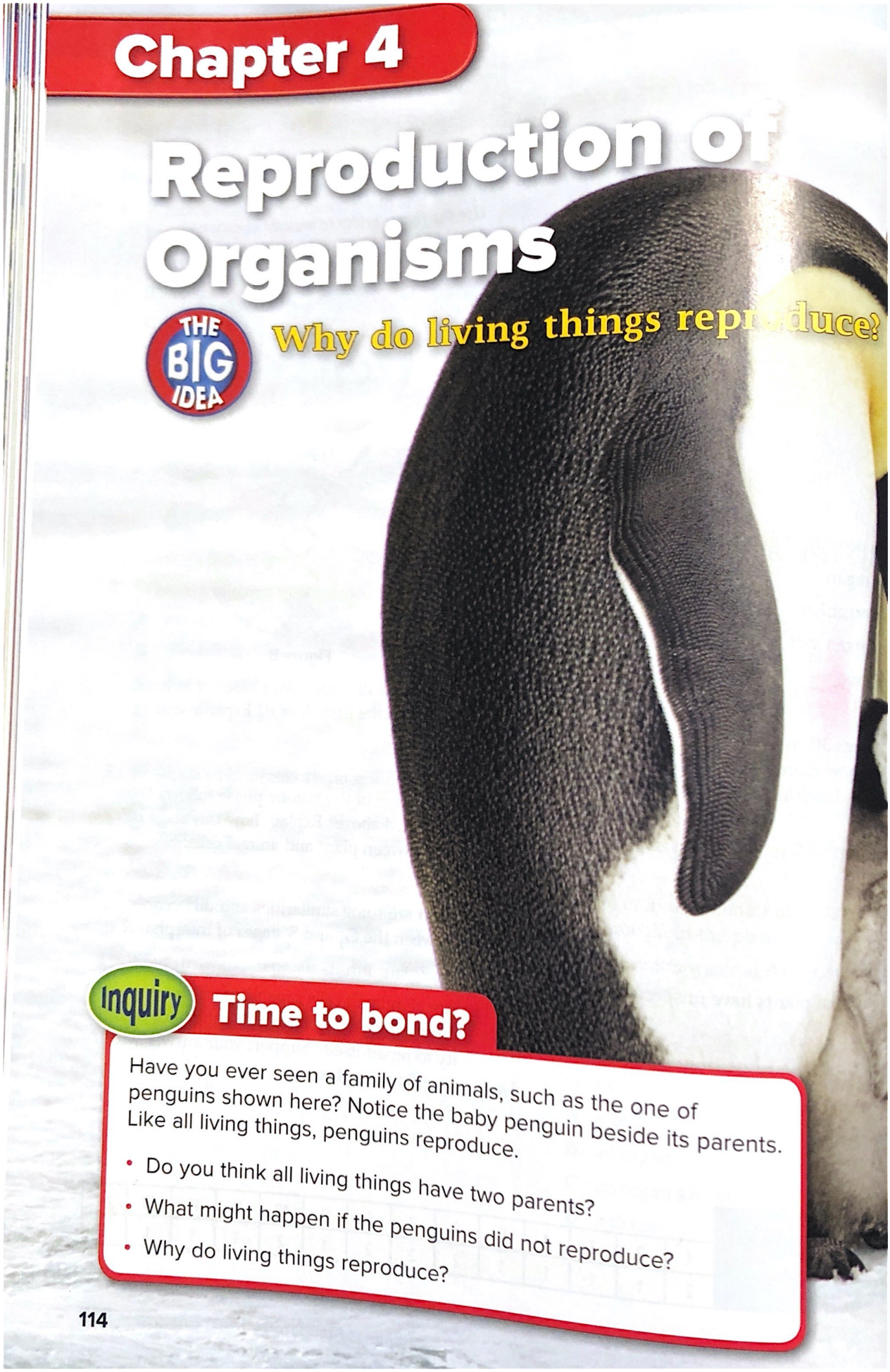
Chapter 4

Reproduction of Organisms

THE BIG IDEA

Why do living things reproduce?



Inquiry

Time to bond?

Have you ever seen a family of animals, such as the one of penguins shown here? Notice the baby penguin beside its parents. Like all living things, penguins reproduce.

- Do you think all living things have two parents?
- What might happen if the penguins did not reproduce?
- Why do living things reproduce?

Get Ready to Read

What do you think?

Before you read, decide if you agree or disagree with each of these statements. As you read this chapter, see if you change your mind about any of the statements.

1. Humans produce two types of cells: body cells and sex cells.
2. Environmental factors can cause variation among individuals.
3. Two parents always produce the best offspring.
4. Cloning produces identical individuals from one cell.
5. All organisms have two parents.
6. Asexual reproduction occurs only in microorganisms.

