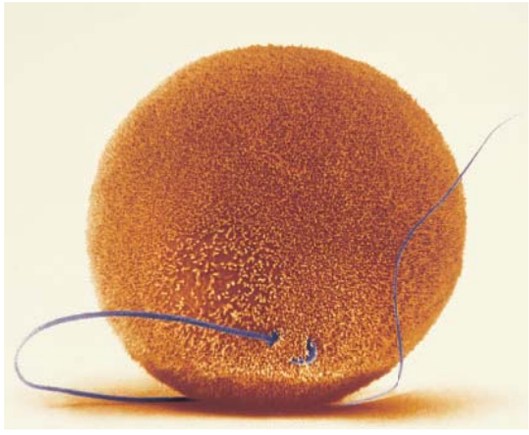


Figure 2 Two gametes, an egg and a sperm, combine during fertilization to form a zygote. ❯ **What types of cells produce gametes?**

Sexual Reproduction

Most eukaryotic organisms reproduce sexually. ❯ **In *sexual reproduction*, two parents give genetic material to produce offspring that are genetically different from their parents.** Each parent produces a reproductive cell, called a **gamete.** A gamete from one parent fuses with a gamete from the other parent, as **Figure 2** shows. The resulting cell, called a **zygote,** has a combination of genetic material from both parents. This process is called *fertilization*. Because both parents give genetic material, the offspring has traits of both parents but is not exactly like either parent.

Germ Cells and Somatic Cells Recall that the cells of a multicellular organism are often specialized for certain functions. Muscle cells, for example, contract and move your body. Cells that are specialized for sexual reproduction are called *germ cells.* Only germ cells can produce gametes. Other body cells are called *somatic cells.* Somatic cells do not participate in sexual reproduction.

Advantages of Sexual Reproduction Asexual reproduction is the simplest, most efficient method of reproduction. Asexual reproduction allows organisms to produce many offspring in a short period of time without using energy to make gametes or to find a mate. But the genetic material of these organisms varies little between individuals, so they may be at a disadvantage in a changing environment. Sexual reproduction, in contrast, produces genetically diverse individuals. A population of diverse organisms is more likely to have some individuals that survive a major environmental change.

Chromosome Number

Genes are located on chromosomes. ❯ **Each chromosome has thousands of genes that play an important role in determining how an organism develops and functions.** Each species has a characteristic number of chromosomes. As shown in **Figure 3,** mosquitoes have only 6 chromosomes in each cell. Chimpanzees have 48 chromosomes in each cell. Some ferns have more than 500! An organism must have exactly the right number of chromosomes. If an organism has too many or too few chromosomes, the organism may not develop and function properly.

In humans, each cell has two copies of 23 chromosomes for a total of 46. When fertilization happens, two cells combine to form a zygote, which still has only 46 chromosomes. Why is the number the same? The gametes that form a zygote have only *one* copy of each chromosome, or one set of 23 chromosomes. This reduction of chromosomes in gametes keeps the chromosome number of human somatic cells at a constant 46.

❯ **Reading Check** ***What kind of cells do germ cells produce?***

Differentiated Instruction

Basic Learners

Advantages and Disadvantages Ask students to explain the difference between asexual and sexual reproduction. During discussion, lead students to realize that both types of reproduction have advantages and disadvantages depending on the species involved and the environment it inhabits. Pose the following question: "If all members of a species were genetically identical, what would happen if a fatal virus spread through the population?" (All members of the species would most likely be wiped out.) LS Logical

Haploid and Diploid Cells A cell, such as a somatic cell, that has two sets of chromosomes is **diploid.** A cell is **haploid** if it has one set of chromosomes. Gametes are haploid cells. The symbol n is used to represent the number of chromosomes in one set. Human gametes have 23 chromosomes, so $n = 23$. The diploid number in somatic cells is written as $2n$. Human somatic cells have 46 chromosomes ($2n = 46$).

Homologous Chromosomes Each diploid cell has pairs of chromosomes made up of two homologous chromosomes. **Homologous chromosomes** are chromosomes that are similar in size, in shape, and in kinds of genes that they contain. Each chromosome in a homologous pair comes from one of the two parents. In humans, one set of 23 chromosomes comes from the mother, and one set comes from the father. Homologous chromosomes can carry different forms of genes. For example, flower color in peas is determined by a gene on one of its chromosomes. The form of this gene can be white or purple. The cells of each pea plant will have two flower-color genes, one on each of the chromosomes that carry the flower-color gene. Both could be genes for white flower color, or both could be genes for purple flower color. Or one gene could be for white color, and the other could be for purple color.

Chromosome Number of Various Organisms

Organism	Number ($2n$) of chromosomes
Penicillium	1–4
Saccharomyces (yeast)	16
Mosquito	6
Housefly	12
Garden pea	14
Corn	20
Fern	480–1,020
Frog	26
Human	46
Orangutan	48
Dog	78

Figure 3
Different species have different numbers of chromosomes.

Autosomes and Sex Chromosomes *Autosomes* are chromosomes with genes that do not determine the sex of an individual. *Sex chromosomes* have genes that determine the sex of an individual. In humans and many other organisms, the two sex chromosomes are referred to as the *X* and *Y chromosomes*. The genes that cause a zygote to develop into a male are located on the Y chromosome. Human males have one X chromosome and one Y chromosome (XY), and human females have two X chromosomes (XX).

READING TOOLBOX

Key-Term Fold On the back of your key-term fold, write a definition in your own words for the key terms in this section.

Section 1 Review

KEY IDEAS

1. **Compare** the offspring in asexual reproduction with the parent.
2. **Describe** how the offspring in sexual reproduction compares genetically with its parent.
3. **Compare** the number of sets of chromosomes between a haploid cell and a diploid cell.
4. **Explain** why chromosomes are important for organisms.

CRITICAL THINKING

5. **Inferring Relationships** Why are haploid cells important in sexual reproduction?
6. **Forming Reasoned Opinions** Do you agree or disagree that homologous chromosomes occur in gametes? Explain.

METHODS OF SIENCE

7. **Evaluating Hypotheses** A student states that organisms that reproduce asexually are at a disadvantage in a stable environment. If you agree with this hypothesis, name one or more of its strengths. If you disagree, name one or more of its weaknesses.

READING TOOLBOX

Key-Term Fold Make sure that students have included terms such as *haploid, diploid, homologous chromosomes, gamete,* and *zygote,* as well as terms such as *asexual reproduction, sexual reproduction,* and any other terms that they feel are important. Encourage students to write descriptions and definitions using their own words.

Teaching Key Ideas

Chromosome Number Direct students to look at **Figure 3,** and ask the following questions: "What is the haploid number of chromosomes for a dog?" (39) "What cell types have n as their number of chromosomes?" (haploid cells, or germ cells)

Close

Formative Assessment

_____ is a process involved in sexual reproduction.

A. Budding (Incorrect. Budding is a means of asexual reproduction.)
B. Fertilization (Correct! Fertilization is the process of combining genetic material from both parents in sexual reproduction.)
C. Fragmentation (Incorrect. Fragmentation is a form of asexual reproduction in which the body of an organism breaks into several pieces.)
D. Parthogenesis (Incorrect. Parthogenesis is an asexual process in which an egg grows into an adult without being fertilized.)

Answers to Section Review

1. The offspring is genetically identical to its parent.
2. The offspring is genetically different from its parents.
3. A haploid cell has half the number of sets of chromosomes as a diploid cell.
4. Chromosomes contain the genes needed for the organism to develop and function.
5. Haploid cells provide offspring with half the genetic material from one parent and the other half of their genetic material from the other parent. This makes the offspring different from its parents and its siblings.
6. Students should disagree. Homologous chromosomes are pairs of similar chromosomes. Because gametes are haploid, they contain only one set of chromosomes. Thus, homologous chromosomes are not normally found in gametes.
7. Most students should disagree. In a stable environment, asexual reproduction allows organisms to produce offspring without using energy to produce gametes or to find a mate.

Section 2

Focus

This section explains the process of meiosis, the difference between meiosis and mitosis, and the three mechanisms of genetic variation that can result from meiosis.

Bellringer

Use the Bellringer transparency to prepare students for this section.

