

Cell Reproduction



chapter preview

sections

- 1** Cell Division and Mitosis
Lab Mitosis in Plant Cells
- 2** Sexual Reproduction and Meiosis
- 3** DNA
Lab Mutations



Virtual Lab *What is the role of DNA and RNA in protein synthesis?*

Why a turtle, not a chicken?

A sweet potato plant can be grown from just one potato, but turtles and most other animals need to have two parents. A cut on your finger heals. How do these things happen? In this chapter, you will find answers to these questions as you learn about cell reproduction.

Science Journal Write three things that you know about how and why cells reproduce.

Start-Up Activities



Infer About Seed Growth

Most flower and vegetable seeds sprout and grow into entire plants in just a few weeks. Although all of the cells in a seed have information and instructions to produce a new plant, only some of the cells in the seed use the information. Where are these cells in seeds? Do the following lab to find out.



1. Carefully split open two bean seeds that have soaked in water overnight.
2. Observe both halves and record your observations.
3. Wrap all four halves in a moist paper towel. Then put them into a self-sealing plastic bag and seal the bag.
4. Make observations every day for a few days.
5. **Think Critically** Write a paragraph that describes what you observe. Hypothesize which cells in seeds use information about how plants grow.



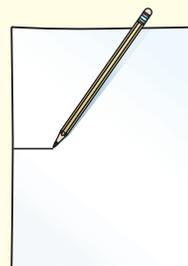
Preview this chapter's content and activities at booka.msscience.com

FOLDABLES™ Study Organizer

How and Why Cells Divide

Make the following Foldable to help you organize information from the chapter about cell reproduction.

- STEP 1** Draw a mark at the midpoint of a vertical sheet of paper along the side edge.



- STEP 2** Turn the paper horizontally and fold the outside edges in to touch at the midpoint mark.



- STEP 3** Use a pencil to draw a cell on the front of your Foldable as shown.

Analyze As you read the chapter, write under the flaps how cells divide. In the middle section, list why cells divide.

Cell Division and Mitosis

as you read

What You'll Learn

- **Explain** why mitosis is important.
- **Examine** the steps of mitosis.
- **Compare** mitosis in plant and animal cells.
- **List** two examples of asexual reproduction.

Why It's Important

Your growth, like that of many organisms, depends on cell division.

Review Vocabulary

nucleus: organelle that controls all the activities of a cell and contains hereditary material made of proteins and DNA

New Vocabulary

- mitosis
- chromosome
- asexual reproduction

Why is cell division important?

What do you, an octopus, and an oak tree have in common? You share many characteristics, but an important one is that you are all made of cells—trillions of cells. Where did all of those cells come from? As amazing as it might seem, many organisms start as just one cell. That cell divides and becomes two, two become four, four become eight, and so on. Many-celled organisms, including you, grow because cell division increases the total number of cells in an organism. Even after growth stops, cell division is still important. Every day, billions of red blood cells in your body wear out and are replaced. During the few seconds it takes you to read this sentence, your bone marrow produced about six million red blood cells. Cell division is important to one-celled organisms, too—it's how they reproduce themselves, as shown in **Figure 1**. Cell division isn't as simple as just cutting the cell in half, so how do cells divide?

The Cell Cycle

A living organism has a life cycle. A life cycle begins with the organism's formation, is followed by growth and development, and finally ends in death. Right now, you are in a stage of your life cycle called adolescence, which is a period of active growth and development. Individual cells also have life cycles.

Figure 1 All organisms use cell division. Many-celled organisms, such as this octopus, grow by increasing the numbers of their cells.



Like this dividing amoeba, a one-celled organism reaches a certain size and then reproduces.

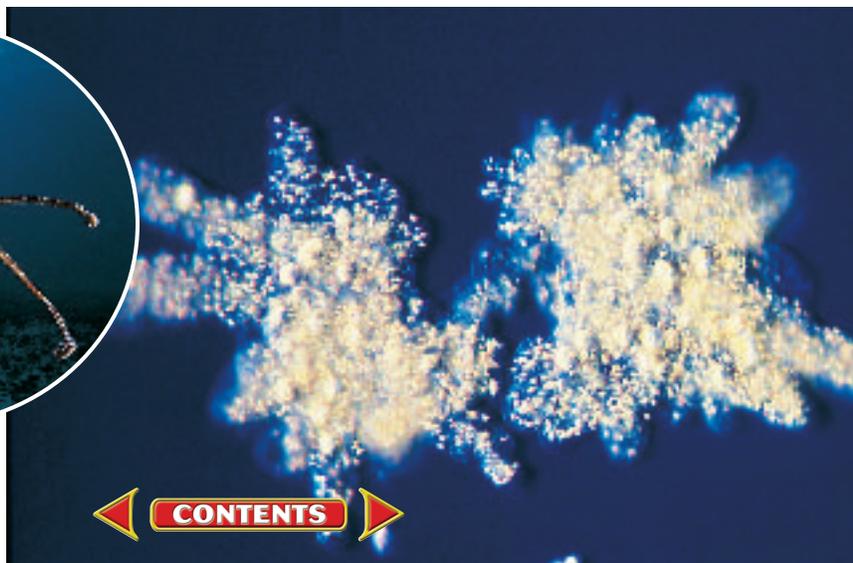
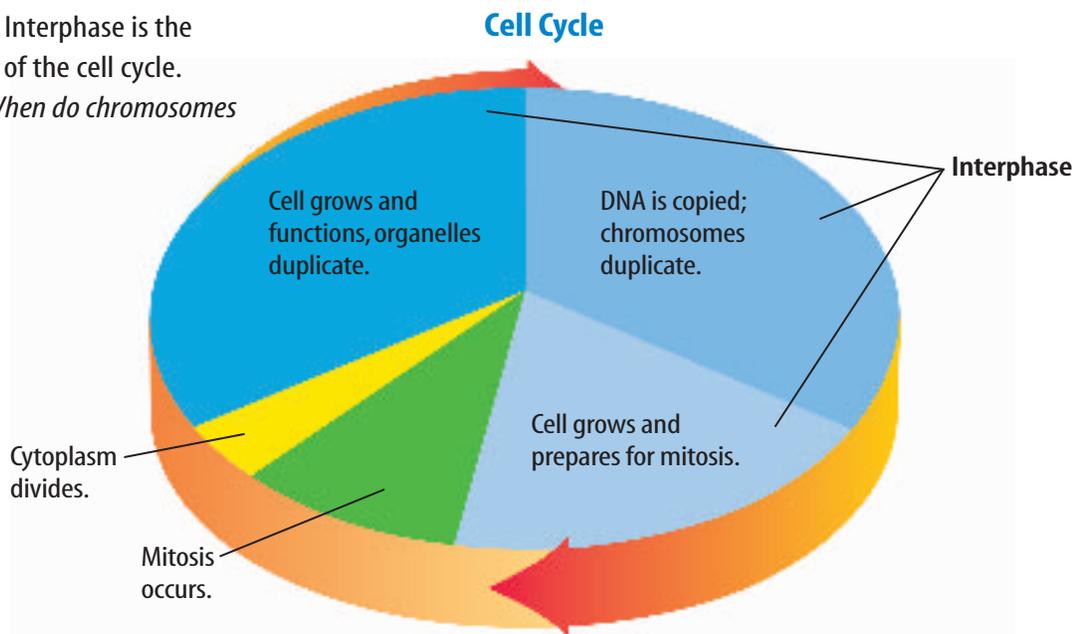


Figure 2 Interphase is the longest part of the cell cycle.

Identify When do chromosomes duplicate?



Length of Cycle The cell cycle, as shown in **Figure 2**, is a series of events that takes place from one cell division to the next. The time it takes to complete a cell cycle is not the same in all cells. For example, the cycle for cells in some bean plants takes about 19 h to complete. Cells in animal embryos divide rapidly and can complete their cycles in less than 20 min. In some human cells, the cell cycle takes about 16 h. Cells in humans that are needed for repair, growth, or replacement, like skin and bone cells, constantly repeat the cycle.

Interphase Most of the life of any eukaryotic cell—a cell with a nucleus—is spent in a period of growth and development called interphase. Cells in your body that no longer divide, such as nerve and muscle cells, are always in interphase. An actively dividing cell, such as a skin cell, copies its hereditary material and prepares for cell division during interphase.

Why is it important for a cell to copy its hereditary information before dividing? Imagine that you have a part in a play and the director has one complete copy of the script. If the director gave only one page to each person in the play, no one would have the entire script. Instead the director makes a complete, separate copy of the script for each member of the cast so that each one can learn his or her part. Before a cell divides, a copy of the hereditary material must be made so that each of the two new cells will get a complete copy. Just as the actors in the play need the entire script, each cell needs a complete set of hereditary material to carry out life functions.

After interphase, cell division begins. The nucleus divides, and then the cytoplasm separates to form two new cells.



Oncologist In most cells, the cell cycle is well controlled. Cancer cells, however, have uncontrolled cell division. Doctors who diagnose, study, and treat cancer are called oncologists. Someone wanting to become an oncologist must first complete medical school before training in oncology. Research the subspecialties of oncology. List and describe them in your Science Journal.

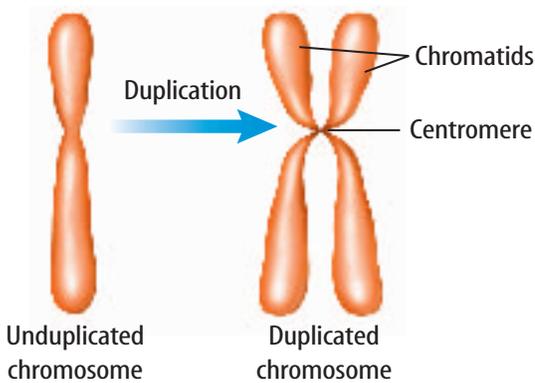
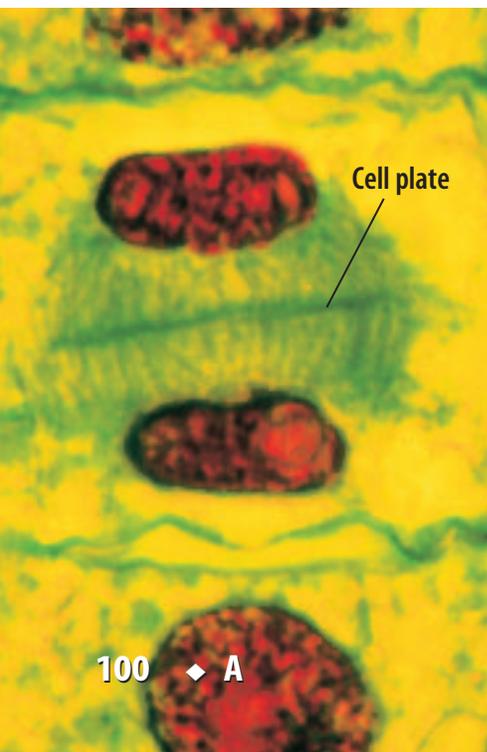


Figure 3 DNA is copied during interphase. An unduplicated chromosome has one strand of DNA. A duplicated chromosome has two identical DNA strands, called chromatids, that are held together at a region called the centromere.

Figure 4 The cell plate shown in this plant cell appears when the cytoplasm is being divided.
Identify what phase of mitosis will be next.



Mitosis

Mitosis (mi TOH sus) is the process in which the nucleus divides to form two identical nuclei. Each new nucleus also is identical to the original nucleus. Mitosis is described as a series of phases, or steps. The steps of mitosis in order are named prophase, metaphase, anaphase, and telophase.

Steps of Mitosis When any nucleus divides, the chromosomes (KROH muh sohmz) play the important part. A **chromosome** is a structure in the nucleus that contains hereditary material. During interphase, each chromosome duplicates. When the nucleus is ready to divide, each duplicated chromosome coils tightly into two thickened, identical strands called chromatids, as shown in **Figure 3**.