Lesson 1

Sexual Reproduction and Meiosis

Reading Guide

Key Concepts

ESSENTIAL QUESTIONS

- What is sexual reproduction, and why is it beneficial?
- What is the order of the phases of meiosis, and what happens during each phase?
- Why is meiosis important?

Vocabulary

sexual reproduction p. 117
egg p. 117
sperm p. 117
fertilization p. 117
zygote p. 117
diploid p. 118
homologous chromosomes p. 118
haploid p. 119
meiosis p. 119

Multilingual eGlossary

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Inquiry Modern Art?

This photo looks like a piece of modern art. It is actually an image of plant cells. The cells are dividing by a process that occurs during the production of sex cells.

Launch Lab

15 minutes

Why do offspring look different?

Unless you're an identical twin, you probably don't look exactly like any siblings you might have. You might have differences in physical characteristics such as eye color, hair color, ear shape, or height. Why are there differences in the offspring from the same parents?

1. Read and complete a lab safety form.
2. Open the **paper bag** labeled *Male Parent,* and, without looking, remove three **beads.** Record the bead colors in your Science Journal, and replace the beads.
3. Open the **paper bag** labeled *Female Parent,* and remove three **beads.** Record the bead colors, and replace the beads.
4. Repeat steps 2 and 3 for each member of the group.
5. After each member has recorded his or her bead colors, study the results. Each combination of male and female beads represents an offspring.

Think About This

1. Compare your group's offspring to another group's offspring. What similarities or differences do you observe?
2. What caused any differences you observed? Explain.
3. **Key Concept** Why might this type of reproduction be beneficial to an organism?

What is sexual reproduction?

Have you ever seen a litter of kittens? One kitten might have orange fur like its mother. A second kitten might have gray fur like its father. Still another kitten might look like a combination of both parents. How is this possible?

The kittens look different because of sexual reproduction. **Sexual reproduction** *is a type of reproduction in which the genetic materials from two different cells combine, producing an offspring.* The cells that combine are called sex cells. Sex cells form in reproductive organs. *The female sex cell, an* **egg,** *forms in an ovary. The male sex cell, a* **sperm,** *forms in a testis. During a process called* **fertilization** (fur tuh luh ZAY shun), *an egg cell and a sperm cell join together.* This produces a new cell. *The new cell that forms from fertilization is called a* **zygote.** As shown in **Figure 1,** the zygote develops into a new organism.

Personal Tutor

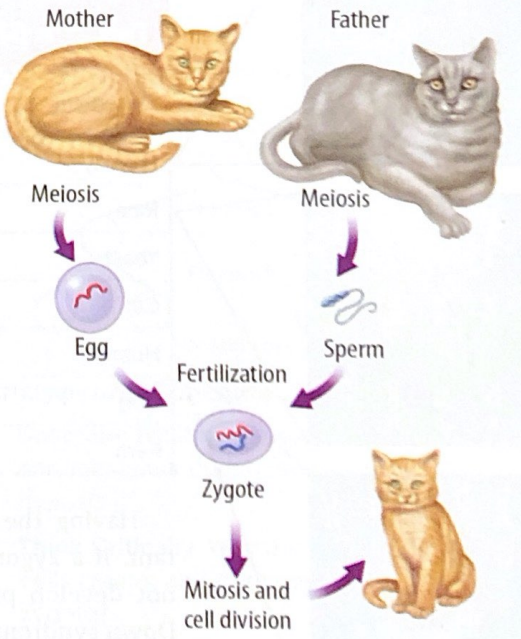


Figure 1 The zygote that forms during fertilization can become a multicellular organism.

Diploid Cells

Following fertilization, a zygote goes through mitosis and cell division. These processes produce nearly all the cells in a multicellular organism. Organisms that reproduce sexually form two kinds of cells–body cells and sex cells. In body cells of most organisms, similar chromosomes occur in pairs. **Diploid** *cells are cells that have pairs of chromosomes.*

Chromosomes

Pairs of chromosomes that have genes for the same traits arranged in the same order are called **homologous** (huh MAH luh gus) **chromosomes.** Because one chromosome is inherited from each parent, the chromosomes are not identical. For example, the kittens mentioned earlier in this lesson inherited a gene for orange fur color from their mother. They also inherited a gene for gray fur color from their father. So, some kittens might be orange, and some might be gray. Both genes for fur color are at the same place on homologous chromosomes, but they code for different colors.