Teach

Demonstration

Counting Chromosomes On the board, draw a sperm cell near an egg cell. Draw three homologous chromosome pairs in each cell. Tell students that when the sperm fertilizes the egg, the number of chromosomes in the resulting cell, the new individual, will be double the number in either the egg or the sperm cell. Lead students to the conclusion that the number of chromosomes in sperm and egg cells must be halved, or the number of chromosomes in each subsequent generation will continue to double. Tell students that the process by which the chromosome number is halved when reproductive cells are formed is called meiosis. LS Visual

Section 2

Meiosis

Key Ideas	Key Terms	Why It Matters
❯ What occurs during the stages of meiosis? ❯ How does the function of mitosis differ from the function of meiosis? ❯ What are three mechanisms of genetic variation?	meiosis crossing-over independent assortment	Meiosis allows genetic information from two parents to combine to form offspring that are different from both parents.

Most cells that divide and produce new cells form two offspring cells that have the same number of chromosomes as the parent cell. How do haploid gametes form from a diploid germ cell? **Meiosis** is a form of cell division that produces daughter cells with half the number of chromosomes that are in the parent cell.

Stages of Meiosis

Before meiosis begins, the chromosomes in the original cell are copied. Meiosis involves two divisions of the nucleus—meiosis I and meiosis II. ❯ **During meiosis, a diploid cell goes through two divisions to form four haploid cells.** In meiosis I, homologous chromosomes are separated. In meiosis II, the sister chromatids of each homologue are separated. As a result, four haploid cells are formed from the original diploid cell. **Figure 4** illustrates the steps of meiosis.

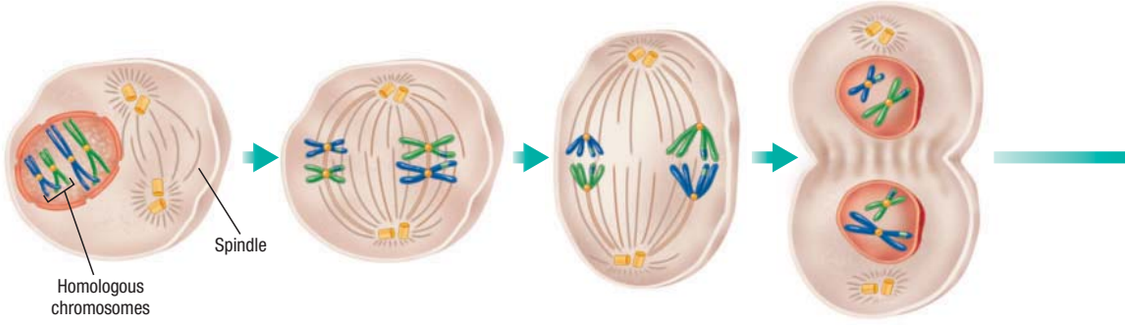
Stages of Meiosis I

1 **Prophase I** Chromosomes condense. The nuclear envelope breaks down.

2 **Metaphase I** Pairs of homologous chromosomes move to the cell's equator.

3 **Anaphase I** Homologous chromosomes move to the cell's opposite poles.

4 **Telophase I** Chromosomes gather at the poles. The cytoplasm divides.



Key Resources

Transparencies
B49 Stages of Meiosis
B51 Meiosis in Male and Female Animals

Visual Concepts
Meiosis
Tetrads and Crossing-over of Genetic Material
Independent Assortment
Formation of a Sperm
Formation of an Egg Cell
Comparing the Results of Meiosis and Mitosis
Comparing Meiosis and Mitosis

Meiosis I Meiosis begins with a diploid cell that has copied its chromosomes. The first phase is prophase I. (1) During prophase I, the chromosomes condense, and the nuclear envelope breaks down. Homologous chromosomes pair. Chromatids exchange genetic material in a process called **crossing-over.** (2) In metaphase I, the spindle moves the pairs of homologous chromosomes to the equator of the cell. The homologous chromosomes remain together. (3) In anaphase I, the homologous chromosomes separate. The spindle fibers pull the chromosomes of each pair to opposite poles of the cell. But the chromatids do not separate at their centromeres. Each chromosome is still made of two chromatids. The genetic material, however, has recombined. (4) During telophase I, the cytoplasm divides (cytokinesis), and two new cells are formed. Both cells have one chromosome from each pair of homologous chromosomes.

Meiosis II Meiosis II begins with the two cells formed at the end of telophase I of meiosis I. The chromosomes are not copied between meiosis I and meiosis II. (5) In prophase II, new spindles form. (6) During metaphase II, the chromosomes line up along the equators and are attached at their centromeres to spindle fibers. (7) In anaphase II, the centromeres divide. The chromatids, which are now called *chromosomes,* move to opposite poles of the cell. (8) During telophase II, a nuclear envelope forms around each set of chromosomes. The spindle breaks down, and the cell goes through cytokinesis. The result of meiosis is four haploid cells.

Reading Check ***In what phase of meiosis is genetic material exchanged?***

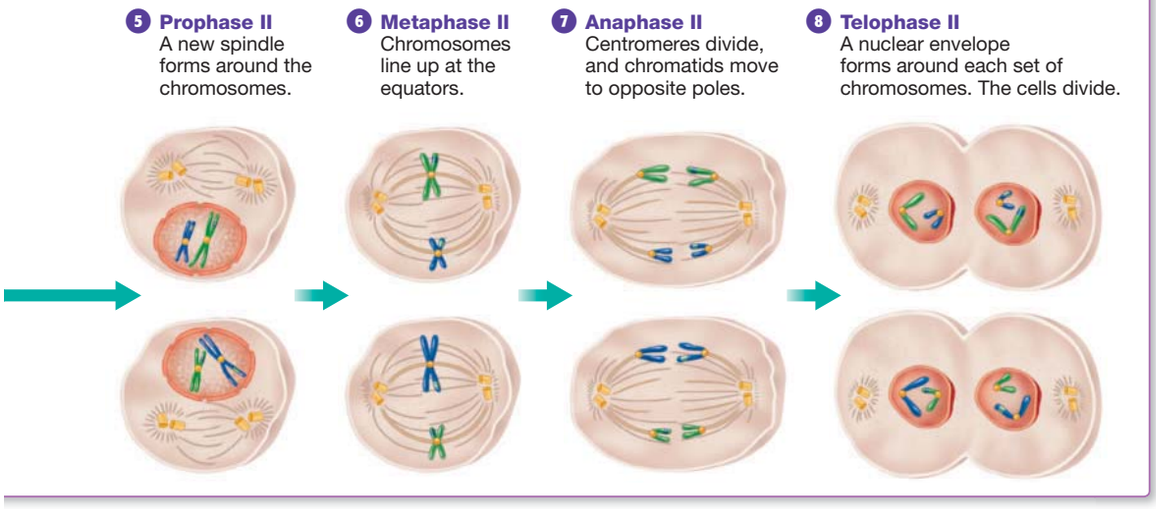
meiosis a process in cell division during which the number of chromosomes decreases to half the original number by two divisions of the nucleus, which results in the production of sex cells (gametes or spores)

crossing-over the exchange of genetic material between homologous chromosomes during meiosis

Figure 4 During meiosis, four haploid cells are produced from a diploid cell.
What is the difference between anaphase I and anaphase II?

go.hrw.com
interact online
Keyword: HX8MEIF4

Stages of Meiosis II



Teaching Key Ideas

Sequencing Have students list each of the stages of meiosis I and II on an index card. Have students shuffle the cards. With their books closed, students should draw the process described on each card. After the drawings are complete, have students trade illustrated cards with a partner and place those cards in the correct sequence. LS Verbal/Visual

go.hrw.com
interact online

Students can interact with "Stages of Meiosis" by going to go.hrw.com and typing in the keyword **HX8MEIF4**.

Answers to Caption Questions

Figure 4: In anaphase I, homologous chromosomes move to opposite poles of the cell. In anaphase II, the centromeres divide and the chromatids move to opposite poles.