Reading Check *How are chromosomes and chromatids related?*

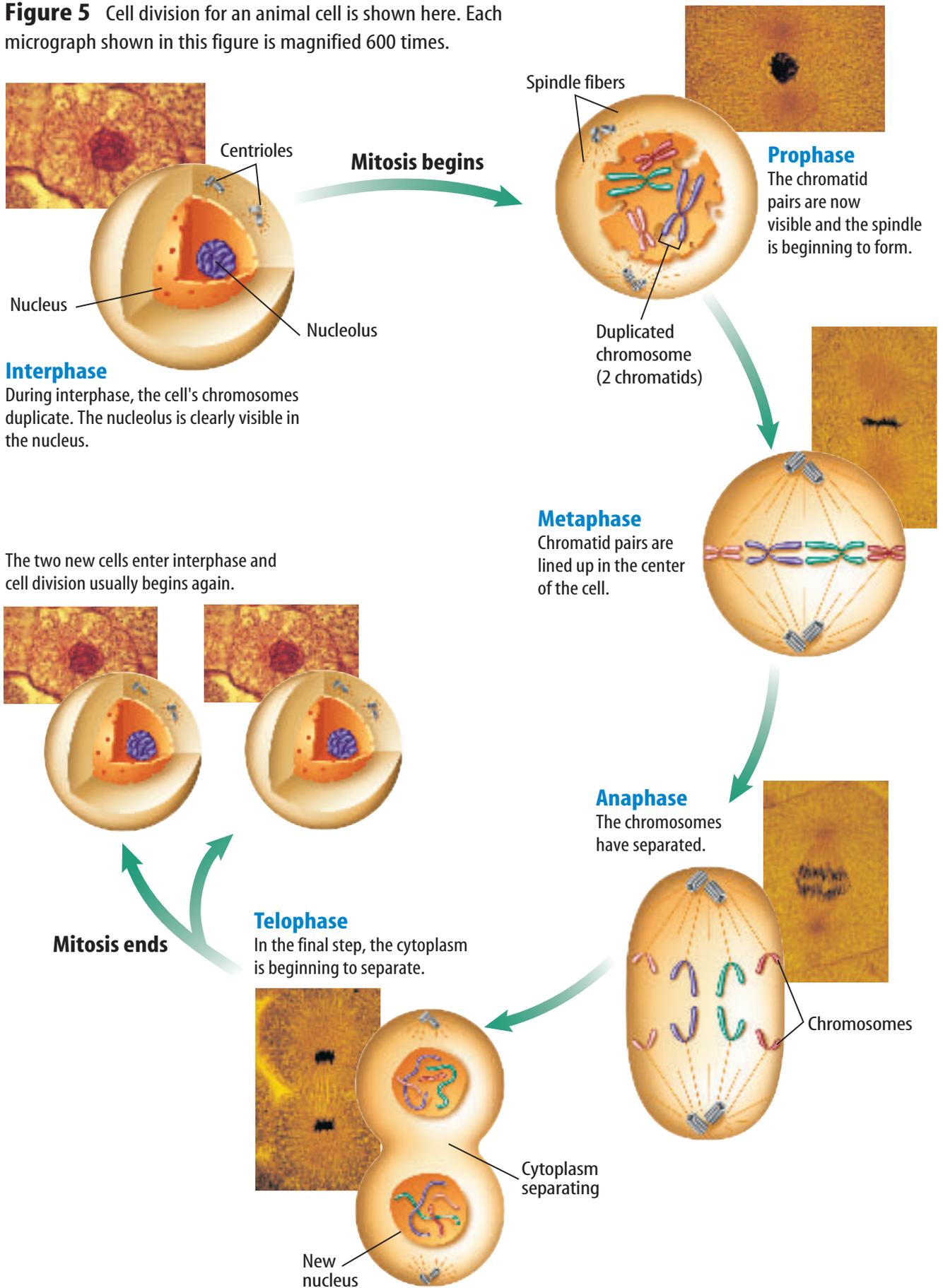
During prophase, the pairs of chromatids are fully visible when viewed under a microscope. The nucleolus and the nuclear membrane disintegrate. Two small structures called centrioles (SEN tree olz) move to opposite ends of the cell. Between the centrioles, threadlike spindle fibers begin to stretch across the cell. Plant cells also form spindle fibers during mitosis but do not have centrioles.

In metaphase, the pairs of chromatids line up across the center of the cell. The centromere of each pair usually becomes attached to two spindle fibers—one from each side of the cell.

In anaphase, each centromere divides and the spindle fibers shorten. Each pair of chromatids separates, and chromatids begin to move to opposite ends of the cell. The separated chromatids are now called chromosomes. In the final step, telophase, spindle fibers start to disappear, the chromosomes start to uncoil, and a new nucleus forms.

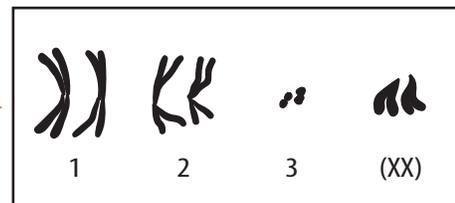
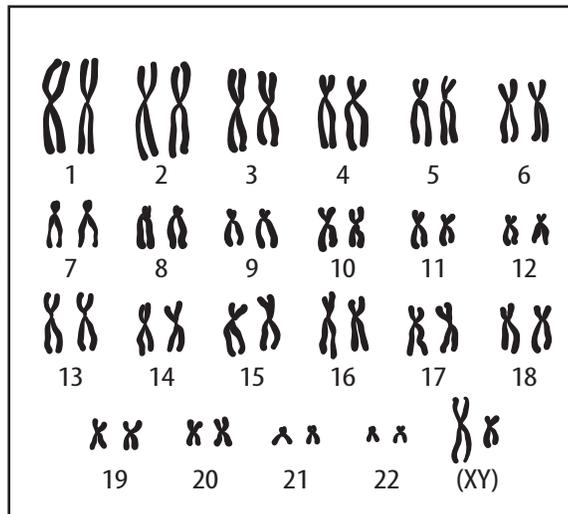
Division of the Cytoplasm For most cells, after the nucleus has divided, the cytoplasm separates and two new cells are formed. In animal cells, the cell membrane pinches in the middle, like a balloon with a string tightened around it, and the cytoplasm divides. In plant cells, the appearance of a cell plate, as shown in **Figure 4**, tells you that the cytoplasm is being divided. New cell walls form along the cell plate, and new cell membranes develop inside the cell walls. Following division of the cytoplasm, most new cells begin the period of growth, or interphase, again. Review cell division for an animal cell using the illustrations in **Figure 5**.

Figure 5 Cell division for an animal cell is shown here. Each micrograph shown in this figure is magnified 600 times.





Chromosomes of a human cell



Chromosomes of a fruit fly cell

Figure 6 Pairs of chromosomes are found in the nucleus of most cells. All chromosomes shown here are in their duplicated form. Most human cells have 23 pairs of chromosomes including one pair of chromosomes that help determine sex such as the XY pair above. Most fruit fly cells have four pairs of chromosomes.

Infer What do you think the XX pair in fruit flies helps determine?

Results of Mitosis You should remember two important things about mitosis. First, it is the division of a nucleus. Second, it produces two new nuclei that are identical to each other and the original nucleus. Each new nucleus has the same number and type of chromosomes. Every cell in your body, except sex cells, has a nucleus with 46 chromosomes—23 pairs. This is because you began as one cell with 46 chromosomes in its nucleus. Skin cells, produced to replace or repair your skin, have the same 46 chromosomes as the original single cell you developed from. Each cell in a fruit fly has eight chromosomes, so each new cell produced by mitosis has a copy of those eight chromosomes. **Figure 6** shows the chromosomes found in most human cells and those found in most fruit fly cells.

Each of the trillions of cells in your body, except sex cells, has a copy of the same hereditary material. Even though all actors in a play have copies of the same script, they do not learn the same lines. Likewise, all of your cells use different parts of the same hereditary material to become different types of cells.

Cell division allows growth and replaces worn out or damaged cells. You are much larger and have more cells than a baby mainly because of cell division. If you cut yourself, the wound heals because cell division replaces damaged cells. Another way some organisms use cell division is to produce new organisms.

Asexual Reproduction

Reproduction is the process by which an organism produces others of its same kind. Among living organisms, there are two types of reproduction—sexual and asexual. Sexual reproduction usually requires two organisms. In **asexual reproduction**, a new organism (sometimes more than one) is produced from one organism. The new organism will have hereditary material identical to the hereditary material of the parent organism.



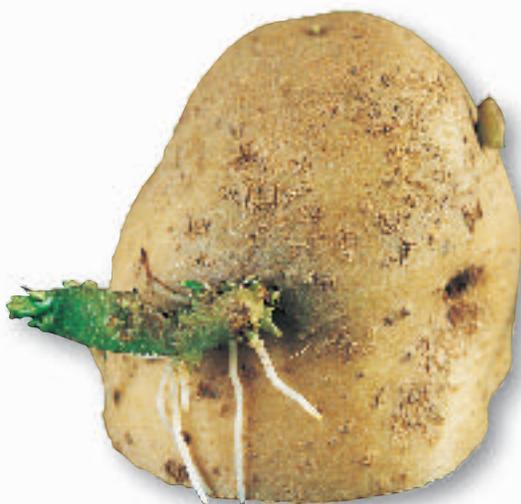
Reading Check

How many organisms are needed for asexual reproduction?

Cellular Asexual Reproduction Organisms with eukaryotic cells asexually reproduce by cell division. A sweet potato growing in a jar of water is an example of asexual reproduction. All the stems, leaves, and roots that grow from the sweet potato have been produced by cell division and have the same hereditary material. New strawberry plants can be reproduced asexually from horizontal stems called runners. **Figure 7** shows asexual reproduction in a potato and a strawberry plant.

Recall that mitosis is the division of a nucleus. However, bacteria do not have a nucleus so they can't use mitosis. Instead, bacteria reproduce asexually by fission. During fission, an organism whose cells do not contain a nucleus copies its genetic material and then divides into two identical organisms.

Figure 7 Many plants can reproduce asexually.



A new potato plant can grow from each sprout on this potato.



Infer how the genetic material in the small strawberry plant above compares to the genetic material in the large strawberry plant.

Mini
LAB

Modeling Mitosis

Procedure

1. Make models of cell division using **materials supplied by your teacher**.
2. Use four chromosomes in your model.
3. When finished, arrange the models in the order in which mitosis occurs.

Analysis

1. In which steps is the nucleus visible?
2. How many cells does a dividing cell form?

Figure 8 Some organisms use cell division for budding and regeneration.



A Hydra, a freshwater animal, can reproduce asexually by budding. The bud is a small exact copy of the adult.



B This sea star is regenerating four new arms.

Budding and Regeneration Look at **Figure 8A**. A new organism is growing from the body of the parent organism. This organism, called a hydra, is reproducing by budding. Budding is a type of asexual reproduction made possible because of cell division. When the bud on the adult becomes large enough, it breaks away to live on its own.

Could you grow a new finger? Some organisms can regrow damaged or lost body parts, as shown in **Figure 8B**. Regeneration is the process that uses cell division to regrow body parts. Sponges, planaria, sea stars, and some other organisms can use regeneration for asexual reproduction. If these organisms break into pieces, a whole new organism will grow from each piece. Because sea stars eat oysters, oyster farmers dislike them. What would happen if an oyster farmer collected sea stars, cut them into pieces, and threw them back into the ocean?

section 1 review

Summary

The Cell Cycle

- The cell cycle is a series of events from one cell division to the next.
- Most of a eukaryotic cell's life is interphase.

Mitosis

- Mitosis is a series of four phases or steps.
- Each new nucleus formed by mitosis has the same number and type of chromosomes.

Asexual Reproduction

- In asexual reproduction, a new organism is produced from one organism.
- Cellular, budding, and regeneration are forms of asexual reproduction.