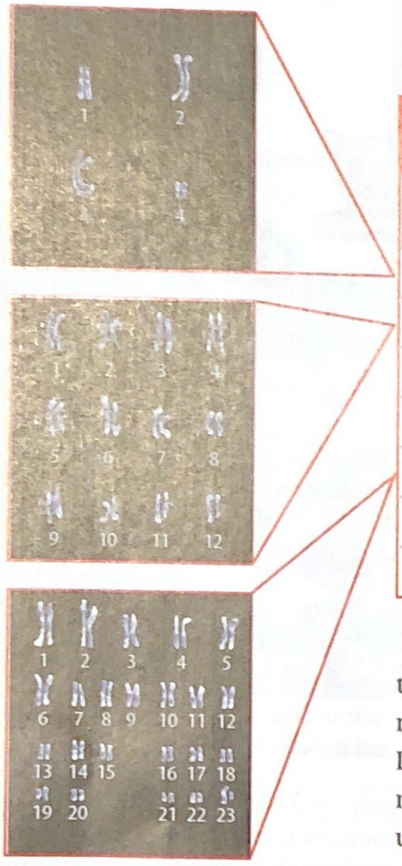
Different organisms have different numbers of chromosomes. Recall that diploid cells have pairs of chromosomes. Notice in Table 1 that human diploid cells have 23 pairs of chromosomes for a total of 46 chromosomes. A fruit fly diploid cell has 4 pairs of chromosomes, and a rice diploid cell has 12 pairs of chromosomes.

Interactive Table

Table 1 Chromosomes of Selected Organisms

Organism	Number of Chromosomes	Number of Homologous Pairs
Fruit fly	8	4
Rice	24	12
Yeast	32	16
Cat	38	19
Human	46	23
Dog	78	39
Fern	1,260	630

Table 1 An organism's chromosomes can be matched as pairs of chromosomes that have genes for the same traits.



Having the correct number of chromosomes is very important. If a zygote has too many or too few chromosomes, it will not develop properly. For example, a genetic condition called Down syndrome occurs when a person has an extra copy of chromosome 21. A person with Down syndrome can have short stature, heart defects, or mental disabilities.

Haploid Cells

Organisms that reproduce sexually also form egg and sperm cells, or sex cells. Sex cells have only one chromosome from each pair of chromosomes. **Haploid** *cells are cells that have only one chromosome from each pair.* Organisms produce sex cells using a special type of cell division called meiosis. *In* **meiosis,** *one diploid cell divides and makes four haploid sex cells.* Meiosis occurs only during the formation of sex cells.

Reading Check How do diploid cells differ from haploid cells?

WORD ORIGIN

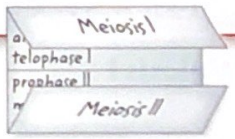
haploid
from Greek *haploeides*, means "single"

The Phases of Meiosis

Next, you will read about the phases of meiosis. Many of the phases might seem familiar to you because they also occur during mitosis. Recall that mitosis and cytokinesis involve one division of the nucleus and the cytoplasm. Meiosis involves two divisions of the nucleus and the cytoplasm. These divisions are called meiosis I and meiosis II. They result in four haploid cells–cells with half the number of chromosomes as the original cell. As you read about meiosis, think about how it produces sex cells with a reduced number of chromosomes.

FOLDABLES

Make a shutter-fold book and label it as shown. Use it to describe and illustrate the phases of meiosis.



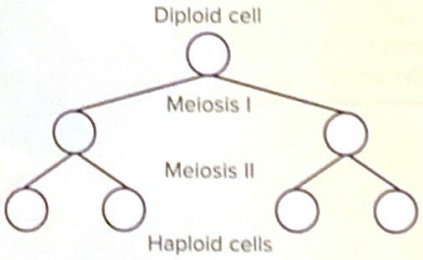
MiniLab

20 minutes

How does one cell produce four cells?

When a diploid cell goes through meiosis, it produces four haploid cells. How does this happen?

1. Read and complete a lab safety form.
2. Make a copy of the diagram by tracing circles around a **jar lid** on your **paper.** Label as shown.
3. Use **chenille craft wires** to make red and blue duplicated chromosomes 2.5 cm long and green and yellow duplicated chromosomes 1.5 cm long. Recall that a duplicated chromosome has two sister chromatids connected at the centromere.
4. Place the chromosomes in the diploid cell.
5. Move one long chromosome and one short chromosome into each of the middle cells.
6. Separate the two strands of the chromosomes, and place one strand into each of the haploid cells.



Analyze and Conclude

1. **Describe** What happened to the chromosomes during meiosis I? During meiosis II?
2. **Think Critically** Why are two haploid cells (sperm and egg) needed to form a zygote?
3. **Key Concept** How does one cell form four cells during meiosis?