Differentiated Instruction

Struggling Readers

Counting Chromosomes Have students look at the first cell at the left in **Figure 4.** Ask them how many chromosomes are in the cell. Some will answer "four" while others may say "eight." Tell students that as long as chromatids are connected by a centromere they are considered a single chromosome. As soon as the chromatid pairs separate, they are considered two separate chromosomes. The first cell in **Figure 4** has four chromosomes, and the final four cells, on the far right, each have two chromosomes. LS Visual

MISCONCEPTION ALERT

Which Organisms Use Sexual Reproduction? Students may think that animals are the only organisms that reproduce sexually. Remind students that many plants, fungi, and algae also reproduce sexually. Point out that a flower, for example, may contain both sperm and egg cells.

Teach, *continued*

READING TOOLBOX

Comparisons

1. Both meiosis and mitosis are processes that result in new cells.
2. Meiosis and mitosis both have a metaphase stage.
1. Mitosis produces two diploid cells; in contrast, meiosis produces four haploid cells.
2. Mitosis produces genetically identical cells; in contrast, meiosis results in genetically different cells.

Why It Matters

Development in Eggs Stanford University researchers recently discovered how sperm-egg contact initiates development in sea urchins. Sea urchin sperm contain an enzyme called nitric oxide synthase that becomes active a few seconds before fertilization. The enzyme quickly causes the production of a large amount of nitric oxide gas, which is injected into the egg once the sperm and egg make contact. The injection of this gas triggers the release of calcium inside the egg. As the calcium levels rise, metabolic changes cause the egg to divide and form into an embryo.

Answers to Caption Questions

Figure 5: Centromeres divide during the anaphase of mitosis. Centromeres do not divide in anaphase I of meiosis I.

READING TOOLBOX

Comparisons Write two sentences that compare and two sentences that contrast meiosis and mitosis.

Comparing Mitosis and Meiosis

The processes of mitosis and meiosis are similar but meet different needs and have different results. **Mitosis makes new cells that are used during growth, development, repair, and asexual reproduction. Meiosis makes cells that enable an organism to reproduce sexually and happens only in reproductive structures.** Mitosis produces two genetically identical diploid cells. In contrast, meiosis produces four genetically different haploid cells. The haploid cells produced by meiosis contain half the genetic information of the parent cell. When two such cells, often an egg cell and a sperm cell, combine, the resulting zygote has the same number of chromosomes as each of the parents' cells.

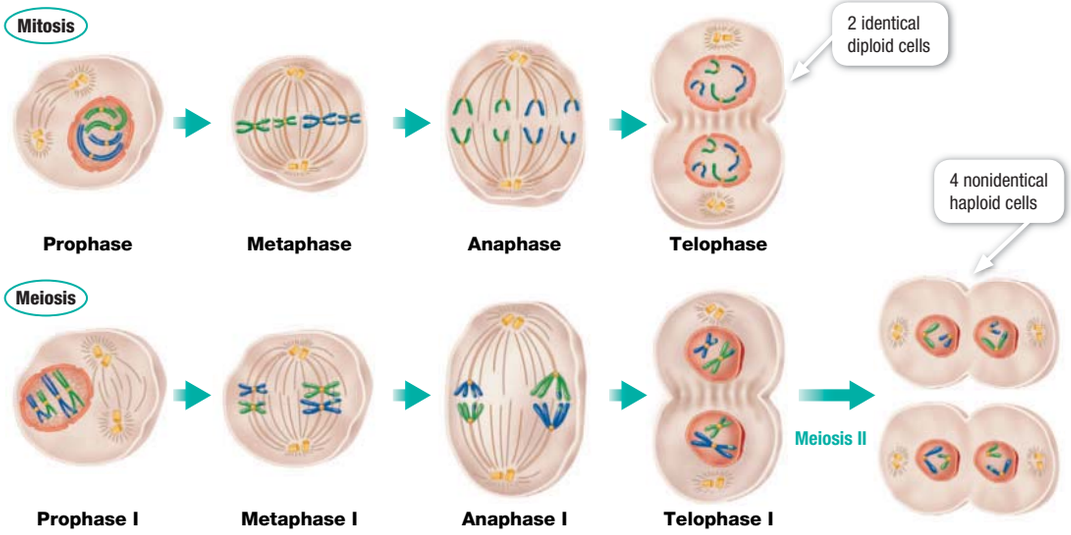
If you compare meiosis and mitosis, as shown in **Figure 5,** you may think that they are alike. For example, in metaphase of mitosis and metaphase I of meiosis, the chromosomes move to the equator. However, there is a major difference that happens in an earlier stage.

In prophase I of meiosis, every chromosome pairs with its homologue. A pair of homologous chromosomes is called a *tetrad.* As the tetrads form, different homologues exchange parts of their chromatids in the process of crossing-over. The pairing of homologous chromosomes and the crossing-over do not happen in mitosis. Therefore, a main difference between meiosis and mitosis is that in meiosis, genetic information is rearranged. The rearranging of genetic information leads to genetic variation in offspring. Crossing-over is one of several processes that lead to genetic variation.

Reading Check ***How are cells formed by mitosis different from cells formed by meiosis in relation to number of chromosomes?***

Figure 5 Mitosis produces two diploid daughter cells that are identical to the parent cell. Meiosis produces four haploid cells from a diploid cell. ***What is the difference between anaphase in mitosis and anaphase I in meiosis I?***

Comparing Mitosis and Meiosis



Differentiated Instruction

Special Education Students

Modeling Meiosis Have students work in groups of four. Give each group 32 beads of one color (red, for example) and 32 of a contrasting color (blue, for example). Give each group four 4-inch sections of pipe cleaner to act as centromeres. Have students make two 6-bead red strands. Attach with a pipe cleaner. This represents a chromosome with 2 chromatids. Make two 6-bead blue strands and attach these together. This represents the homologous chromosome. Make two 10-bead blue strands and attach together, and two 10-bead red strands. Ask what the diploid number is for this cell. (4) Have students show the process of meiosis. Crossing-over can be demonstrated by removing two beads at the ends of non-sister chromatids (having opposite colors) and switching them. When finished, the four gametes should each have one long and one short chromosome with varying crossover patterns. Blind and visually impaired students can use different sizes of beads. LS Kinesthetic

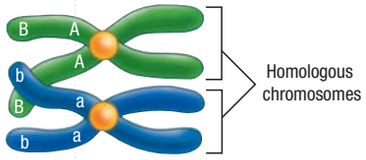
Hands On

QuickLab

30 min

Crossing-Over Model

You can use paper strips and pencils to model the process of crossing-over.



Procedure

1. Use a **colored pencil** to write "A" and "B" on **two paper strips.** These two strips will represent one of the two homologous chromosomes shown.
2. Use a **second colored pencil** to write "a" and "b" on **two paper strips**. These two strips will represent the second homologous chromosome shown.
3. **CAUTION: Handle scissors with care.** Use your chromosome models, **scissors,** and **tape** to demonstrate crossing-over between two chromatids.

Analysis

1. **Determine** what the letters *A, B, a,* and *b* represent.
2. **Making Inferences** Explain why the chromosomes that you made are homologous.
3. **Compare** the number of different types of chromatids (combinations of *A, B, a,* and *b*) before crossing-over with the number after crossing-over.
4. CRITICAL THINKING **Analyzing Information** How does crossing-over relate to genetic recombination?

Genetic Variation

Genetic variation is advantageous for a population. Genetic variation can help a population survive a major environmental change. For example, in the Arctic, if temperatures drop below average, those polar bears with genes that make thicker fur will survive. Polar bears without the genes for thicker fur may die out. The polar bears with the genes for thicker fur reproduce, and the population grows. Now, suppose that all of the individuals in the population have the same genes, but none of the genes are for thicker fur. What do you think will happen if the temperature drops below average? The entire population of polar bears may die out.

Genetic variation is made possible by sexual reproduction. In sexual reproduction, existing genes are rearranged. Meiosis is the process that makes the rearranging of genes possible. Fusion of haploid cells from two different individuals adds further variation.

Three key contributions to genetic variation are crossing-over, independent assortment, and random fertilization.

Crossing-Over During prophase I, homologous chromosomes line up next to each other. Each homologous chromosome is made of two sister chromatids attached at the centromere. Crossing-over happens when one arm of a chromatid crosses over the arm of the other chromatid, as illustrated in the QuickLab. The chromosomes break at the point of the crossover, and each chromatid re-forms its full length with the piece from the other chromosome. Thus, the sister chromatids of a homologous chromosome no longer have identical genetic information.