Self Check

1. **Define** mitosis. How does it differ in plants and animals?
2. **Identify** two examples of asexual reproduction in many-celled organisms.
3. **Describe** what happens to chromosomes before mitosis.
4. **Compare and contrast** the two new cells formed after mitosis and cell division.
5. **Think Critically** Why is it important for the nuclear membrane to disintegrate during mitosis?

Applying Math

6. **Solve One-Step Equations** If a cell undergoes cell division every 5 min, how many cells will there be after 1 h?

LAB

Mitosis in Plant Cells

Reproduction of most cells in plants and animals uses mitosis and cell division. In this lab, you will study mitosis in plant cells by examining prepared slides of onion root-tip cells.

Real-World Question

How can plant cells in different stages of mitosis be distinguished from each other?

Goals

- **Compare** cells in different stages of mitosis and observe the location of their chromosomes.
- **Observe** what stage of mitosis is most common in onion root tips.

Materials

prepared slide of an onion root tip
microscope

Safety Precautions

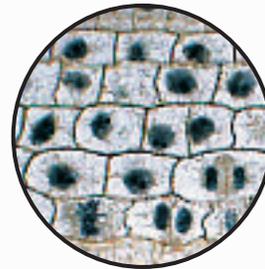


Procedure

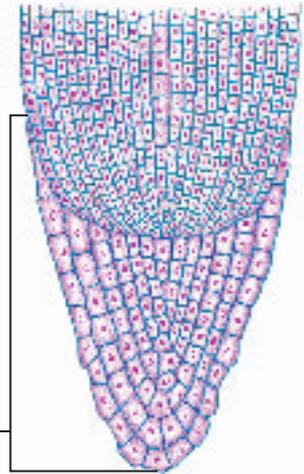
1. Copy the data table in your Science Journal.

Number of Root-Tip Cells Observed		
Stage of Mitosis	Number of Cells Observed	Percent of Cells Observed
Prophase		
Metaphase		
Anaphase	Do not write in this book.	
Telophase		
Total		

2. **Obtain** a prepared slide of cells from an onion root tip.



Zone of cell division
Root cap



3. Set your microscope on low power and examine the slide. The large, round cells at the root tip are called the root cap. Move the slide until you see the cells just behind the root cap. Turn to the high-power objective.
4. Find an area where you can see the most stages of mitosis. Count and record how many cells you see in each stage.
5. Return the nosepiece to low power. Remove the onion root-tip slide.

Conclude and Apply

1. **Compare** the cells in the region behind the root cap to those in the root cap.
2. **Calculate** the percent of cells found in each stage of mitosis. Infer which stage of mitosis takes the longest period of time.

Communicating Your Data

Write and illustrate a story as if you were a cell undergoing mitosis. Share your story with your class. **For more help, refer to the Science Skill Handbook.**

Sexual Reproduction and Meiosis

as you read

What You'll Learn

- **Describe** the stages of meiosis and how sex cells are produced.
- **Explain** why meiosis is needed for sexual reproduction.
- **Name** the cells that are involved in fertilization.
- **Explain** how fertilization occurs in sexual reproduction.

Why It's Important

Meiosis and sexual reproduction are the reasons why no one else is exactly like you.

Review Vocabulary

organism: any living thing; uses energy, is made of cells, reproduces, responds, grows, and develops

New Vocabulary

- sexual reproduction
- sperm
- egg
- fertilization
- zygote
- diploid
- haploid
- meiosis

Sexual Reproduction

Sexual reproduction is another way that a new organism can be produced. During **sexual reproduction**, two sex cells, sometimes called an egg and a sperm, come together. Sex cells, like those in **Figure 9**, are formed from cells in reproductive organs. **Sperm** are formed in the male reproductive organs. **Eggs** are formed in the female reproductive organs. The joining of an egg and a sperm is called **fertilization**, and the cell that forms is called a **zygote** (ZI goht). Generally, the egg and the sperm come from two different organisms of the same species. Following fertilization, cell division begins. A new organism with a unique identity develops.

Diploid Cells Your body forms two types of cells—body cells and sex cells. Body cells far outnumber sex cells. Your brain, skin, bones, and other tissues and organs are formed from body cells. A typical human body cell has 46 chromosomes. Each chromosome has a mate that is similar to it in size and shape and has similar DNA. Human body cells have 23 pairs of chromosomes. When cells have pairs of similar chromosomes, they are said to be **diploid** (DIH ployd).

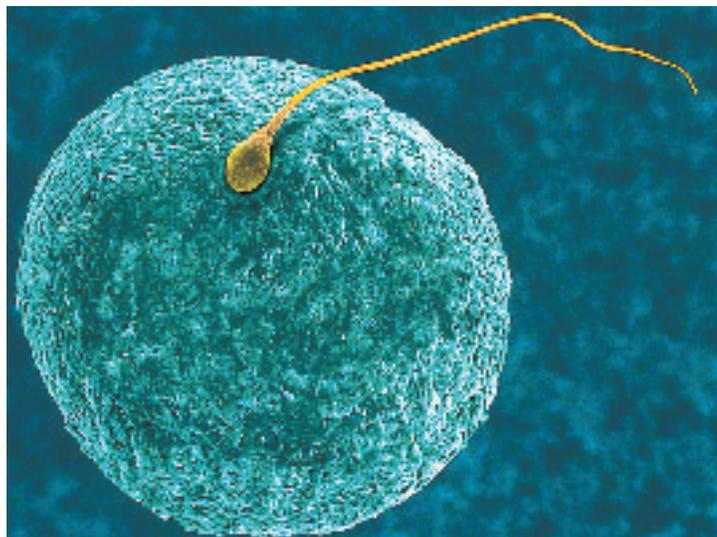


Figure 9 A human egg and a human sperm at fertilization.

Haploid Cells Because sex cells do not have pairs of chromosomes, they are said to be **haploid** (HA ploid). They have only half the number of chromosomes as body cells. *Haploid* means “single form.” Human sex cells have only 23 chromosomes—one from each of the 23 pairs of similar chromosomes. Compare the chromosomes found in a sex cell, as shown in **Figure 9**, to the full set of human chromosomes seen in **Figure 6**.

Reading Check How many chromosomes are usually in each human sperm?

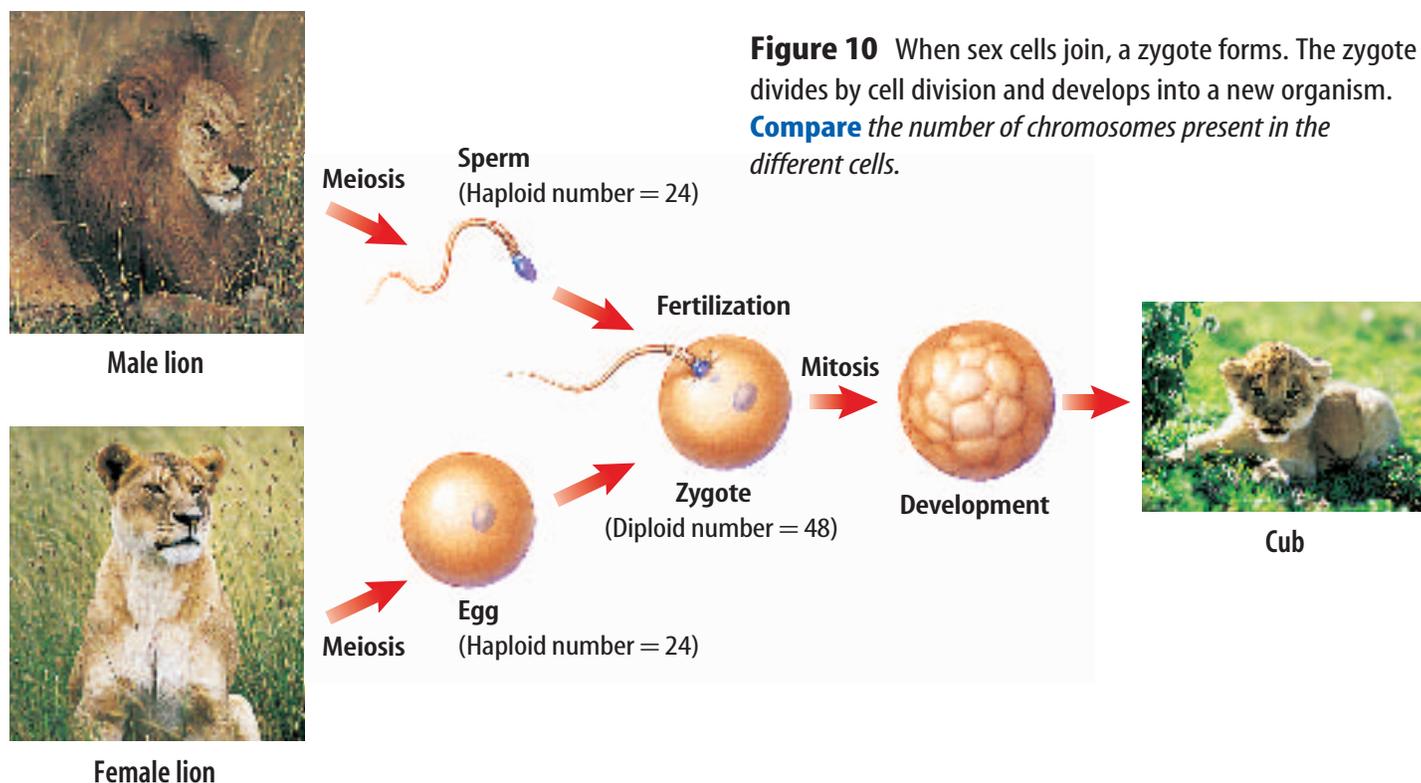
Meiosis and Sex Cells

A process called **meiosis** (mi OH sus) produces haploid sex cells. What would happen in sexual reproduction if two diploid cells combined? The offspring would have twice as many chromosomes as its parent. Although plants with twice the number of chromosomes as the parent plants are often produced, most animals do not survive with a double number of chromosomes. Meiosis ensures that the offspring will have the same diploid number as its parent, as shown in **Figure 10**. After two haploid sex cells combine, a diploid zygote is produced that develops into a new diploid organism.

During meiosis, two divisions of the nucleus occur. These divisions are called meiosis I and meiosis II. The steps of each division have names like those in mitosis and are numbered for the division in which they occur.



Diploid Zygote The human egg releases a chemical into the surrounding fluid that attracts sperm. Usually, only one sperm fertilizes the egg. After the sperm nucleus enters the egg, the cell membrane of the egg changes in a way that prevents other sperm from entering. What adaptation in this process guarantees that the zygote will be diploid? Write a paragraph describing your ideas in your Science Journal.



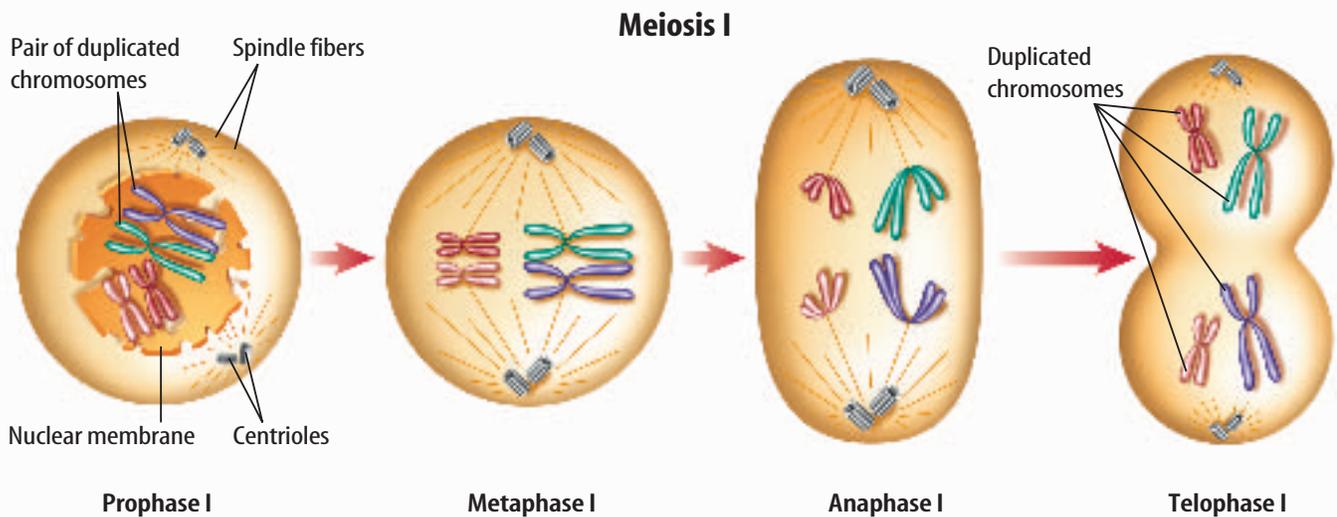


Figure 11 Meiosis has two divisions of the nucleus—meiosis I and meiosis II.

