CHAPTER

2

Cell Growth and Reproduction

KEY IDEAS

- The functions of cell division are growth, repair, and reproduction.
- DNA in the nucleus plays a key role in normal cell functions and in cell division.
- The cell cycle includes the normal cell functions and cell division.
- Mutations in a cell's DNA can cause diseases, including cancer.
- Some organisms reproduce asexually through cell division.

Chapter Preview

Think about how you and your friends have changed over the last year. Have you or one of your friends had a growth spurt? Why hasn't everyone grown the same amount? Every living thing grows, but not at the same rate. What causes these differences in growth? Why don't you grow to the same size as the blue whale? Is there something that determines the characteristics of all organisms, including growth rates? Cell division is necessary for growth. Just like you and your friends, the blue whale and other giants on Earth, such as the Douglas fir tree, are made of cells. How old are their cells? Cell division replaces old cells. Do animal cells divide the same way that plant cells do? What directs a muscle cell to contract or a leaf cell to perform photosynthesis? Why are some types of cells more abundant than other types?

In this chapter, you will learn about deoxyribonucleic acid (DNA), the molecule that carries the instructions for cell division and determines the characteristics of cells, individuals, and species. You will also learn about the cellular basis of growth and repair. Organisms increase in size through cell division. Dead and damaged cells are replaced by cell division. Some organisms even reproduce entirely using cell division.

TRY THIS: Replacing Cells

Skills Focus: predicting, observing, measuring, recording

Materials: permanent marker

You lose millions of skin cells through daily wear and tear. These cells are constantly replaced.

1. Use the permanent marker to place a dot of ink on the back of your hand and on the palm of the same hand. The skin cells that absorb the ink will be permanently stained, since the ink is not water-soluble.
2. Predict which stain—the stain on your palm or the stain on the back of your hand—will disappear first. Record your prediction.
3. Observe the stained areas daily. Record your observations.

A. Explain your observations.

Do not use permanent markers if you may be allergic to the ink. Use food colouring instead. Use caution with the marker and food colouring, as they can stain clothing.

2.1 The Importance of Cell Division

Have you ever peeled away the dead skin from a sunburn or a blister? What would you look like if every cut or scratch on your skin remained? Imagine the condition of your skin if dead skin cells were not replaced by new cells. Recall from Grade 8 science that new cells arise from pre-existing cells. Damaged cells are replaced through the process of cell division. Throughout your life, your body will undergo cell division to replace damaged or dead cells. Cell division slows down as you age, but it never entirely stops until you die.

Figure 1 Like all living things, humans grow throughout most of their life. Cell division allows living things to grow larger.

Functions of Cell Division

There are three main functions of cell division: growth, repair, and reproductio

Growth

All living things are composed of one or more cells. All organisms begin lif as a single cell. Multicellular organisms, such as dogwood trees and human undergo cell division to increase their size. Why don't cells simply increase size to grow? Recall from Grade 8 science that there are limits to the size of cell. As a cell grows, the volume of the cytoplasm increases at a greater rate than the surface area of the cell. Once a cell grows beyond a certain size, it cannot function efficiently. It has to divide into two smaller cells that will perform the same functions. Thus, to increase in size (grow), a multicellul organism has to use cell division. In a multicellular organism, after the bo has a certain number of cells, the cells begin to specialize and form tissues and organs (Figure 1).

Repair

Multicellular organisms repair damaged cells by cell division. You do not go through life with the same cells you started with at birth. Old and dead cells are replaced every second as millions of your approximately 100 trillion cells are damaged through normal body activities. This replacement of cells also occurs in other multicellular organisms. Look at a tree where a branch has been cut off. The inner cells of the bark divide to produce new bark tissue, which covers and protects the damaged cells where the branch was cut off (Figure 2).

(a)

(b)

Figure 2 Both animals (a) and plants (b cell division to grow new cells over a cu else would plants grow new cells to rep damaged cells?

Reproduction

Unicellular organisms, such as a paramecium, use cell division to reproduce (Figure 3). A single-celled bacterium uses cell division to form two identical bacteria. These new cells contain the same structures and carry out the same functions as the parent cell. Some multicellular organisms, such as a mushroom, also reproduce by cell division. You will learn more about cell division and reproduction in Section 2.6.

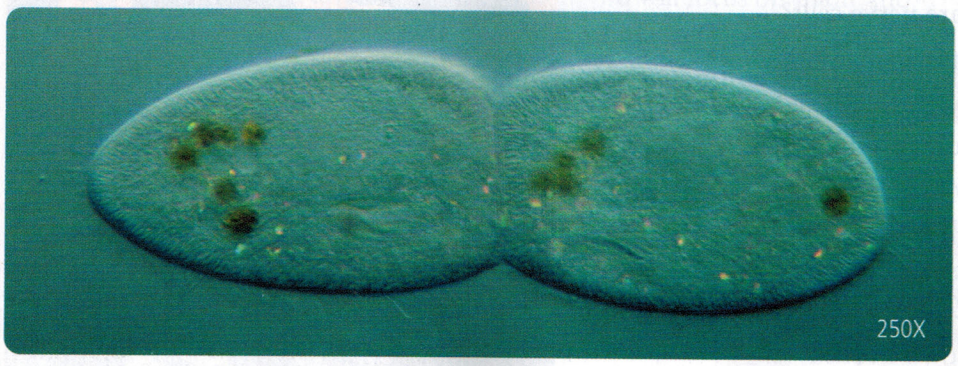


Figure 3 This single-celled paramecium is reproducing itself by cell division.