Reading Check *How can crossing-over increase genetic variation?*

SCILINKS
www.scilinks.org
Topic: Genetic Variation
Code: HX80658

ACADEMIC VOCABULARY

exist to occur or be present

Differentiated Instruction

Basic Learners

Crossing-Over Draw two large chromosomes on the board with colored chalk. Each chromosome should have two chromatids and a centromere. Use different colors along the length of each chromatid to represent genes. Ask volunteers to show crossing-over in two different places by erasing and redrawing the chromosomes with the corresponding gene color. Point out that because of the random orientation of chromosomes at metaphase I and because of crossing-over, children resemble their parents but never look exactly like them. LS Interpersonal

Advanced Learners/GATE

Genetic Variation Have interested students research genetic variation in a population of their choice and report their findings to the class. LS Verbal

QuickLab

Teacher's Notes Prepare the paper strips before assigning the lab.

Materials
- colored pencils, different colors (2)
- paper
- scissors
- tape

Answers to Analysis

1. individual genes
2. The chromosomes are of similar size, shape, and genetic content.
3. before crossing-over: AB, AB ab, and ab; after crossing over: answers will vary (for example, AB, Ab, aB, and ab)
4. Crossing-over causes genetic recombination.

Teaching Key Ideas

Crossing-Over Model Have students look at the diagram of the two homologous chromosomes in the Quick Lab. Point out that the two green strands attached together by a centromere are called *sister chromatids*. Ask students how sister chromatids compare genetically. (They are identical.) The green and blue chromatids are known as *non-sister chromatids*. Ask students what would happen to the genetic makeup of a chromosome if crossing-over occurred between sister chromatids. (Because sister chromatids are copies of each other, the genetic makeup would not change.) LS Visual

Teach, *continued*

Teaching Key Ideas

Distinguishing Between Mitosis and Meiosis Have students make a graphic organizer using **Figure 5** to summarize the difference in chromosomal number between mitosis and meiosis. Ask students to include a brief paragraph that compares the two processes. LS Logical

Close

Formative Assessment

Which type of cell might only result from mitosis?

A. egg cell (Incorrect. Egg cells result from meiosis.)

B. sperm cell (Incorrect. Sperm cells result from meiosis.)

C. germ cell (Incorrect. Germ cells also result from meiosis.)

D. somatic cell (Correct! Somatic cells are non-sexual cells that could result from mitosis.)

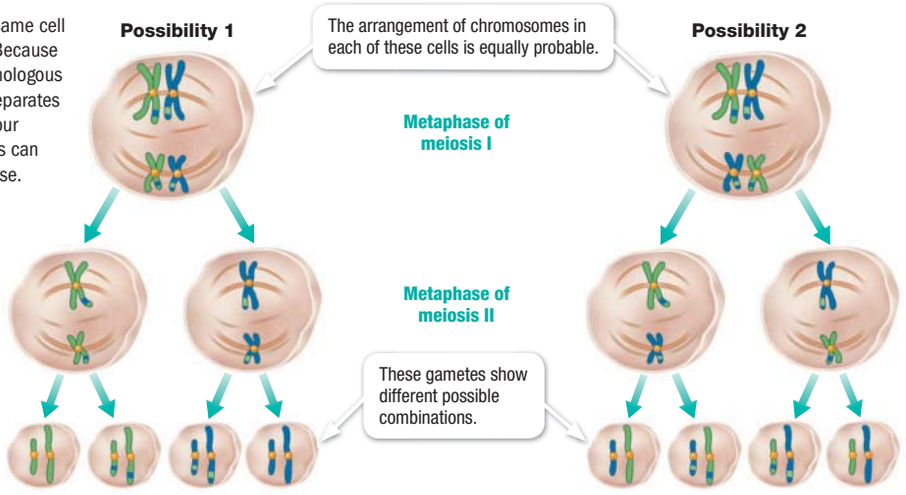


Figure 6 The same cell is shown twice. Because each pair of homologous chromosomes separates independently, four different gametes can result in each case.

independent assortment the random distribution of the pairs of genes on different chromosomes to the gametes

Independent Assortment During metaphase I, homologous pairs of chromosomes line up at the equator of the cell. The two pairs of chromosomes can line up in either of two equally probable ways. This random distribution of homologous chromosomes during meiosis is called **independent assortment.** The four haploid cells formed in possibility 1 in **Figure 6** have entirely different combinations of chromosomes than do the four cells made in possibility 2.

In humans, each gamete receives one chromosome from each of 23 pairs of homologous chromosomes. Each of the 23 pairs of chromosomes separates independently. Thus, there are 2^{23} (more than 8 million) different possibilities for the gene combinations in gametes that form from a single original cell.

Random Fertilization Fertilization is a random process that adds genetic variation. The zygote that forms is made by the random joining of two gametes. Because fertilization of an egg by a sperm is random, the number of possible outcomes is *squared.* In humans, the possibility is $2^{23} \times 2^{23}$, or about 70 trillion, different combinations!

Section 2 Review

KEY IDEAS

1. **Summarize** the different phases of meiosis.
2. **Explain** how the function of meiosis differs from the function of mitosis.
3. **Describe** three mechanisms of genetic variation.

CRITICAL THINKING

4. **Comparing Functions** Compare the processes of crossing-over and independent assortment. How does each contribute to genetic variation?
5. **Inferring Conclusions** Why might sexual reproducers better adapt to a changing environment than asexual reproducers?

ALTERNATIVE ASSESSMENT

6. **Word Problem** If one cell in a dog ($2n = 78$) undergoes meiosis and another cell undergoes mitosis, how many chromosomes will each resulting cell contain?

Answers to Section Review

1. Students' answers should be consistent with the stages in **Figure 4.**
2. Mitosis produces new cells that are used during growth, development, repair, and asexual reproduction. Meiosis produces cells that enable an organism to reproduce sexually, and it occurs only in reproductive structures.
3. crossing-over, independent assortment, and random fertilization
4. Crossing-over occurs when the arms of two chromatids exchange genetic material. This process leads to genetic variation among the chromosomes. Independent assortment is the random distribution of homologous chromosomes during meiosis. This process leads to further genetic variation in the gametes formed from meiosis.
5. Meiosis leads to the rearranging of genes, which leads to genetic variation throughout a species. Genetic variation ensures individuals throughout a species have different traits. Varied traits give a species an advantage in surviving and producing more offspring. This is the mechanism necessary for evolution to occur.
6. The cells resulting from meiosis will contain 39 chromosomes each. The cells resulting from mitosis will contain 78 chromosomes each.

Why It Matters

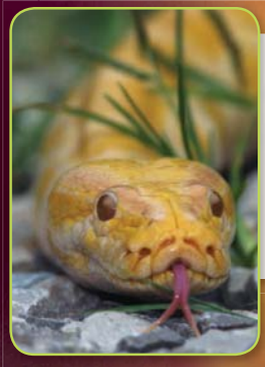
Girls, Girls, Girls

Did you know that some species, such as the predatory brush cricket to the right, and the lupin aphid below, have only females? These species, with only females, reproduce asexually.

Parthenogenesis

In animals, the process of a female producing an egg that can grow into a new individual without being fertilized by a male is called *parthenogenesis*. The major advantage of parthenogenesis is that every individual can reproduce and the population can grow quickly. The disadvantage is that every individual has the same genes. The animals may not have the genes that produce the traits that are necessary for adaptation. If a species cannot adapt, it could become extinct.

Apomixis Asexual reproduction in plants in which embryos develop in the absence of fertilization by pollen is called *apomixis*. There are more than 300 apomictic plant species, such as dandelions. Apomictic plants still produce seeds, and the offspring are genetically identical to the mother plant.



New Discovery Until recently, scientists believed that all snakes reproduced sexually. However, this Burmese python is parthenogenetic. Scientists discovered that the Burmese python was parthenogenetic only after an isolated female in a zoo had offspring.

Research Some species of mango and of cereals are apomictic. Conduct Internet research, and investigate how these species can benefit humans.

Why It Matters

Teacher's Notes Ask students what organisms might exhibit parthenogenesis. (Answers can include water fleas, honeybees, and aphids.)