Phases of Meiosis I

A reproductive cell goes through interphase before beginning meiosis I, which is shown in Figure 2. During interphase, the reproductive cell grows and copies, or duplicates, its chromosomes. Each duplicated chromosome consists of two sister chromatids joined together by a centromere.

1 Prophase I In the first phase of meiosis I, duplicated chromosomes condense and thicken. Homologous chromosomes come together and form pairs. The membrane surrounding the nucleus breaks apart, and the nucleolus disappears.

2 Metaphase I Homologous chromosome pairs line up along the middle of the cell. A spindle fiber attaches to each chromosome.

3 Anaphase I Chromosome pairs separate and are pulled toward the opposite ends of the cell. Notice that the sister chromatids stay together.

4 Telophase I A nuclear membrane forms around each group of duplicated chromosomes. The cytoplasm divides through cytokinesis and two daughter cells form. Sister chromatids remain together.

Meiosis Animation

Meiosis I

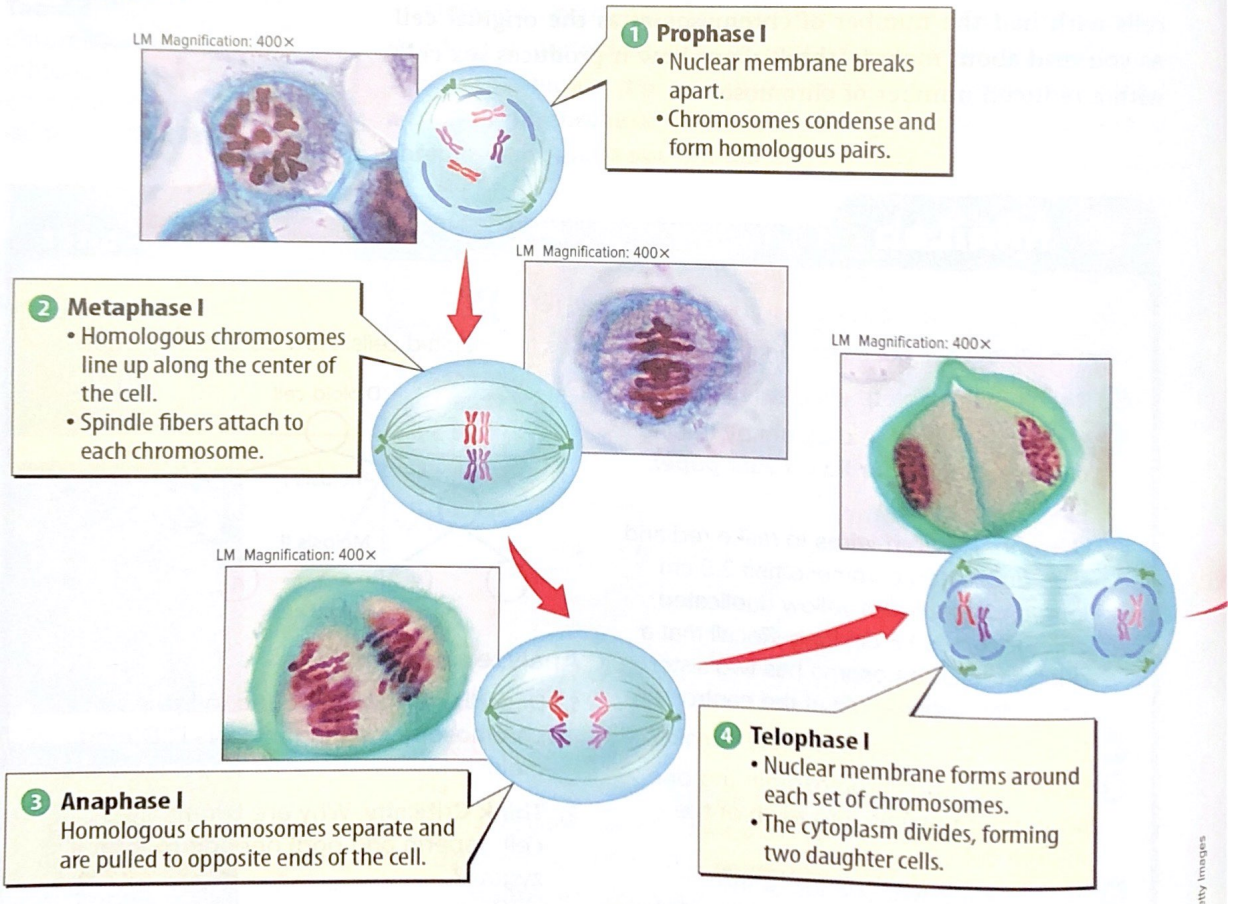


Figure 2 Unlike mitosis, meiosis involves two divisions of the nucleus and the cytoplasm.