Determine how many sex cells are finally formed after both divisions are completed.

Meiosis I Before meiosis begins, each chromosome is duplicated, just as in mitosis. When the cell is ready for meiosis, each duplicated chromosome is visible under the microscope as two chromatids. As shown in **Figure 11**, the events of prophase I are similar to those of prophase in mitosis. In meiosis, each duplicated chromosome comes near its similar duplicated mate. In mitosis they do not come near each other.

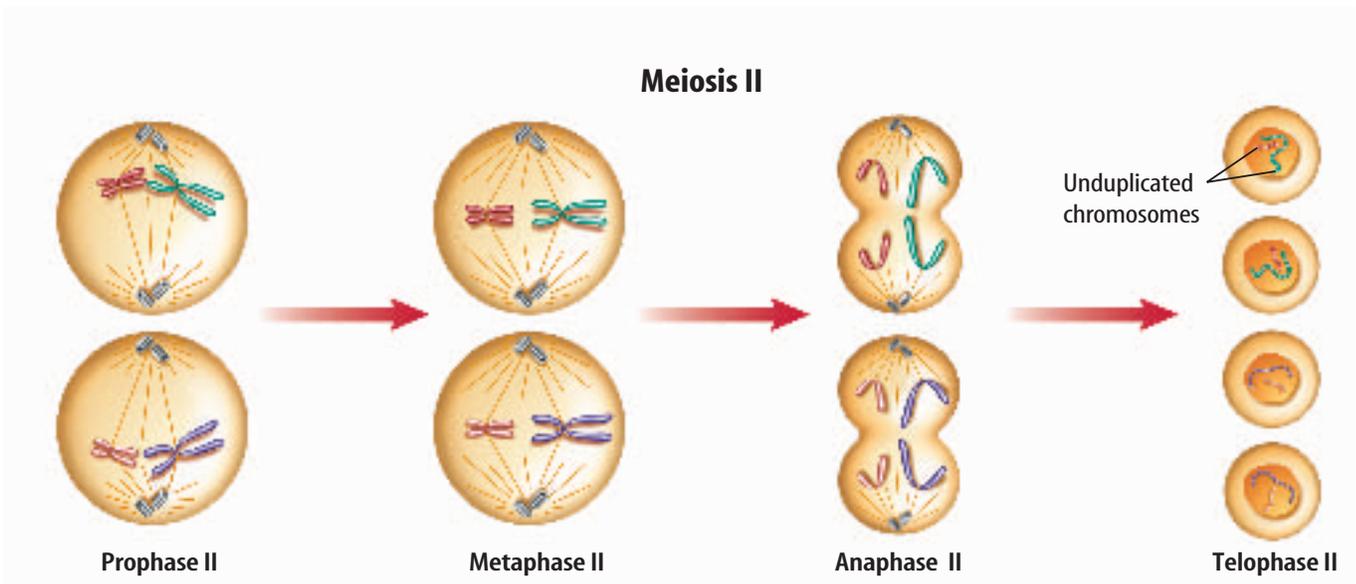
In metaphase I, the pairs of duplicated chromosomes line up in the center of the cell. The centromere of each chromatid pair becomes attached to one spindle fiber, so the chromatids do not separate in anaphase I. The two pairs of chromatids of each similar pair move away from each other to opposite ends of the cell. Each duplicated chromosome still has two chromatids. Then, in telophase I, the cytoplasm divides, and two new cells form. Each new cell has one duplicated chromosome from each similar pair.



Reading Check

What happens to duplicated chromosomes during anaphase I?

Meiosis II The two cells formed during meiosis I now begin meiosis II. The chromatids of each duplicated chromosome will be separated during this division. In prophase II, the duplicated chromosomes and spindle fibers reappear in each new cell. Then in metaphase II, the duplicated chromosomes move to the center of the cell. Unlike what occurs in metaphase I, each centromere now attaches to two spindle fibers instead of one. The centromere divides during anaphase II, and the chromatids separate and move to opposite ends of the cell. Each chromatid now is an individual chromosome. As telophase II begins, the spindle fibers disappear, and a nuclear membrane forms around the chromosomes at each end of the cell. When meiosis II is finished, the cytoplasm divides.



Summary of Meiosis Two cells form during meiosis I. In meiosis II, both of these cells form two cells. The two divisions of the nucleus result in four sex cells. Each has one-half the number of chromosomes in its nucleus that was in the original nucleus. From a human cell with 46 paired chromosomes, meiosis produces four sex cells each with 23 unpaired chromosomes.

Applying Science

How can chromosome numbers be predicted?

Offspring get half of their chromosomes from one parent and half from the other. What happens if each parent has a different diploid number of chromosomes?

Identifying the Problem

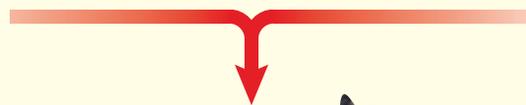
A zebra and a donkey can mate to produce a zonkey. Zebras have a diploid number of 46. Donkeys have a diploid number of 62.

Solving the Problem

1. How many chromosomes would the zonkey receive from each parent?
2. What is the chromosome number of the zonkey?
3. What would happen when meiosis occurs in the zonkey's reproductive organs?
4. Predict why zonkeys are usually sterile.



Donkey
62 chromosomes



Zonkey



Zebra
46 chromosomes

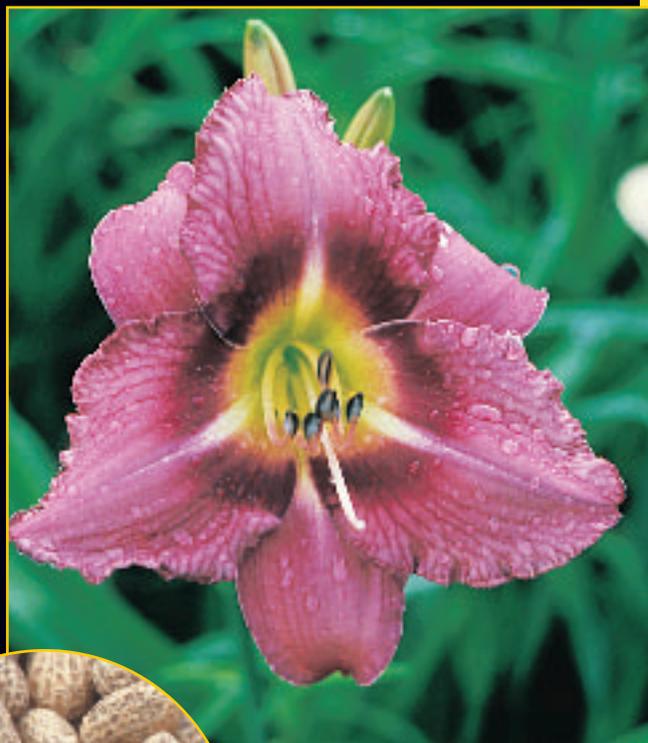


Figure 12

You received a haploid (n) set of chromosomes from each of your parents, making you a diploid ($2n$) organism. In nature, however, many plants are polyploid—they have three ($3n$), four ($4n$), or more sets of chromosomes. We depend on some of these plants for food.



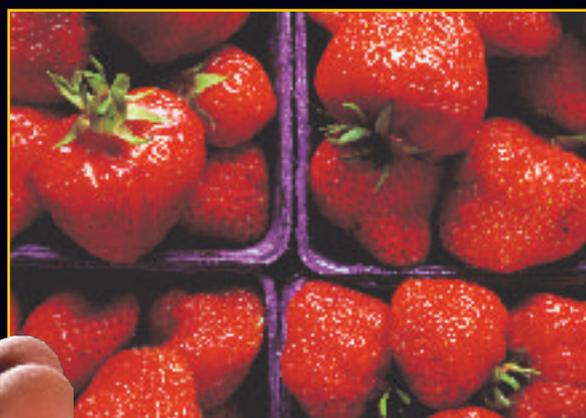
▲ **TRIPLOID** Bright yellow bananas typically come from triploid ($3n$) banana plants. Plants with an odd number of chromosome sets usually cannot reproduce sexually and have very small seeds or none at all.



▲ **TETRAPLOID** Polyploidy occurs naturally in many plants—including peanuts and daylilies—due to mistakes in mitosis or meiosis.

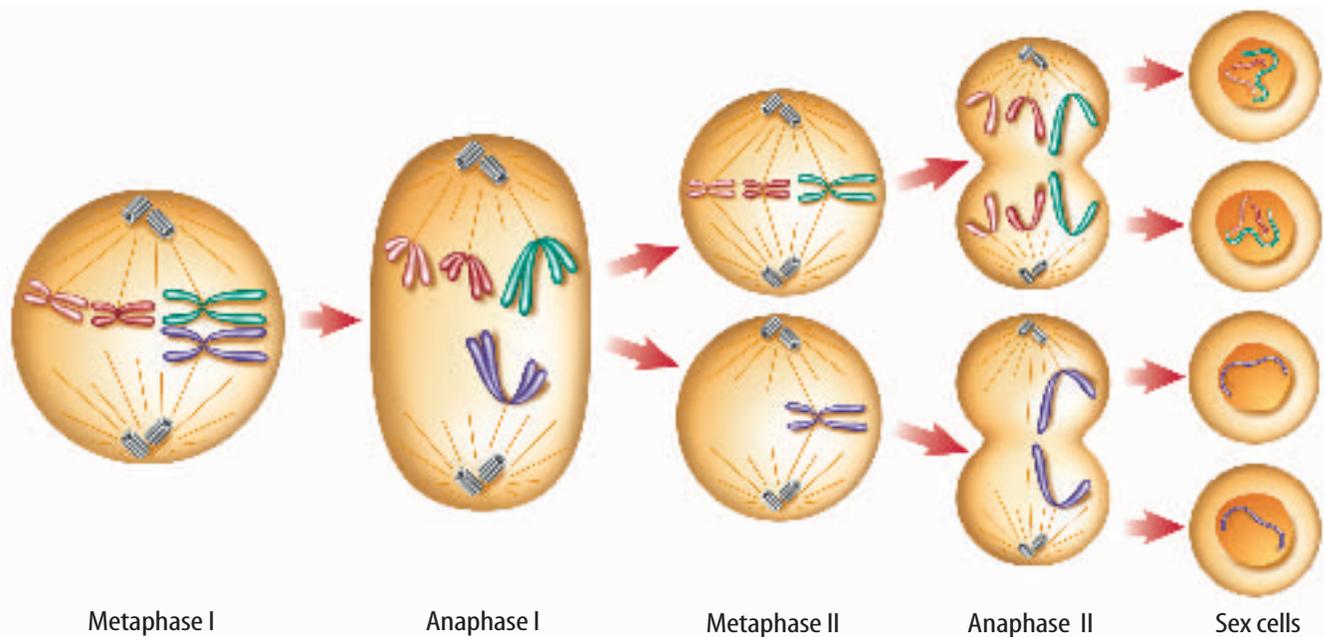


▼ **HEXAPLOID** Modern cultivated strains of oats have six sets of chromosomes, making them hexaploid ($6n$) plants.