Parthenogenesis is not the only variation on sexual reproduction that occurs among vertebrates. Among many species of fish, individuals can change their sex. Some begin life as females and then change into males, a phenomenon called protogyny. Others change from males into females, which is known as protandry. Even more unusual, some deep-sea fish are hermaphrodites—both male and female at the same time.

READING TOOLBOX

Visual Literacy Direct students' attention to the picture of the Burmese python. Tell students that its natural habitat is southeast Asia. Python populations are being threatened by loss of habitat. Ask what the advantage is to the python of being capable of parthenogenesis. (Parthenogenesis solves the problem of bringing together females and males at the right moment for successful fertilization. In the wild and in captivity, sufficient numbers of males and females may not be present to sexually reproduce.) LS Visual/Logical

Answer to Research

Students should find that research is underway regarding many important food and horticultural crops, such as corn, sorghum, beets, and strawberries that propagate by apomixis.

Section 3 Multicellular Life Cycles

Key Ideas	Key Terms	Why It Matters
What is a diploid life cycle? What is a haploid life cycle? What is alternation of generations?	life cycle sperm ovum	Some life cycles are mainly diploid, others are mainly haploid, and still others alternate between haploid and diploid phases.

Focus

This section explains the role of meiosis in diploid and haploid life cycles. It also discusses the alternation of generations that occurs in plants and some protists.

Bellringer

Use the Bellringer transparency to prepare students for this section.

Teach

Teaching Key Ideas

Characteristics of a Life Cycle
Direct students to look at **Figure 7.** Ask: Why is this diagram called a life cycle? (The child will grow and develop to become an adult, and then the process repeats.) What is the number of chromosomes in the egg and sperm cells? (23) Which cell(s) are diploid? (the zygote and all somatic cells) What is the result of meiosis? (haploid cells) Why is this life cycle called a diploid life cycle? (The diploid individual occupies the major portion of the life cycle.)
LS Visual

Answers to Caption Questions

Figure 7: The gametes—sperm and egg—are the only haploid cells in a diploid life cycle.

All of the events in the growth and development of an organism until the organism reaches sexual maturity are called a **life cycle.** All organisms that reproduce sexually have both diploid stages and haploid stages.

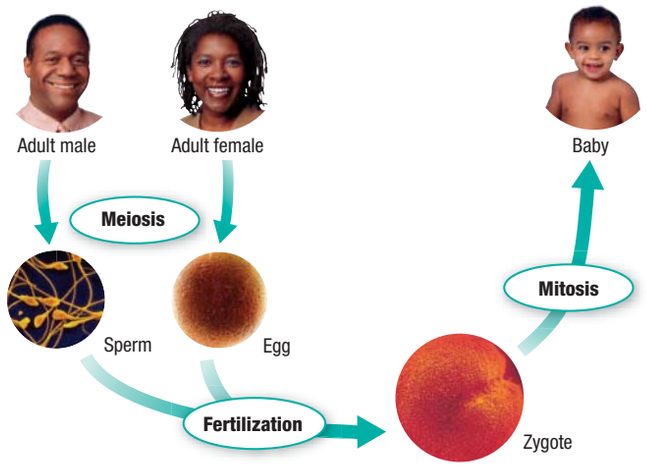
Diploid Life Cycle

Most animals have a diploid life cycle. **Figure 7** illustrates this type of life cycle. Most of the life cycle is spent in the diploid state. All of the cells except the gametes are diploid.

A diploid germ cell in a reproductive organ goes through meiosis and forms gametes. The gametes, the sperm and the egg, join during fertilization. The result is a diploid zygote. This single diploid cell goes through mitosis and eventually gives rise to all of the cells of the adult, which are also diploid. **In diploid life cycles, meiosis in germ cells of a multicellular diploid organism results in the formation of haploid gametes.**

Figure 7 Humans and most other animals have a life cycle dominated by a diploid individual. *What are the only haploid cells in a diploid life cycle?*

Diploid Life Cycle



life cycle all of the events in the growth and development of an organism until the organism reaches sexual maturity

sperm the male gamete (sex cell)

ovum a mature egg cell

Key Resources

Transparencies
B48 Diploid Life Cycle
F13 Haploid Life Cycle
G5 Alternation of Generations

Visual Concepts
Comparing Haploid and Diploid Cells
Alternation of Generations

Meiosis and Gamete Formation

Male animals produce gametes called **sperm.** As **Figure 8** illustrates, a diploid germ cell goes through meiosis I. Two cells are formed, each of which goes through meiosis II. The result is four haploid cells. The four cells change in form and develop a tail to form four sperm.

Female animals produce gametes called eggs, or ova (singular, **ovum**). A diploid germ cell begins to divide by meiosis. Meiosis I results in the formation of two haploid cells that have unequal amounts of cytoplasm. One of the cells has nearly all of the cytoplasm. The other cell, called a *polar body,* is very small and has a small amount of cytoplasm. The polar body may divide again, but its offspring cells will not survive. The larger cell goes through meiosis II, and the division of the cell's cytoplasm is again unequal. The larger cell develops into an ovum. The smaller cell, the second polar body, dies. Because of its larger share of cytoplasm, the mature ovum has a rich storehouse of nutrients. These nutrients nourish the young organism that develops if the ovum is fertilized.

Reading Check *How many gametes are formed from one female germ cell?*

Data

QuickLab

15 min

Chromosome Combinations

When a sperm and egg fuse, two sets of chromosomes are combined. In this lab, you will model this cross between two sets of chromosomes.

Procedure

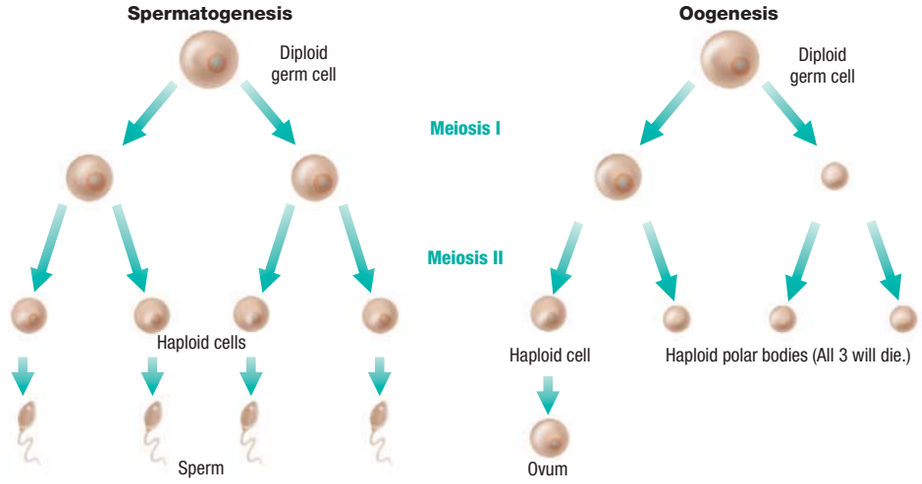
1. **Write** "F1F2 X M1M2" on a sheet of paper. F1 and F2 represent the father's chromosomes. M1 and M2 represent the mother's chromosomes.
2. **Determine** all of the possible chromosome combinations in the zygote that forms from the fusion of the gametes with the chromosomes that you wrote in step 1.

Analysis

1. **Calculate** the number of chromosome combinations that are possible in the zygote.
2. CRITICAL THINKING **Analyzing Data** List all of the possible chromosome combinations.

Figure 8 Meiosis of diploid germ cells results in haploid gametes.

Meiosis in Male and Female Animals



Differentiated Instruction

English Learners

Reading Organizer Point out to students that the section is divided into three main ideas. Ask students if they can identify them. (They are the haploid life cycle, the diploid life cycle, and alternation of generations.) Have them use these three main ideas to organize their notes. LS Logical

Alternative Assessment

Modeling Life Cycles Have students use manipulatives, such as beads, paper clips, and so forth, to model the various life cycles presented in this section. LS Kinesthetic/Visual

QuickLab

Teacher's Notes Explain to students that the zygote will have one F chromosome and one M chromosome. You may want to provide students with an example, such as F1M2.

Answers to Analysis

1. four
2. F1M1, F1M2, F2M1, F2M2

Teach, *continued*

READING TOOLBOX

Two-Column Notes Advise students to use the text to help them write the steps shown in **Figure 9,** and then to use the figure to organize their notes into two columns.