Ed Reschke/Getty Images

Phases of Meiosis II

After meiosis I, the two cells formed during this stage go through a second division of the nucleus and the cytoplasm. This process, shown in Figure 2, is called meiosis II.

5 Prophase II Chromosomes are not copied again before prophase II. They remain as condensed, thickened sister chromatids. The nuclear membrane breaks apart, and the nucleolus disappears in each cell.

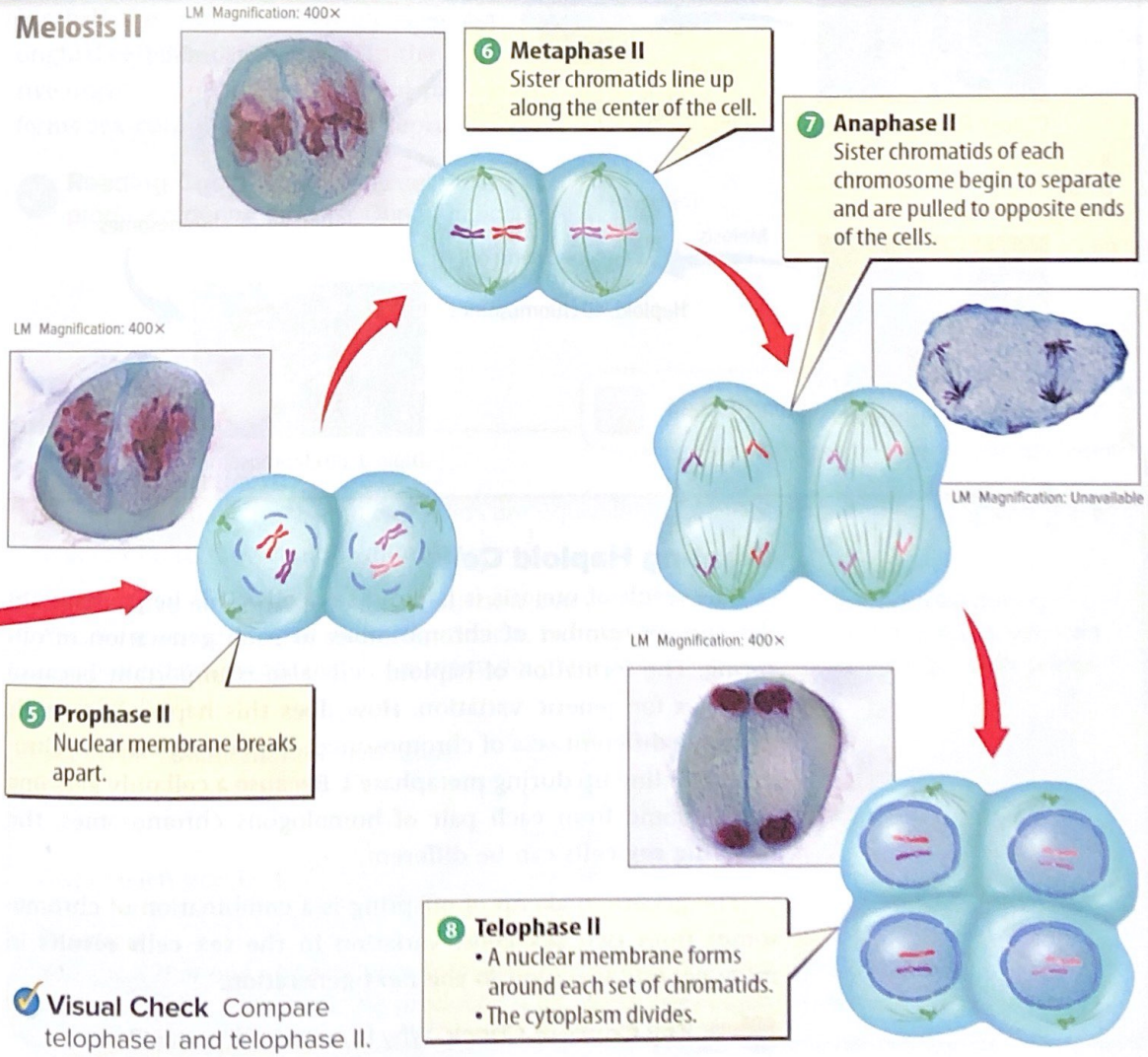
6 Metaphase II The pairs of sister chromatids line up along the middle of the cell in single file.

7 Anaphase II The sister chromatids of each duplicated chromosome are pulled away from each other and move toward opposite ends of the cells.

8 Telophase II During the final phase of meiosis–telophase II–a nuclear membrane forms around each set of chromatids, which are again called chromosomes. The cytoplasm divides through cytokinesis, and four haploid cells form.