▲ **OCTAPLOID** Polyploid plants often are bigger than nonpolyploid plants and may have especially large leaves, flowers, or fruits. Strawberries are an example of octaploid ($8n$) plants.





Mistakes in Meiosis Meiosis occurs many times in reproductive organs. Although mistakes in plants, as shown in **Figure 12**, are common, mistakes are less common in animals. These mistakes can produce sex cells with too many or too few chromosomes, as shown in **Figure 13**. Sometimes, zygotes produced from these sex cells die. If the zygote lives, every cell in the organism that grows from that zygote usually will have the wrong number of chromosomes. Organisms with the wrong number of chromosomes may not grow normally.

Figure 13 This diploid cell has four chromosomes. During anaphase I, one pair of duplicated chromosomes did not separate. **Infer** how many chromosomes each sex cell usually has.

section 2 review

Summary

Sexual Reproduction

- During sexual reproduction, two sex cells come together.
- Cell division begins after fertilization.
- A typical human body cell has 46 chromosomes, and a human sex cell has 23 chromosomes.

Meiosis and Sex Cells

- Each chromosome is duplicated before meiosis, then two divisions of the nucleus occur.
- During meiosis I, duplicated chromosomes are separated into new cells.
- Chromatids separate during meiosis II.
- Meiosis I and meiosis II result in four sex cells.

Self Check

1. **Describe** a zygote and how it is formed.
2. **Explain** where sex cells form.
3. **Compare** what happens to chromosomes during anaphase I and anaphase II.
4. **Think Critically** Plants grown from runners and leaf cuttings have the same traits as the parent plant. Plants grown from seeds can vary from the parent plants in many ways. Why can this happen?

Applying Skills

5. **Make and use a table** to compare mitosis and meiosis in humans. Vertical headings should include: *What Type of Cell (Body or Sex)*, *Beginning Cell (Haploid or Diploid)*, *Number of Cells Produced*, *End-Product Cell (Haploid or Diploid)*, and *Number of Chromosomes in New Cells*.

as you read

What You'll Learn

- **Identify** the parts of a DNA molecule and its structure.
- **Explain** how DNA copies itself.
- **Describe** the structure and function of each kind of RNA.

Why It's Important

DNA helps determine nearly everything your body is and does.

Review Vocabulary

heredity: the passing of traits from parents to offspring

New Vocabulary

- DNA
- RNA
- gene
- mutation

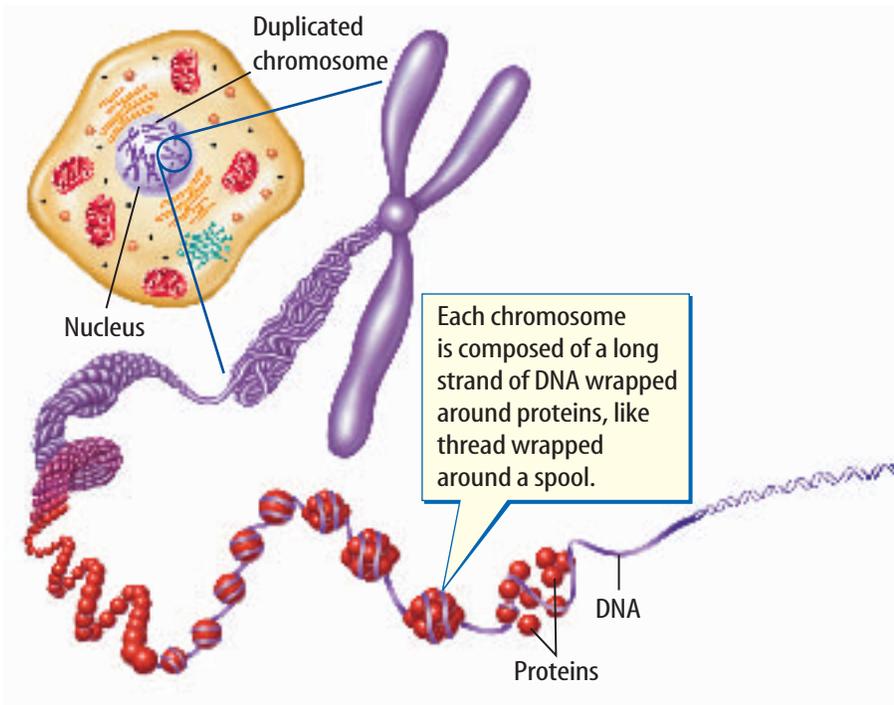
What is DNA?

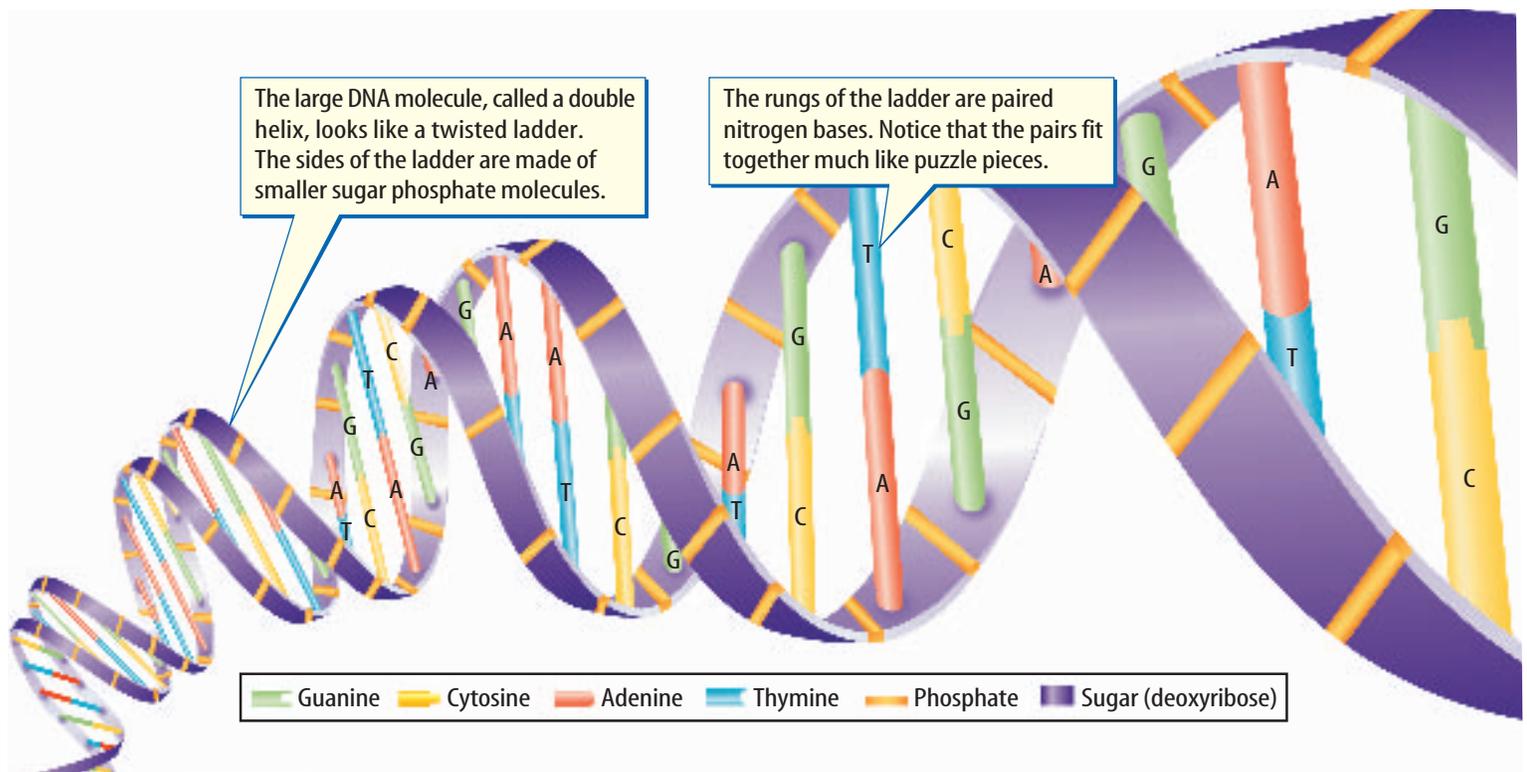
Why was the alphabet one of the first things you learned when you started school? Letters are a code that you need to know before you learn to read. A cell also uses a code that is stored in its hereditary material. The code is a chemical called deoxyribonucleic (dee AHK sih ri boh noo klay ihk) acid, or **DNA**. It contains information for an organism's growth and function. **Figure 14** shows how DNA is stored in cells that have a nucleus. When a cell divides, the DNA code is copied and passed to the new cells. In this way, new cells receive the same coded information that was in the original cell. Every cell that has ever been formed in your body or in any other organism contains DNA.



Discovering DNA Since the mid-1800s, scientists have known that the nuclei of cells contain large molecules called nucleic acids. By 1950, chemists had learned what the nucleic acid DNA was made of, but they didn't understand how the parts of DNA were arranged.

Figure 14 DNA is part of the chromosomes found in a cell's nucleus.





DNA's Structure In 1952, scientist Rosalind Franklin discovered that DNA is two chains of molecules in a spiral form. By using an X-ray technique, Dr. Franklin showed that the large spiral was probably made up of two spirals. As it turned out, the structure of DNA is similar to a twisted ladder. In 1953, using the work of Franklin and others, scientists James Watson and Francis Crick made a model of a DNA molecule.

A DNA Model What does DNA look like? According to the Watson and Crick DNA model, each side of the ladder is made up of sugar-phosphate molecules. Each molecule consists of the sugar called deoxyribose (dee AHK sih ri boh) and a phosphate group. The rungs of the ladder are made up of other molecules called nitrogen bases. Four kinds of nitrogen bases are found in DNA—adenine (A duh neen), guanine (GWAH neen), cytosine (SI tuh seen), and thymine (THI meen). The bases are represented by the letters A, G, C, and T. The amount of cytosine in cells always equals the amount of guanine, and the amount of adenine always equals the amount of thymine. This led to the hypothesis that these bases occur as pairs in DNA. **Figure 14** shows that adenine always pairs with thymine, and guanine always pairs with cytosine. Like interlocking pieces of a puzzle, each base bonds only with its correct partner.

Reading Check

What are the nitrogen base pairs in a DNA molecule?

Mini LAB

Modeling DNA Replication

Procedure

1. Suppose you have a segment of DNA that is six nitrogen base pairs in length. On **paper**, using the letters A, T, C, and G, write a combination of six pairs, remembering that A and T are always a pair and C and G are always a pair.
2. Duplicate your segment of DNA. On paper, diagram how this happens and show the new DNA segments.

Analysis

Compare the order of bases of the original DNA to the new DNA molecules.