Teaching Key Ideas

Using Models Remind students that **Figure 9** is another form of a life cycle diagram. The illustration shows a generic model, meaning that it reflects a process for most haploid organisms without being specific to any. Ask the following: "Why is there a line down the middle of each cycle?" (to separate the diploid and haploid stages) "What is misleading about the placement of the line?" (It conveys the idea that each stage is about equal in the organism's life span.)

Close

Formative Assessment

All of the following are haploid cells in the alternation of generations cycle except _____.

A. a gametophyte (Incorrect! A gametophyte is haploid.)
B. a gamete (Incorrect. A gamete is haploid.)
C. a spore (Incorrect. A spore is haploid.)
D. a zygote (Correct! The zygote is a fertilized egg, so it is diploid.)

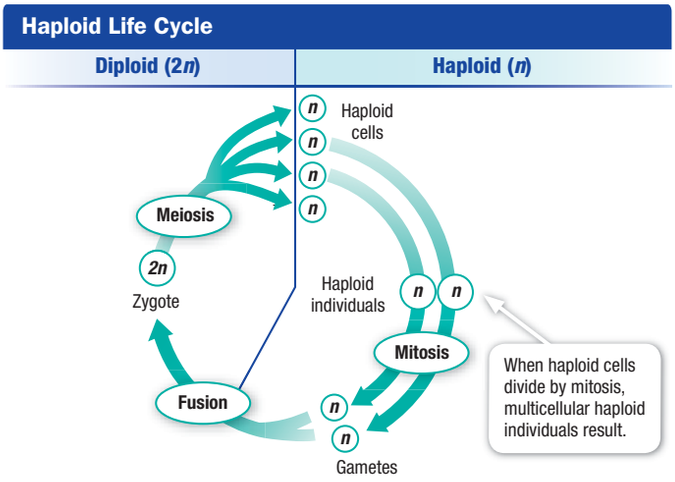


Figure 9 Some organisms, such as fungi, have haploid cells as a major portion of their life cycles.

READING TOOLBOX

Two-column notes Use two-column notes to summarize the stages and details of the haploid life cycle.

Haploid Life Cycle

The haploid life cycle, shown in **Figure 9,** happens in most fungi and some protists. Haploid stages make up the major part of this life cycle. The zygote, the only diploid structure, goes through meiosis immediately after it is formed and makes new haploid cells. The haploid cells divide by mitosis and give rise to multicellular haploid individuals. **In haploid life cycles, meiosis in a diploid zygote results in the formation of the first cell of a multicellular haploid individual.**

Alternation of Generations

Plants and most multicellular protists have a life cycle that alternates between a haploid phase and a diploid phase called *alternation of generations.* In plants, the multicellular diploid phase in the life cycle is called a *sporophyte.* Spore-forming cells in the sporophyte undergo meiosis and produce spores. A spore forms a multicellular gametophyte. The *gametophyte* is the haploid phase that produces gametes by mitosis. The gametes fuse and give rise to the diploid phase.

Section 3 Review

KEY IDEAS

1. **Summarize** the process in a diploid life cycle.
2. **Describe** what happens in a haploid life cycle.
3. **Describe** what happens to the polar bodies formed during meiosis of a female diploid cell in animal.
4. **Explain** the alternation of generations life cycle.

CRITICAL THINKING

5. **Evaluating Processes** How does the formation of sperm through meiosis of a diploid germ cell differ from the formation of an ovum from a diploid germ cell?
6. **Analyzing Information** What type of cell or structure is the first stage of every sexual life cycle?

WRITING IN SCIENCE

7. **Lesson Plan** Write a lesson plan that you can use to teach a classmate the difference between a haploid and a diploid life cycle. In your own words, write a summary of each. Include diagrams with your explanation.

Answers to Section Review

1. In the diploid life cycle, meiosis in germ cells of a multicellular diploid organism results in the formation of haploid gametes.
2. In haploid life cycles, meiosis in a diploid zygote results in the formation of the first cell of a multicellular haploid individual.
3. The polar bodies have very little cytoplasm and disintegrate.
4. Plants and most multicellular protists have a life cycle that alternates between a haploid phase and a diploid phase.
5. Because meiosis in oogenesis produces cells with unequal amounts of cytoplasm, only one gamete is formed. However, in spermatogenesis, four gametes are produced.
6. A zygote is the first stage in all sexual reproductive life cycles.
7. Students' lesson plans should include a presentation and comparison of haploid and diploid life cycles. Diagrams of the two cycles should be included.

Skills Practice

Chapter 11 Lab

45 min

Lab

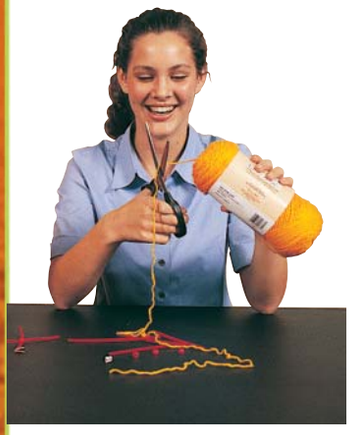
Objectives

- Model the stages of meiosis.
- Describe the events that occur in each stage of the process of meiosis.
- Compare your meiosis model to meiosis stages in a set of prepared slides of lily anther microsporocytes.

Materials

- beads, wooden (40)
- index cards (8)
- marker
- microscope
- microscope slides of lilium anther, 1st and 2nd meiotic division
- scissors
- tape, masking
- yarn

Safety



Meiosis Model

In this laboratory, you will work with a partner to develop a meiosis model. You will also have the opportunity to compare your model to the stages of meiosis found in the sacs of a lily anther.

Procedure

Build a Model

1. Work in a team of two. Review the stages of meiosis I and meiosis II. Note the structures and organization that are characteristic of each stage. Pay particular attention to the appearance and behavior of the chromosomes.
2. Work with your partner to design a model of a cell by using the materials listed for this lab. Select and assign a different material to represent each cell structure and keep this consistent in all models. Have your teacher approve the plan.
3. Label each of eight index cards with a specific stage of meiosis, such as "Prophase II."
4. Using your model plan that you designed in step 2, you or your partner will construct a set of models representing the four stages of meiosis I. The other team member will construct another set of models representing the four stages of meiosis II.
5. Once you have completed your set of models, position the cards in two horizontal rows. The top row illustrates the stages of meiosis I. The bottom row illustrates the stages of meiosis II. Compare and contrast the corresponding stages.

Observe Meiosis

6. **CAUTION: Handle glass slides with care.** Obtain a set of prepared slides of lily anther microsporocytes that include a variety of meiotic stages.
7. Use your microscope to view each slide. Locate the various stages of meiosis within the anther sacs.
8. Compare what you observe in the prepared slides to the models that you have constructed.

Analyze and Conclude

1. **Analyzing Processes** Identify and label each stage of meiosis as a haploid stage or a diploid stage.
2. **Comparing Functions** How does anaphase I differ from anaphase II?
3. SCIENTIFIC METHODS **Critiquing Models** Based upon the observations of real cells, evaluate your model. How would you improve your model?

Time Required

One 45-minute lab period

Ratings

EASY → HARD

Teacher Prep	
Student Setup	
Concept Level	
Cleanup	

Safety Caution

Review all safety symbols with students before beginning the lab.

Tips and Tricks

Review the stages of meiosis before beginning the lab. If students have difficulty building their models, ask the following questions to guide them:

1. Which of these materials would make the best cell membrane? (yarn)
2. Which would make the best spindle fibers? (yarn)
3. Which would make the best chromosomes? (pipe cleaners)
4. Which would make the best centromeres? (beads)

Emphasize that each pair of chromatids represents one chromosome. Be sure students show that homologous chromosomes pair during prophase of meiosis.

Answers to Analyze and Conclude

1. Refer students to **Figure 4** and **Figure 8** for help identifying the different stages. Within meiosis I but prior to telophase I, the cell is in diploid state. At the end of telophase I the haploid state is formed.
2. In anaphase I, homologous chromosomes are pulled to opposite sides of the cell. In anaphase II, chromosomes are separated at their centromeres and are pulled to opposite sides of the cell.
3. Students may suggest using different materials.