The process of cell division raises many questions. Why do some cells reproduce at different rates at different times? Skin cells can reproduce quickly to form calluses on your hands after a few hours of raking leaves or paddling a canoe. Why do fertilized eggs and bone marrow cells divide quickly whereas red blood cells are unable to divide at all? Why do cancer cells divide out of control? A great deal has been discovered through advances in technology, but there is much more to learn.

Did You KNOW?

Cell Lifespan

Human red blood cells live for approximately four months, whereas white blood cells live anywhere from less than one day to 10 years.

TRY THIS: From One Cell to Trillions

Skills Focus: recording, analyzing, predicting

Materials: calculator

The human body contains trillions of cells. They all came from a single cell. In this activity, you will investigate the number of cell divisions needed to form a human body.

Table 1

Number of divisions	Number of cells
0	1
1	2
2	4
3	

1. Copy Table 1 into your notebook, and complete it to help you answer the questions.
2. Calculate the number of cells after three, four, and five cell divisions.

A. How does the number of cells that are produced relate to the number of cell divisions that occur?

B. How many cells would there be after 25 cell divisions?

C. Make a prediction: How many cell divisions are needed to produce more than a trillion cells?

2.1 CHECK YOUR Understanding

1. Give three reasons why cells divide.
2. Explain how cell division is responsible for growth.
3. Why might scientists want to figure out a way to promote cell division in mature nerve cells?
4. Why do skin cells reproduce faster than other types of cells?
5. Give a location, other than human skin, where cells might reproduce quickly.
6. What evidence is there that all cells in your body do not reproduce at the same rate?
7. Examine the photographs in Figure 5. What function of cell division is shown in each photograph?

(a)

(b)

(c)

(d)

Figure 5

8. Doctors once transfused blood from young people into elderly people, believing that the younger blood would provide the elderly people with more energy. Do elderly people actually have older blood? Explain your answer.
9. Why do you think skin cells divide faster than muscle cells?
10. Do all cells undergo cell division? Give an example of cells that do not.
11. Explain why cells can only grow to a limited size.
12. Do larger organisms have larger cells? Explain.
13. List two organisms that use cell division to reproduce.
14. A colony of bacteria has 12 cells. Assuming that each cell divides and no cells die, how many cells would there be after six divisions?

2.2 Cell Structures Involved in Cell Division

Recall, from Grade 8 science, that cells are either eukaryotic (have a nucleus surrounded by a membrane) or prokaryotic (have no nucleus). Plants, animals, fungi, and protists have eukaryotic cells, and bacteria have prokaryotic cells. Both types of cells undergo cell division. In this section, you will focus on plant and animal cells. Although all the cell structures in animal cells (Figure 1(b)) and plant cells (Figure 2) are reproduced during cell division, some structures play a more active role than others. Before you look at the process of cell division, you need to look at the cell structures that have a role in cell division.

LEARNING TIP

Stop and think. As you look at each of the diagrams in this section, ask yourself, "What is the purpose of this diagram? How is it connected to other information on the page? How do the words in bold type help me interpret it?"