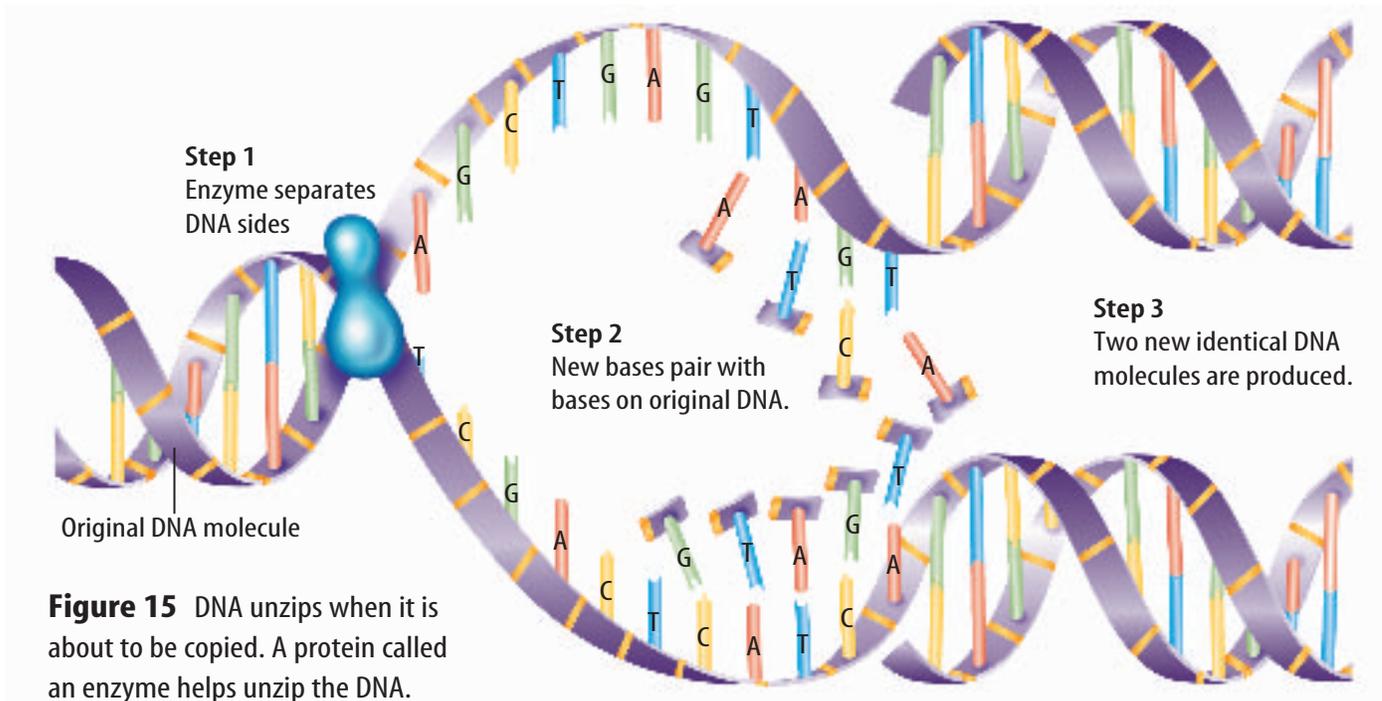
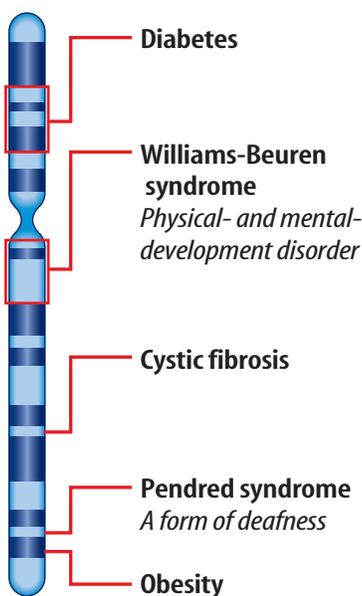


Figure 15 DNA unzips when it is about to be copied. A protein called an enzyme helps unzip the DNA.

Figure 16 This diagram shows just a few of the genes that have been identified on human chromosome 7. The bold print is the name that has been given to each gene.

Chromosome 7



Copying DNA When chromosomes are duplicated before mitosis or meiosis, the amount of DNA in the nucleus is doubled. The Watson and Crick model shows how this takes place. The two sides of DNA unwind and separate. Each side then becomes a pattern on which a new side forms, as shown in **Figure 15**. The new DNA has bases that are identical to those of the original DNA and are in the same order.

Genes

Most of your characteristics, such as the color of your hair, your height, and even how things taste to you, depend on the kinds of proteins your cells make. DNA in your cells stores the instructions for making these proteins.

Proteins build cells and tissues or work as enzymes. The instructions for making a specific protein are found in a **gene** which is a section of DNA on a chromosome. As shown in **Figure 16**, each chromosome contains hundreds of genes. Proteins are made of chains of hundreds or thousands of amino acids. The gene determines the order of amino acids in a protein. Changing the order of the amino acids makes a different protein. What might occur if an important protein couldn't be made or if the wrong protein was made in your cells?

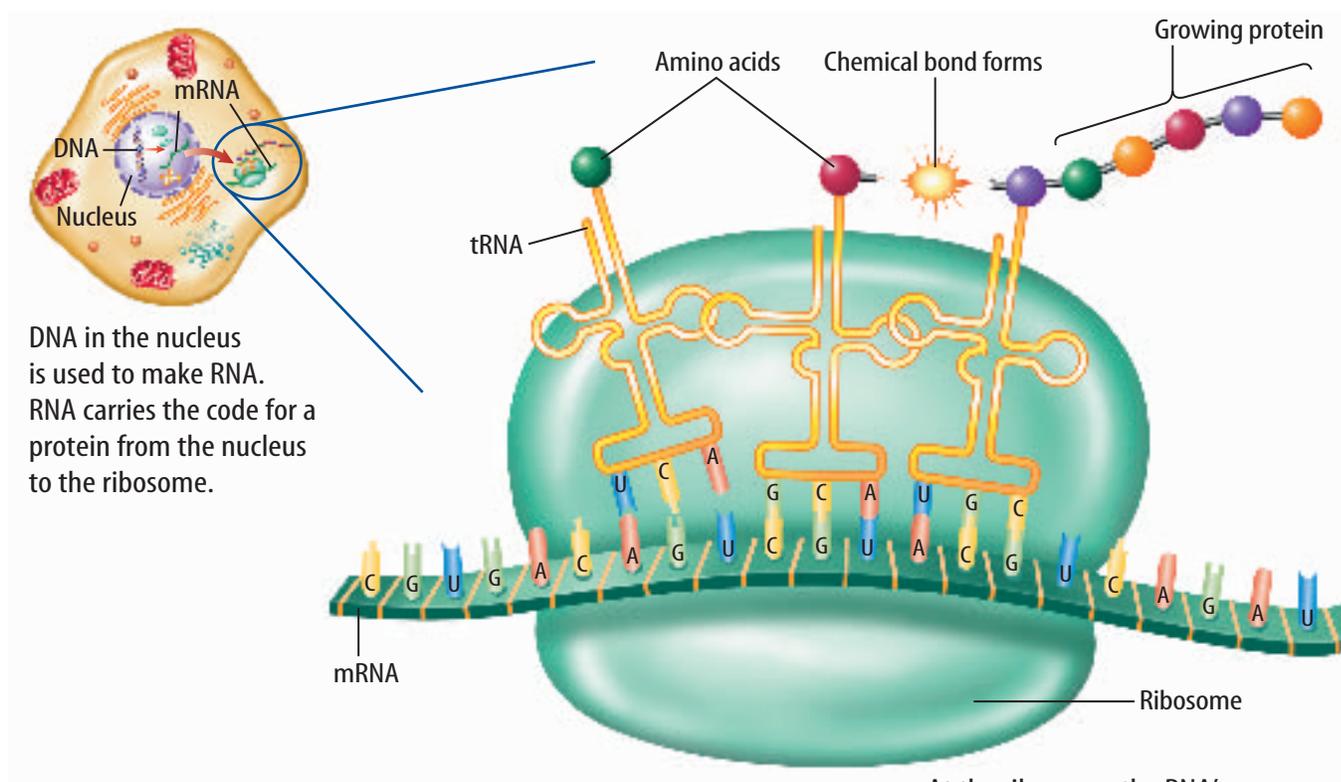
Making Proteins Genes are found in the nucleus, but proteins are made on ribosomes in cytoplasm. The codes for making proteins are carried from the nucleus to the ribosomes by another type of nucleic acid called ribonucleic acid, or **RNA**.

Ribonucleic Acid RNA is made in the nucleus on a DNA pattern. However, RNA is different from DNA. If DNA is like a ladder, RNA is like a ladder that has all its rungs sawed in half. Compare the DNA molecule in **Figure 14** to the RNA molecule in **Figure 17**. RNA has the bases A, G, and C like DNA but has the base uracil (U) instead of thymine (T). The sugar-phosphate molecules in RNA contain the sugar ribose, not deoxyribose.

The three main kinds of RNA made from DNA in a cell's nucleus are messenger RNA (mRNA), ribosomal RNA (rRNA), and transfer RNA (tRNA). Protein production begins when mRNA moves into the cytoplasm. There, ribosomes attach to it. Ribosomes are made of rRNA. Transfer RNA molecules in the cytoplasm bring amino acids to these ribosomes. Inside the ribosomes, three nitrogen bases on the mRNA temporarily match with three nitrogen bases on the tRNA. The same thing happens for the mRNA and another tRNA molecule, as shown in **Figure 17**. The amino acids that are attached to the two tRNA molecules bond. This is the beginning of a protein.

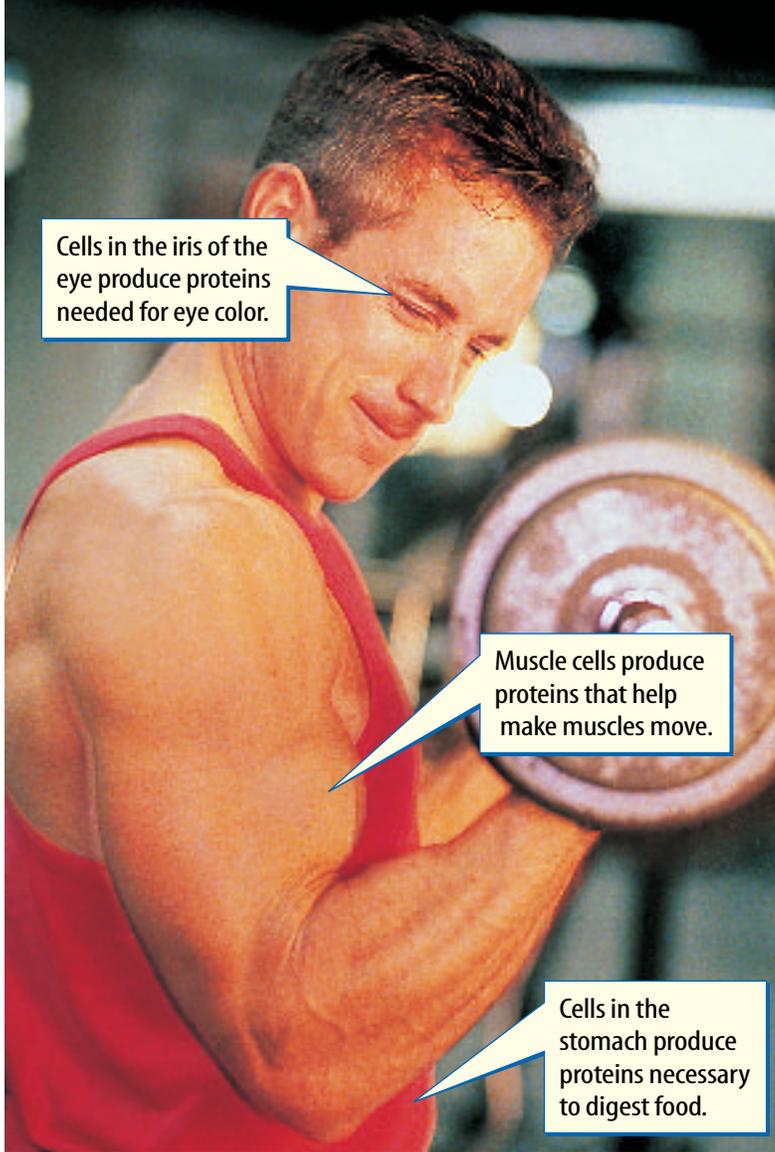
The code carried on the mRNA directs the order in which the amino acids bond. After a tRNA molecule has lost its amino acid, it can move about the cytoplasm and pick up another amino acid just like the first one. The ribosome moves along the mRNA. New tRNA molecules with amino acids match up and add amino acids to the protein molecule.