Key Resources

- Holt Lab Generator
- Lab Datasheet (Levels A, B, C)
- Holt Science Biology Video Labs
- Virtual Investigations

Chapter 11

SUPER SUMMARY

Have students connect the major concepts in this chapter through an interactive Super Summary. Visit **go.hrw.com** and type in the keyword **HX8MEIS** to access the Super Summary for this chapter.

Reteaching Key Ideas

Asexual Reproduction Models Have students draw their own interpretations of binary fission, fragmentation, budding, and parthenogenesis. Student drawings should indicate why the offspring is genetically identical to the parent. LS Visual

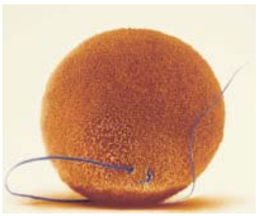
Meiosis Ask students to describe the outcome of a meiotic process where one set of homologous chromosomes does not separate during anaphase I. (Two of the four cells would have an extra pair of chromosomes; the other two cells would have one less pair of chromosomes than is normal.) LS Verbal

Organizing Concepts Have students construct a graphic organizer that compares and contrasts the diploid life cycle, haploid life cycle, and alternation of generations. LS Visual

Chapter 11 Summary

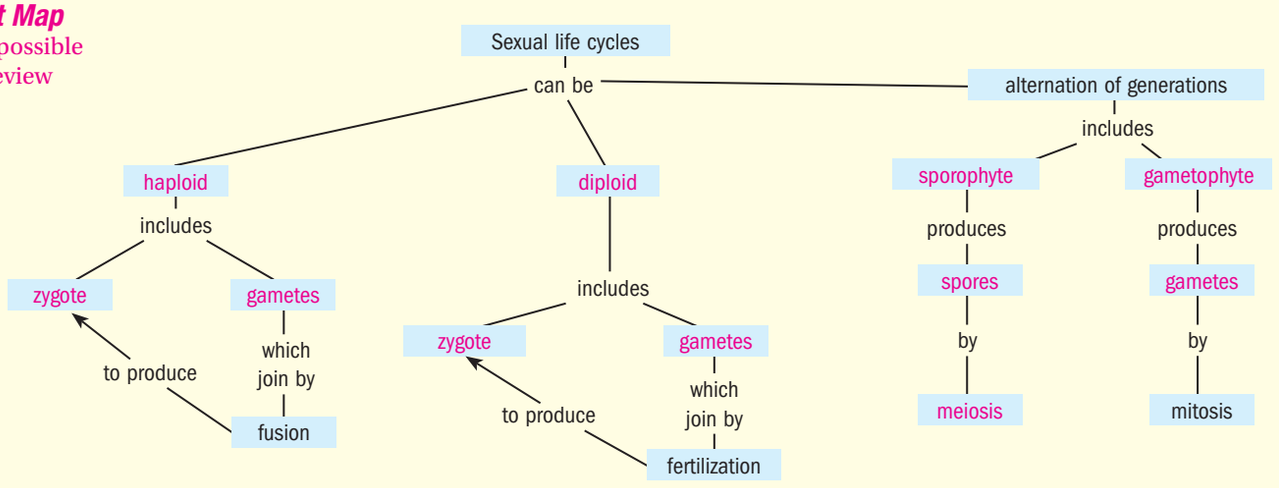
go.hrw.com
SUPER SUMMARY
Keyword: HX8MEIS

Key Ideas	Key Terms
1 Reproduction › An individual formed by asexual reproduction is genetically identical to its parent. › In sexual reproduction, two parents give genetic material to produce offspring that are genetically different from their parents. › Each chromosome has thousands of genes that play an important role in determining how an organism develops and functions.	**gamete** (248) **zygote** (248) **diploid** (249) **haploid** (249) **homologous chromosomes** (249)
2 Meiosis › During meiosis, a diploid cell goes through two divisions to form four haploid cells. › Mitosis produces cells that are used during growth, development, repair, and asexual reproduction. Meiosis makes cells that enable an organism to reproduce sexually and it only happens in reproductive structures. › Three key contributions to genetic variation are crossing-over, independent assortment, and random fertilization.	**meiosis** (250) **crossing-over** (251) **independent assortment** (254)
3 Multicellular Life Cycles › In diploid life cycles, meiosis in germ cells of a multicellular diploid organism results in the formation of haploid gametes. › In haploid life cycles, meiosis in a diploid zygote results in the formation of the first cell of a multicellular haploid individual. › Plants and most multicellular protists have a life cycle that alternates between a haploid phase and a diploid phase called *alternation of generations*.	**life cycle** (256) **sperm** (257) **ovum** (257)



Answer to Concept Map

The following is one possible answer to Chapter Review question 2.



Chapter 11 Review

READING TOOLBOX

1. **Two-Column Notes** Use two-column notes to summarize the phases of meiosis. Label the left column "Phases of meiosis" and the right column "Details."
2. **Concept Mapping** Make a concept map that shows the three sexual life cycles in multicellular organisms. Include the following words in your map: *meiosis, gametes, spores, zygote, haploid, gametophyte, sporophyte,* and *diploid.*

Using Key Terms

3. Use the following terms in the same sentence: *meiosis, crossing-over,* and *chromatids.*

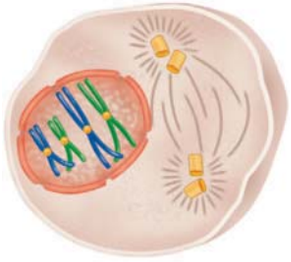
For each pair of terms, explain how the meanings of the terms differ.

4. *haploid* and *diploid*
5. *sperm* and *ovum*

Understanding Key Ideas

6. Cells that undergo meiosis are
   a. zygotes. **c.** germ cells.
   b. gametes. **d.** somatic cells.

Use the diagram to answer the following question(s).



7. Which phase in meiosis is represented in the diagram?
   a. anaphase I **c.** anaphase II
   b. prophase I **d.** telophase I

8. Genes are exchanged between homologous chromosomes during
   a. mitosis. **c.** fertilization.
   b. meiosis II. **d.** crossing-over.

9. Which of the following is not directly produced by a germ cell?
   a. egg **c.** zygote
   b. sperm **d.** gamete

10. Which is *not* a form of asexual reproduction?
    a. budding
    b. binary fission
    c. fragmentation
    d. alternation of generations

11. Homologous chromosomes move to opposite poles during
    a. prophase I. **c.** prophase II.
    b. anaphase I. **d.** anaphase II.

12. Chromosomes that have the same shape, size, and type of genes, but not necessarily the same form of these genes, are called
    a. autosomes. **c.** chromatids.
    b. homologues. **d.** sex chromosomes.

13. Which of the following is a difference between a sporophyte and a gametophyte?
    a. A sporophyte is diploid, and a gametophyte is haploid.
    b. A sporophyte is a plant, and a gametophyte is an animal.
    c. A sporophyte is multicellular, and a gametophyte is unicellular.
    d. A sporophyte undergoes only mitosis, and a gametophyte undergoes both mitosis and meiosis.

Explaining Key Ideas

14. **Explain** the difference between a diploid life cycle and a haploid life cycle.
15. **Distinguish** mitosis from meiosis.
16. **Identify** what type of organisms have a life cycle that alternates between diploid and haploid.
17. **Describe** the process of alternation of generations.

Assignment Guide

Section	Questions
1	10, 25
2	1, 2, 4, 5, 6, 7, 8, 9, 11, 12, 15, 21, 22, 23, 24, 26, 27, 28, 29, 30
3	2, 13, 14, 16, 17, 18, 19, 20

Review

Reading Toolbox

1. Encourage students to use their own words as part of the descriptions.
2. See previous page for answer to concept map.

Using Key Terms

3. In prophase I of *meiosis,* genetic variation increases when one *chromatid* overlaps another in a process called *crossing-over.*
4. A *haploid* cell contains one set of chromosomes. A *diploid* cell contains two sets of chromosomes.
5. *Sperm* is the male gamete produced by animals. *Ovum* is the female gamete produced by animals.