Key Concept Check List the phases of meiosis in order.

Meiosis II



(t. l. to)Ed Reschke/Getty Images; (r)Biophoto Associates/Science Source

Visual Check Compare telophase I and telophase II.

Why is meiosis important?

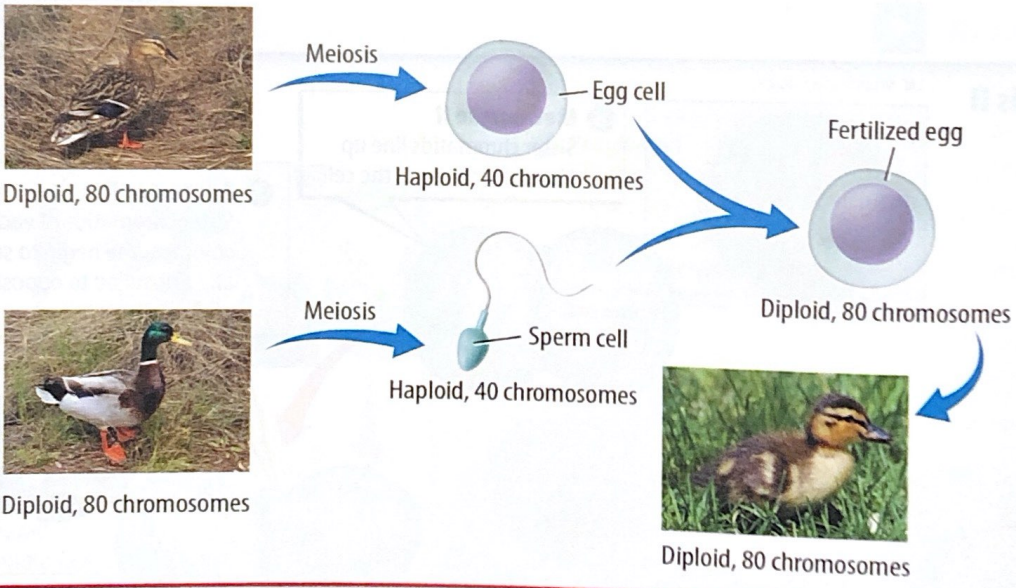
Meiosis forms sex cells with the correct haploid number of chromosomes. This maintains the correct diploid number of chromosomes in organisms when sex cells join. Meiosis also creates genetic variation by producing haploid cells.

Maintaining Diploid Cells

Recall that diploid cells have pairs of chromosomes. Meiosis helps to maintain diploid cells in offspring by making haploid sex cells. When haploid sex cells join together during fertilization, they make a diploid zygote, or fertilized egg. The zygote then divides by mitosis and cell division and creates a diploid organism. **Figure 3** illustrates how the diploid number is maintained in ducks.

Figure 3 Meiosis ensures that the chromosome number of a species stays the same from generation to generation.

Animation



Creating Haploid Cells

The result of meiosis is haploid sex cells. This helps maintain the correct number of chromosomes in each generation of offspring. The formation of haploid cells also is important because it allows for genetic variation. How does this happen? Sex cells can have different sets of chromosomes, depending on how chromosomes line up during metaphase I. Because a cell only gets one chromosome from each pair of homologous chromosomes, the resulting sex cells can be different.

The genetic makeup of offspring is a combination of chromosomes from two sex cells. Variation in the sex cells results in more genetic variation in the next generation.

Key Concept Check Why is meiosis important?

How do mitosis and meiosis differ?

Sometimes, it's hard to remember the differences between mitosis and meiosis. Use Table 2 to review these processes.

During mitosis and cell division, a body cell and its nucleus divide once and produce two identical cells. These processes are important for growth and repair or replacement of damaged tissue. Some organisms reproduce by these processes. The two daughter cells produced by mitosis and cell division have the same genetic information.

During meiosis, a reproductive cell and its nucleus divide twice and produce four cells–two pairs of identical haploid cells. Each cell has half the number of chromosomes as the original cell. Meiosis happens in the reproductive organs of multicellular organisms. Meiosis forms sex cells used for sexual reproduction.

Reading Check How many cells are produced during mitosis? During meiosis?

Interactive Table

Table 2 Comparison of Types of Cell Division

Characteristic	Meiosis	Mitosis and Cell Division
Number of chromosomes in parent cell	diploid	diploid
Type of parent cell	reproductive	body
Number of divisions of nucleus	2	1
Number of daughter cells produced	4	2
Chromosome number in daughter cells	haploid	diploid
Function	forms sperm and egg cells	growth, cell repair, some types of reproduction

Math Skills

Math Practice Personal Tutor

Use Proportions

An equation that shows that two ratios are equivalent is a proportion. The ratios $\frac{1}{2}$ and $\frac{3}{6}$ are equivalent, so they can be written as $\frac{1}{2} = \frac{3}{6}$.