Figure 17 Cells need DNA, RNA, and amino acids to make proteins.



DNA in the nucleus is used to make RNA. RNA carries the code for a protein from the nucleus to the ribosome.

At the ribosome, the RNA's message is translated into a specific protein.



Cells in the iris of the eye produce proteins needed for eye color.

Muscle cells produce proteins that help make muscles move.

Cells in the stomach produce proteins necessary to digest food.

Controlling Genes You might think that because most cells in an organism have exactly the same chromosomes and the same genes, they would make the same proteins, but they don't. In many-celled organisms like you, each cell uses only some of the thousands of genes that it has to make proteins. Just as each actor uses only the lines from the script for his or her role, each cell uses only the genes that direct the making of proteins that it needs. For example, muscle proteins are made in muscle cells, as represented in **Figure 18**, but not in nerve cells.

Cells must be able to control genes by turning some genes off and turning other genes on. They do this in many different ways. Sometimes the DNA is twisted so tightly that no RNA can be made. Other times, chemicals bind to the DNA so that it cannot be used. If the incorrect proteins are produced, the organism cannot function properly.

Figure 18 Each cell in the body produces only the proteins that are necessary to do its job.

Mutations

Sometimes mistakes happen when DNA is being copied. Imagine that the copy of the script the director gave you was missing three pages. You use your copy to learn your lines. When you begin rehearsing for the play, everyone is ready for one of the scenes except for you. What happened? You check your copy of the script against the original and find that three of the pages are missing. Because your script is different from the others, you cannot perform your part correctly.

If DNA is not copied exactly, the proteins made from the instructions might not be made correctly. These mistakes, called **mutations**, are any permanent change in the DNA sequence of a gene or chromosome of a cell. Some mutations include cells that receive an entire extra chromosome or are missing a chromosome. Outside factors such as X rays, sunlight, and some chemicals have been known to cause mutations.



Reading Check

When are mutations likely to occur?

Figure 19 Because of a defect on chromosome 2, the mutant fruit fly has short wings and cannot fly.

Predict Could this defect be transferred to the mutant's offspring? Explain.



Results of a Mutation Genes control the traits you inherit. Without correctly coded proteins, an organism can't grow, repair, or maintain itself. A change in a gene or chromosome can change the traits of an organism, as illustrated in **Figure 19**.

If the mutation occurs in a body cell, it might or might not be life threatening to the organism. However, if a mutation occurs in a sex cell, then all the cells that are formed from that sex cell will have that mutation. Mutations add variety to a species when the organism reproduces. Many mutations are harmful to organisms, often causing their death. Some mutations do not appear to have any effect on the organism, and some can even be beneficial. For example, a mutation to a plant might cause it to produce a chemical that certain insects avoid. If these insects normally eat the plant, the mutation will help the plant survive.

Scienceonline

Topic: Fruit Fly Genes

Visit booka.msscience.com for Web links to information about what genes are present on the chromosomes of a fruit fly.

Activity Draw a picture of one of the chromosomes of a fruit fly and label some of its genes.

section **3** review

Summary

What is DNA?

- Each side of the DNA ladder is made up of sugar-phosphate molecules, and the rungs of the ladder are made up of nitrogenous bases.
- When DNA is copied, the new DNA has bases that are identical to those of the original DNA.

Genes

- The instructions for making a specific protein are found in genes in the cell nucleus. Proteins are made on ribosomes in the cytoplasm.
- There are three main kinds of RNA—mRNA, rRNA, and tRNA.

Mutations

- If DNA is not copied exactly, the resulting mutations may cause proteins to be made incorrectly.

Self Check

1. **Describe** how DNA makes a copy of itself.
2. **Explain** how the codes for proteins are carried from the nucleus to the ribosomes.
3. **Apply** A strand of DNA has the bases AGTAAC. Using letters, show a matching DNA strand.
4. **Determine** how tRNA is used when cells build proteins.
5. **Think Critically** You begin as one cell. Compare the DNA in your brain cells to the DNA in your heart cells.

Applying Skills

6. **Concept Map** Using a Venn diagram, compare and contrast DNA and RNA.
7. **Use a word processor** to make an outline of the events that led up to the discovery of DNA. Use library resources to find this information.

Mutations

Real-World Question

Mutations can result in dominant or recessive genes. A recessive characteristic can appear only if an organism has two recessive genes for that characteristic. However, a dominant characteristic can appear if an organism has one or two dominant genes for that characteristic. Why do some mutations result in more common traits while others do not? Form a hypothesis about how a mutation can become a common trait.

Make a Plan

- 1. Observe** common traits in various animals, such as household pets or animals you might see in a zoo.
- 2. Learn** what genes carry these traits in each animal.
- 3. Research** the traits to discover which ones are results of mutations. Are all mutations dominant? Are any of these mutations beneficial?



Fantail pigeon

Goals

- **Observe** traits of various animals.
- **Research** how mutations become traits.
- Gather data about mutations.
- Make a frequency table of your findings and communicate them to other students.

Data Source



Visit booka.msscience.com/internet_lab for more information on common genetic traits in different animals, recessive and dominant genes, and data from other students.



White tiger

Using Scientific Methods

Follow Your Plan

1. Make sure your teacher approves your plan before you start.
2. Visit the link shown below to access different Web sites for information about mutations and genetics.
3. **Decide** if a mutation is beneficial, harmful, or neither. Record your data in your Science Journal.

Analyze Your Data

1. **Record** in your Science Journal a list of traits that are results of mutations.
2. **Describe** an animal, such as a pet or an animal you've seen in the zoo. Point out which traits are known to be the result of a mutation.
3. **Make** a chart that compares recessive mutations to dominant mutations. Which are more common?
4. **Share** your data with other students by posting it at the link shown below.



Siberian Husky's eyes

Conclude and Apply

1. **Compare** your findings to those of your classmates and other data at the link shown below. What were some of the traits your classmates found that you did not? Which were the most common?
2. Look at your chart of mutations. Are all mutations beneficial? When might a mutation be harmful to an organism?
3. **Predict** how your data would be affected if you had performed this lab when one of these common mutations first appeared. Do you think you would see more or less animals with this trait?
4. Mutations occur every day but we only see a few of them. Infer how many mutations over millions of years can lead to a new species.

Communicating Your Data

Find this lab using the link below. **Post** your data in the table provided. Combine your data with that of other students and make a chart that shows all of the data.

Scienceonline

booka.msscience.com/internet_lab



Accidents in SCIENCE

**SOMETIMES
GREAT
DISCOVERIES
HAPPEN BY
ACCIDENT!**

A Tangled Tale

How did a scientist get chromosomes to separate?



Thanks to chromosomes, each of us is unique!

Viewed under the microscope, chromosomes in cells sometimes look a lot like spaghetti. That's why scientists had such a hard time figuring out how many chromosomes are in each human cell. Imagine, then, how Dr. Tao-Chiu Hsu (dow shew•SEW) must have felt when he looked into a microscope and saw "beautifully scattered chromosomes." The problem was, Hsu didn't know what he had done to separate the chromosomes into countable strands.

"I tried to study those slides and set up some more cultures to repeat the miracle," Hsu explained. "But nothing happened."

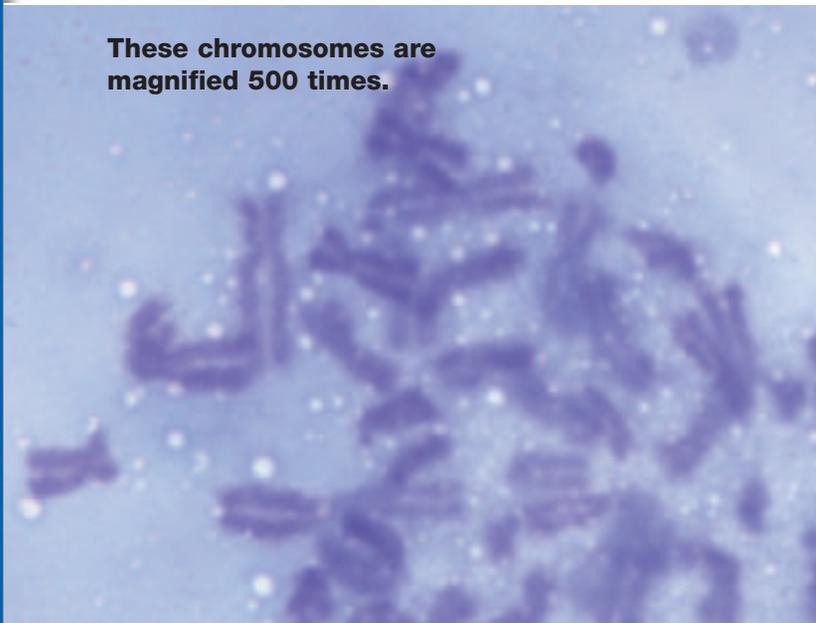
For three months Hsu tried changing every variable he could think of to make the chromosomes separate again. In April 1952, his efforts were finally rewarded. Hsu quickly realized that the chromosomes separated because of osmosis.

Osmosis is the movement of water molecules through cell membranes. This movement occurs in predictable ways. The water molecules move from areas with higher concentrations of water to areas with lower concentrations of water. In Hsu's case, the solution he used to prepare the cells had a

higher concentration of water than the cell did. So water moved from the solution into the cell and the cell swelled until it finally exploded. The chromosomes suddenly were visible as separate strands.

What made the cells swell the first time? Apparently a technician had mixed the solution incorrectly. "Since nearly four months had elapsed, there was no way to trace who actually had prepared that particular [solution]," Hsu noted. "Therefore, this heroine must remain anonymous."

These chromosomes are magnified 500 times.



Research What developments led scientists to conclude that the human cell has 46 chromosomes? Visit the link shown to the right to get started.

Science  **online**

For more information, visit booka.msscience.com/oops

Reviewing Main Ideas

Section 1 Cell Division and Mitosis

1. The life cycle of a cell has two parts—growth and development, and cell division.
2. In mitosis, the nucleus divides to form two identical nuclei. Mitosis occurs in four continuous steps, or phases—prophase, metaphase, anaphase, and telophase.
3. Cell division in animal cells and plant cells is similar, but plant cells do not have centrioles and animal cells do not form cell walls.
4. Organisms use cell division to grow, to replace cells, and for asexual reproduction. Asexual reproduction produces organisms with DNA identical to the parent's DNA. Fission, budding, and regeneration can be used for asexual reproduction.

Section 2 Sexual Reproduction and Meiosis

1. Sexual reproduction results when an egg and sperm join. This event is called fertilization, and the cell that forms is called the zygote.

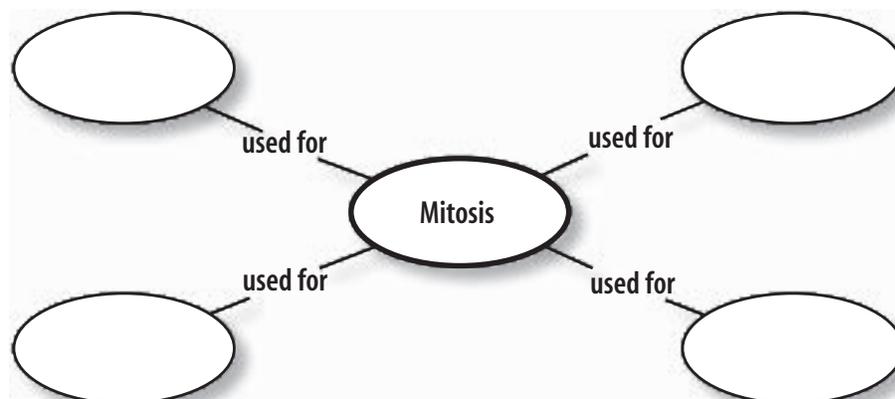
2. Meiosis occurs in the reproductive organs, producing four haploid sex cells.
3. During meiosis, two divisions of the nucleus occur.
4. Meiosis ensures that offspring produced by fertilization have the same number of chromosomes as their parents.