Understanding Key Ideas

6. c 7. b 8. d 9. c
10. d 11. b 12. b 13. a

Explaining Key Ideas

14. A diploid life cycle occurs with cells in the diploid state that undergo meiosis to create haploid gametes. A haploid life cycle occurs with cells in the haploid state that undergo mitosis to create multicellular organisms.
15. Mitosis produces new cells that are genetically identical. Meiosis produces new cells that are genetically different.
16. Plants and most multicellular protists have a life cycle that alternates between haploid and diploid phases.
17. Alternation of generations is marked by the cycle of haploid and diploid stages in the life cycle of the organism.

Using Science Graphics

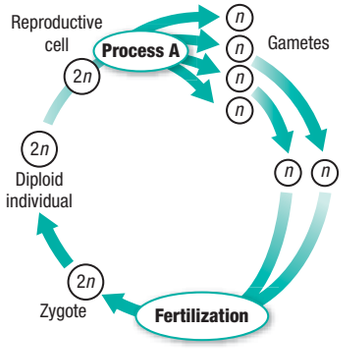
18. meiosis
19. animals

Critical Thinking

20. An alternation of generations life cycle has both multicellular diploid structures and multicellular haploid structures. A diploid life cycle has only multicellular diploid structures, and a haploid life cycle has only multicellular haploid structures.

Using Science Graphics

Use the diagram below to answer the following question(s).



18. What occurs at Process A?

19. What organisms typically have the life cycle shown in this diagram?

Critical Thinking

20. Recognizing Patterns Which feature of an alternation of generations life cycle distinguishes this life cycle from both a diploid life cycle and a haploid life cycle?

21. Evaluating Results What would be the result of crossing-over between chromatids of the same homologous chromosome?

22. Analyzing Results Occasionally, homologous chromosomes fail to separate during meiosis I. Using the hypothetical example of an adult organism that has two pairs of chromosomes, describe the chromosomal makeup of the eggs that would result from this error in meiosis.

23. Evaluating Results If a cell begins meiosis with two pairs of homologous chromosomes, how many chromatids will be in each cell that is produced at the end of meiosis I?

24. Forming Reasoned Opinions Is there a relationship between the number of chromosomes and the complexity of an organism? Give support for your answer.

Connecting Key Ideas

25. Constructing Explanations The unicellular protist *Paramecium* can reproduce asexually by binary fission. How would binary fission in this eukaryote differ from binary fission in a prokaryote?

Alternative Assessment

26. Research Use the Internet to investigate captive-breeding programs for endangered species in zoos. Compare the genetic variation of captive-bred animals with the genetic variation of wild animals. What can researchers do to help maintain genetic diversity in breeding programs?

27. Building Models Collect materials to use in building models of the different stages of meiosis and mitosis. Attach your models to poster boards, and label each stage and the structures present in meiosis and mitosis.

Writing for Science

28. Report Write a brief report that summarizes the effects of various treatments for infertility. Find out how the production of gametes may be affected in some people who are infertile.

Math Skills

29. Making Calculations If the diploid chromosome number of a species is 24, how many chromosomes would a haploid cell have?

a. 12
b. 24
c. 36
d. 48

30. Problem Solving Consider a hypothetical species with a diploid number of 4 chromosomes. What would be the diploid chromosome number of the offspring in the 10th generation after meiotic production of gametes?

Connecting Key Ideas

25. Binary fission in a eukaryote would involve breaking down the nuclear envelope and then reforming it around two new sets of genetic material, which a prokaryote would not have to do because they do not have nuclear membranes.

Alternative Assessment

26. Captive breeding programs attempt to increase genetic diversity through selective breeding, but this can be difficult if numbers are low. Researchers can document the genetic makeup of each individual in a breeding program in order to mate individuals that are genetically different.

27. Answers should represent the stages as shown in **Figure 4.**

Writing for Science

28. Answers might include summaries of one or more of the following types of treatments for infertility: in vitro fertilization (IVF); donor egg IVF; artificial insemination; tubal embryo transfer (TET); gamete intrafallopian transfer (GIFT); and drug treatments, (such as clomiphine citrate, pergonal, and metrodin).

Math Skills

29. a

30. After 10 generations in which gametes were produced by meiosis, the diploid chromosome number would still be 4.

21. There would be no new genetic combinations resulting from crossing-over between chromatids of the same homologous chromosome because they are genetically identical.

22. If one pair of chromosomes failed to separate, eggs would have either three chromosomes or one chromosome.

23. There will be four chromatids because there will be two chromosomes with two chromatids each.

24. No. Students should use **Figure 3** to give examples of simple organisms that have more chromosomes than more complex organisms do.

Chapter 11 Standardized Test Prep

TEST TIP If you are unsure of the answer to a particular question, put a question mark beside it and go on to the next question. If you have time, go back and reconsider any question that you skipped. (Do not write in this book.)

Science Concepts

1. Which of the following sex chromosomes do most human females have?

A XY **C** YY
B XX **D** XN

2. If the diploid chromosome number of a species is 24, then a cell with 12 chromosomes would be

F a zygote. **H** a haploid cell.
G a polyploid cell. **J** a diploid cell.

3. The random distribution of homologous chromosomes during meiosis is called

A fission.
B budding.
C crossing-over.
D independent assortment.

4. In addition to the genetic variability produced during meiosis, sexual reproduction generates genetic variability as a result of

F mitosis.
G spore formation.
H random fertilization.
J harsh environments.

5. Sperm formation produces

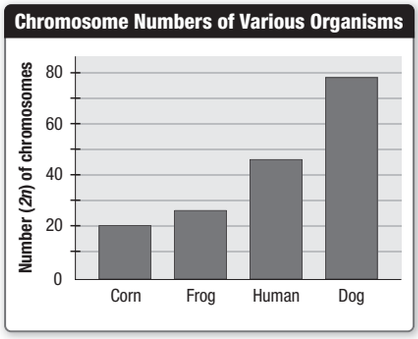
A four diploid cells.
B four haploid cells.
C four polar bodies.
D two haploid cells.

6. In a haploid sexual life cycle, meiosis occurs

F at any stage in the life cycle.
G in cells of multicellular individuals.
H immediately after a zygote is formed.
J at the time when an individual reaches its mature size.

Using Science Graphics

The graph shows chromosome number for different animals. Use the diagram to answer the following question(s).



7. How many chromosomes are in a frog gamete?

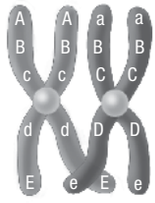
A 13 **C** 26
B 20 **D** 62

8. Which organism has 10 chromosomes in one of its gametes?

F dog **H** corn
G frog **J** human

The diagram shows crossing over of two chromatids. Use the diagram to answer the following question(s).

9. After crossing-over as shown, what would the sequence of genes be for each of the chromatids?



A ABcdE, ABcde, aBCDE, aBCDe
B ABEcd, ABcde, aBCDE, aBCDe
C ABcdE, ABcde, aBCDE, aBCdeE
D ABcdE, ABcdE, aBCDE, aBCde

Writing Skills

10. Essay Write a one-page report explaining why meiosis is important in sexual reproduction.

State Resources

For specific resources for your state, visit go.hrw.com and type in the keyword **HSHSTR**.

Test Practice with Guided Reading Development

Answers

1. B **2.** H **3.** D
4. H **5.** B **6.** H
7. A **8.** H **9.** A
10. Reports should include that meiosis increases genetic variation within a species giving the population a better chance of surviving changing conditions.

TEST DOCTOR

Question 1 Students should understand that sex chromosomes determine the sex of the offspring. Sex chromosomes can be either X or Y. Females have X chromosomes for both sex chromosomes, so **B** is correct. Students should recognize that the combination XN is not possible, so **D** is incorrect. Most males have XY chromosomes, so **A** is incorrect. **C** is not correct, because all humans have at least one X chromosome.

Question 2 A diploid cell contains two copies of each chromosome. A haploid cell contains only one copy of each chromosome. Therefore, a haploid cell would contain half the chromosomes of a diploid cell and the correct answer would be **H.**

Question 3 The random distribution of chromosomes during meiosis is called independent assortment, so **D** is correct. Fission and budding are terms that describe asexual reproduction, which does not involve meiosis, so **A** and **B** are incorrect. Crossing-over describes how parts of chromosomes may switch places during prophase in meiosis, so **C** is incorrect.