You can use proportions to figure out how many daughter cells will be produced during mitosis. If you know that one cell produces two daughter cells at the end of mitosis, you can use proportions to calculate how many daughter cells will be produced by eight cells undergoing mitosis.

Set up an equation of the two ratios. $\frac{1}{2} = \frac{8}{y}$

Cross-multiply. $1 \times y = 8 \times 2$

$1y = 16$

Divide each side by 1. $y = 16$

Practice

You know that one cell produces four daughter cells at the end of meiosis. How many daughter cells would be produced if eight sex cells undergo meiosis?

Advantages of Sexual Reproduction

REVIEW VOCABULARY

DNA
the genetic information in a cell

Did you ever wonder why a brother and a sister might not look alike? The answer is sexual reproduction. The main advantage of sexual reproduction is that offspring inherit half their DNA from each parent. Offspring are not likely to inherit the same DNA from the same parents. Different DNA means that each offspring has a different set of traits. This results in genetic variation among the offspring.

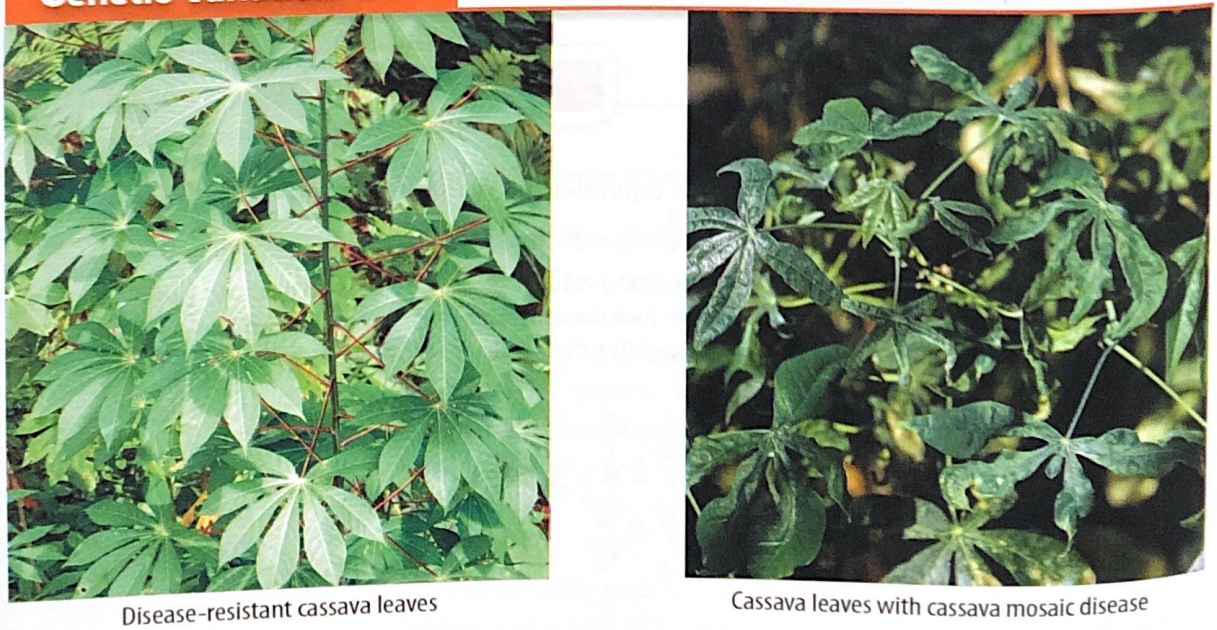
Key Concept Check Why is sexual reproduction beneficial?

Genetic Variation

As you just read, genetic variation exists among humans. You can look at your friends to see genetic variation. Genetic variation occurs in all organisms that reproduce sexually. Consider the plants shown in **Figure 4.** The plants are members of the same species, but they have different traits, such as the ability to resist disease.

Due to genetic variation, individuals within a population have slight differences. These differences might be an advantage if the environment changes. Some individuals might have traits that enable them to survive unusually harsh conditions such as a drought or severe cold. Other individuals might have traits that make them resistant to disease.

Genetic Variation



Disease-resistant cassava leaves

Cassava leaves with cassava mosaic disease

Figure 4 These plants belong to the same species. However, one is more disease-resistant than the other.

Visual Check How does cassava mosaic disease affect cassava leaves?