Section 3 DNA

1. DNA is a large molecule made up of two twisted strands of sugar-phosphate molecules and nitrogen bases.
2. All cells contain DNA. The section of DNA on a chromosome that directs the making of a specific protein is a gene.
3. DNA can copy itself and is the pattern from which RNA is made. Messenger RNA, ribosomal RNA, and transfer RNA are used to make proteins.
4. Permanent changes in DNA are called mutations.

Visualizing Main Ideas

Think of four ways that organisms can use mitosis. Copy and complete the spider diagram below.



Using Vocabulary

asexual reproduction p. 103	haploid p. 107
chromosome p. 100	meiosis p. 107
diploid p. 106	mitosis p. 100
DNA p. 112	mutation p. 116
egg p. 106	RNA p. 114
fertilization p. 106	sexual reproduction p. 106
gene p. 114	sperm p. 106
	zygote p. 106

Fill in the blanks with the correct vocabulary word or words.

- _____ and _____ cells are sex cells.
- _____ produces two identical cells.
- An example of a nucleic acid is _____.
- A(n) _____ is the code for a protein.
- A(n) _____ sperm is formed during meiosis.
- Budding is a type of _____.
- A(n) _____ is a structure in the nucleus that contains hereditary material.
- _____ produces four sex cells.
- As a result of _____, a new organism develops that has its own unique identity.
- An error made during the copying of DNA is called a(n) _____.

Checking Concepts

Choose the word or phrase that best answers the question.

- Which of the following is a double spiral molecule with pairs of nitrogen bases?

A) RNA	C) protein
B) amino acid	D) DNA

- What is in RNA but not in DNA?

A) thymine	C) adenine
B) thyrod	D) uracil
- If a diploid tomato cell has 24 chromosomes, how many chromosomes will the tomato's sex cells have?

A) 6	C) 24
B) 12	D) 48
- During a cell's life cycle, when do chromosomes duplicate?

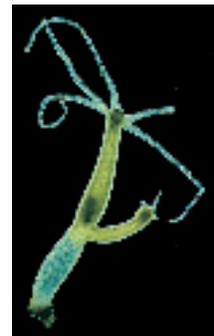
A) anaphase	C) interphase
B) metaphase	D) telophase
- When do chromatids separate during mitosis?

A) anaphase	C) metaphase
B) prophase	D) telophase
- How is the hydra shown in the picture reproducing?

A) asexually, by budding
B) sexually, by budding
C) asexually, by fission
D) sexually, by fission
- What is any permanent change in a gene or a chromosome called?

A) fission	C) replication
B) reproduction	D) mutation
- What does meiosis produce?

A) cells with the diploid chromosome number
B) cells with identical chromosomes
C) sex cells
D) a zygote



- What type of nucleic acid carries the codes for making proteins from the nucleus to the ribosome?

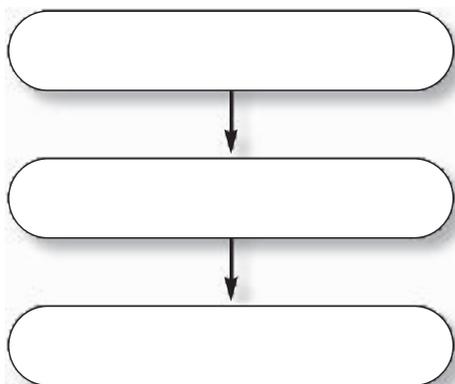
A) DNA	C) protein
B) RNA	D) genes

Thinking Critically

- 20. **List** the base sequence of a strand of RNA made using the DNA pattern ATCCGTC. Look at **Figure 14** for a hint.
- 21. **Predict** whether a mutation in a human skin cell can be passed on to the person's offspring. Explain.
- 22. **Explain** how a zygote could end up with an extra chromosome.
- 23. **Classify** Copy and complete this table about DNA and RNA.

DNA and RNA		
	DNA	RNA
Number of strands		
Type of sugar	Do not write in this book.	
Letter names of bases		
Where found		

- 24. **Concept Map** Make an events-chain concept map of what occurs from interphase in the parent cell to the formation of the zygote. Tell whether the chromosome's number at each stage is haploid or diploid.
- 25. **Concept Map** Copy and complete the events-chain concept map of DNA synthesis.



- 26. **Compare and Contrast** Meiosis is two divisions of a reproductive cell's nucleus. It occurs in a continuous series of steps. Compare and contrast the steps of meiosis I to the steps of meiosis II.
- 27. **Describe** what occurs in mitosis that gives the new cells identical DNA.
- 28. **Form a hypothesis** about the effect of an incorrect mitotic division on the new cells produced.
- 29. **Determine** how many chromosomes are in the original cell compared to those in the new cells formed by cell division. Explain.

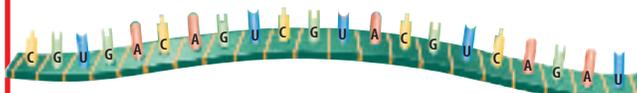
Performance Activities

- 30. **Flash Cards** Make a set of 11 flash cards with drawings of a cell that show the different stages of meiosis. Shuffle your cards and then put them in the correct order. Give them to another student in the class to try.

Applying Math

- 31. **Cell Cycle** Assume an average human cell has a cell cycle of 20 hours. Calculate how many cells there would be after 80 hours.

Use the diagram below to answer question 32.



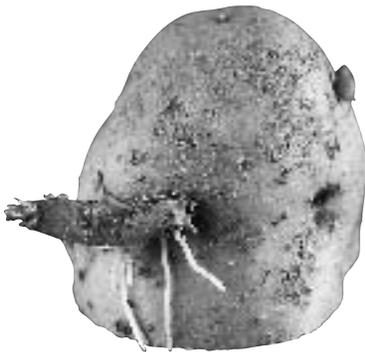
- 32. **Amino Acids** Sets of three nitrogen bases code for an amino acid. How many amino acids will make up the protein molecule that is coded for by the mRNA molecule above?

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

- What stage of the cell cycle involves growth and function?
 - A. prophase
 - B. interphase
 - C. mitosis
 - D. cytoplasmic division
- During interphase, which structure of a cell is duplicated?
 - A. cell plate
 - B. mitochondrion
 - C. chromosome
 - D. chloroplast

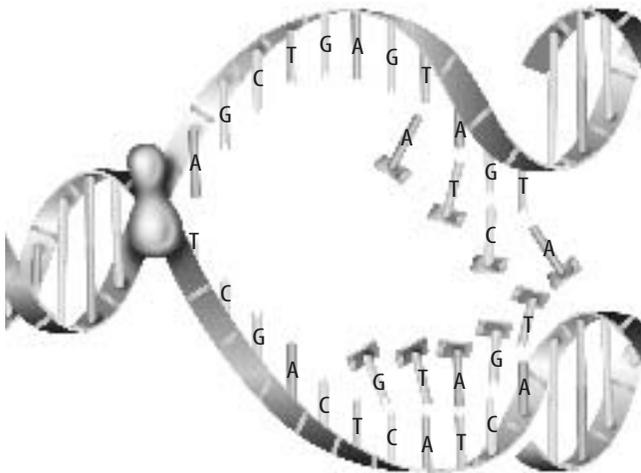
Use the figure below to answer questions 3 and 4.



- What form of asexual reproduction is shown here?
 - A. regeneration
 - B. cell division
 - C. sprouting
 - D. meiosis
- How does the genetic material of the new organism above compare to that of the parent organism?
 - A. It is exactly the same.
 - B. It is a little different.
 - C. It is completely different.
 - D. It is haploid.
- Organisms with three or more sets of chromosomes are called
 - A. monoploid.
 - B. diploid.
 - C. haploid.
 - D. polyploid.

- If a sex cell has eight chromosomes, how many chromosomes will there be after fertilization?
 - A. 8
 - B. 16
 - C. 32
 - D. 64

Use the diagram below to answer questions 7 and 8.



- What does this diagram illustrate?
 - A. DNA duplication
 - B. RNA
 - C. cell reproduction
 - D. RNA synthesis
- When does the process shown occur in the cell cycle?
 - A. prophase
 - B. metaphase
 - C. interphase
 - D. anaphase
- Proteins are made of
 - A. genes
 - B. bases
 - C. amino acids
 - D. chromosomes

Test-Taking Tip

Prepare Avoid rushing on test day. Prepare your clothes and test supplies the night before. Wake up early and arrive at school on time on test day.

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

- In the human body, which cells are constantly dividing? Why is this important? How can this be potentially harmful?
- Arrange the following terms in the correct order: *fertilization, sex cells, meiosis, zygote, mitosis*.
- What are the three types of RNA used during protein synthesis? What is the function of each type of RNA?
- Describe the relationship between gene, protein, DNA and chromosome.

Use the table below to answer question 14.

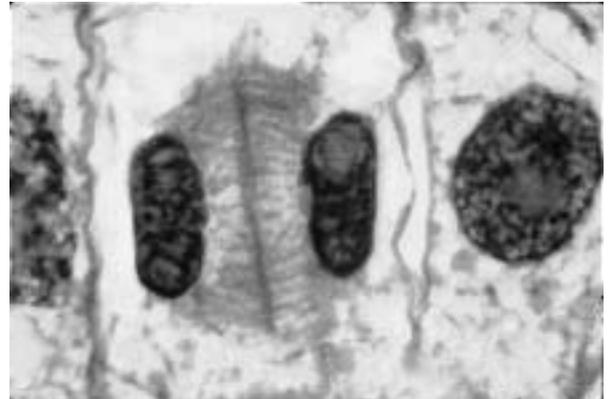
Phase of Cell Cycle	Action within the Cell
	Chromosomes duplicate
Prophase	
Metaphase	
	Chromosomes have separated
Telophase	

- Fill in the blanks in the table with the appropriate term or definition.
- What types of cells would constantly be in interphase?
- Why is regeneration important for some organisms? In what way could regeneration of nerve cells be beneficial for humans?
- What types of organisms are polyploidy? Why are they important?
- What happens to chromosomes in meiosis I and meiosis II?
- Describe several different ways that organisms can reproduce.

Part 3 Open Ended

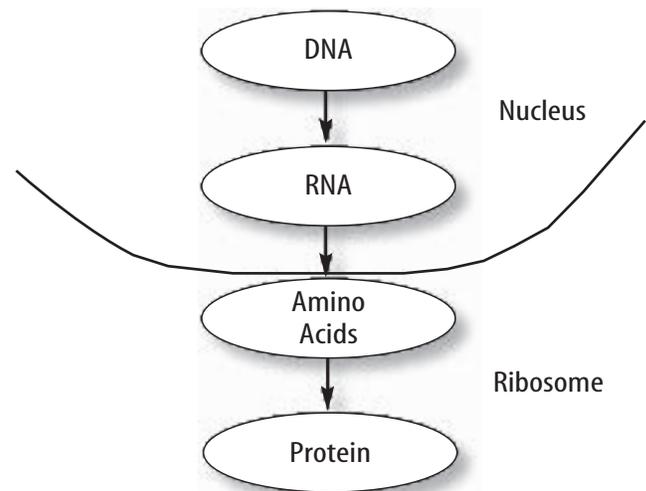
Record your answers on a sheet of paper.

Use the photo below to answer question 20.



- Is this a plant or an animal cell? Compare and contrast animal and plant cell division.
- Describe in detail the structure of DNA.

Use the diagram below to answer question 22.



- Discuss in detail what is taking place at each step of protein synthesis diagrammed above.
- If a skin cell and a stomach cell have the same DNA then why are they so different?
- What is mutation? Give examples where mutations could be harmful, beneficial or neutral.