Selective Breeding

Did you know that broccoli, kohlrabi, kale, and cabbage all descended from one type of mustard plant? It's true. More than 2,000 years ago farmers noticed that some mustard plants had different traits, such as larger leaves or bigger flower buds. The farmers started to choose which traits they wanted by selecting certain plants to reproduce and grow. For example, some farmers chose only the plants with the biggest flowers and stems and planted their seeds. Over time, the offspring of these plants became what we know today as broccoli, shown in **Figure 5.** This process is called selective breeding. Selective breeding has been used to develop many types of plants and animals with desirable traits. It is another example of the benefits of sexual reproduction.

Figure 5 The wild mustard is the common ancestor to all these plants.

Selective Breeding

Disadvantages of Sexual Reproduction

Although sexual reproduction produces more genetic variation, it does have some disadvantages. Sexual reproduction takes time and energy. Organisms have to grow and develop until they are mature enough to produce sex cells. Then the organisms have to form sex cells–either eggs or sperm. Before they can reproduce, organisms usually have to find mates. Searching for a mate can take a long time and requires energy. The search for a mate might also expose individuals to predators, diseases, or harsh environmental conditions. In addition, sexual reproduction is limited by certain factors. For example, fertilization cannot take place during pregnancy, which can last as long as two years in some mammals.

Reading Check What are the disadvantages of sexual reproduction?

Lesson 1 Review

Online Quiz

Visual Summary

Fertilization occurs when an egg cell and a sperm cell join together.

Organisms produce sex cells through meiosis.

Sexual reproduction results in genetic variation among individuals.

FOLDABLES

Use your lesson Foldable to review the lesson. Save your Foldable for the project at the end of the chapter.

What do you think NOW?

You first read the statements below at the beginning of the chapter.

1. Humans produce two types of cells: body cells and sex cells.
2. Environmental factors can cause variation among individuals.
3. Two parents always produce the best offspring.

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

Use Vocabulary

1. **Use the terms** *egg*, *sperm*, and *zygote* in a sentence.
2. **Distinguish** between haploid and diploid.
3. **Define** *homologous chromosomes* in your own words.

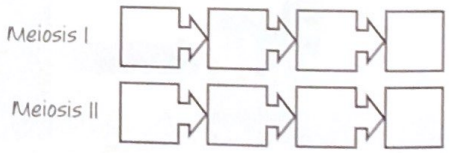
Understand Key Concepts

4. **Define** sexual reproduction.
5. **Draw and label** the phases of meiosis.
6. Homologous chromosomes separate during which phase of meiosis?

   A. anaphase I
   B. anaphase II
   C. metaphase I
   D. metaphase II

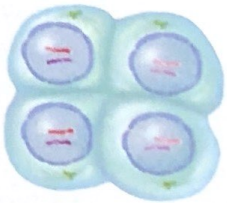
Interpret Graphics

7. **Organize** Copy and fill in the graphic organizer below to sequence the phases of meiosis I and meiosis II.



Critical Thinking

8. **Analyze** Why is the result of the stage of meiosis shown below an advantage for organisms that reproduce sexually?



Math Skills

Math Practice

9. If 15 cells undergo meiosis, how many daughter cells would be produced?
10. If each daughter cell from question 9 undergoes meiosis, how many total daughter cells will there be?

ne Spider Mating Dance

CAREERS in SCIENCE

t Norman Platnick, a scientist studying spiders.

orman Platnick is fascinated by all spider species—from the dwarf tarantula-like spiders of Panama to the blind spiders of New Zealand. These are just two of the over 1,400 species he's discovered worldwide.

How does Platnick identify new species? One way is the pedipalps. Every spider has two pedipalps, but they vary in shape and size among the over 40,000 species. Pedipalps look like legs but function more like antennae and mouthparts. Male spiders use their pedipalps to aid in reproduction.

Getting Ready When a male spider is ready to mate, he places a drop of sperm onto a sheet of silk he constructs. Then he dips his pedipalps into the drop to draw up the sperm.

Finding a Mate The male finds a female of the same species by touch or by sensing certain chemicals she releases.

Courting and Mating Males of some species court a female with a special dance. For other species, a male might present a female with a gift, such as a fly wrapped in silk. During mating, the male uses his pedipalps to transfer sperm to the female.

What happens to the male after mating? That depends on the species. Some are eaten by the female, while others move on to find new mates.

▲ **Spiders reproduce sexually, so each offspring has a unique combination of genes from its parents. Over many generations, this genetic variation has led to the incredible diversity of spiders in the world today.**

◀ **Norman Platnick is an arachnologist (uh rak NAH luh just) at the American Museum of Natural History. Arachnologists are scientists who study spiders.**

It's Your Turn

RESEARCH Select a species of spider and research its mating rituals. What does a male do to court a female? What is the role of the female? What happens to the spiderlings after they hatch? Use images to illustrate a report on your research.