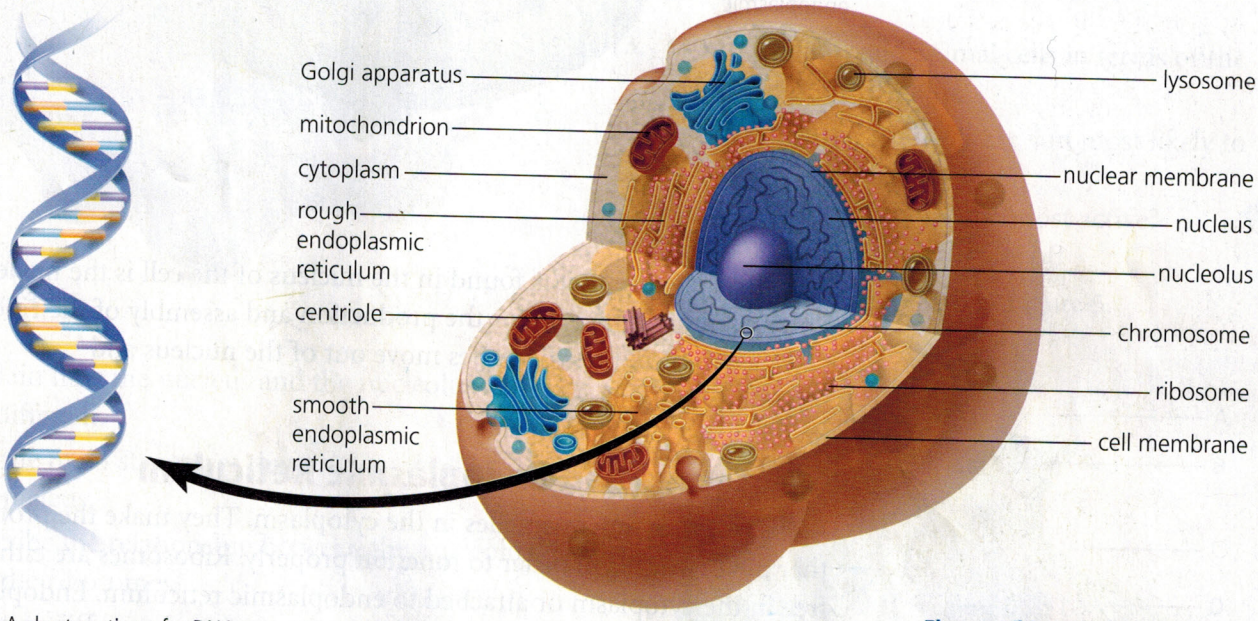


Figure 1(a) A short section of a DNA molecule, which makes up a chromosome

Figure 1(b) Animal cell structures

The Nucleus

The nucleus acts as the control centre of the cell. It directs all cell activities, including cell division. The nucleus is surrounded by the nuclear membrane. The **nuclear membrane** allows some materials to pass into and out of the nucleus. The nucleus contains several structures that allow it to perform its functions.

Chromosomes

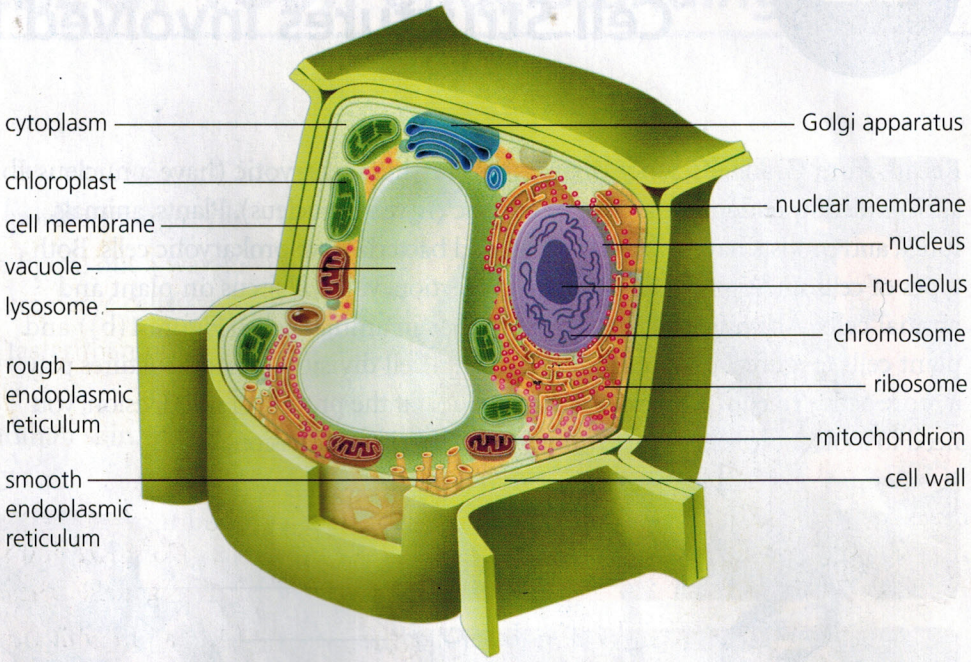
The material that directs all the activities of the cell is contained in the nucleus, in structures called chromosomes. Practically all human cells have 23 pairs of chromosomes. Chromosomes are made of **DNA** (deoxyribonucleic acid) and protein. DNA is a very long molecule that looks like a twisted ladder (Figure 1(a)). Each chromosome is made of one extremely long strand of DNA. The DNA provides the directions for all the cell structures and activities, including repairing worn and damaged cells and replacing dead cells.

Did You KNOW?

Chromosome Numbers

The number of chromosomes varies among living organisms. Humans have 23 pairs of chromosomes in each body cell, goldfish have 47 pairs, crayfish have 100 pairs, fruit flies have 4 pairs, and both dogs and chickens have 39 pairs.

Figure 2 Plant cell structures



Nucleolus

Another structure that is found in the nucleus of the cell is the nucleolus. The **nucleolus** is the site for the production and assembly of the ribosomes. Once assembled, the ribosomes move out of the nucleus and into the cytoplasm.

Ribosomes and Endoplasmic Reticulum

Ribosomes are tiny organelles in the cytoplasm. They make the proteins that the cell needs in order to function properly. Ribosomes are either free in the cytoplasm or attached to endoplasmic reticulum. Endoplasmic reticulum (ER) is a series of tubes and flattened sacs that transport materials throughout the cell. Endoplasmic reticulum that has ribosomes attached is called rough ER. Rough ER transports proteins throughout the cell. Endoplasmic reticulum that has no ribosomes attached is called smooth ER. Smooth ER manufactures and transports fats in the cell.

Cytoplasm

Inside the cell membrane is the cytoplasm, which contains all the organelles in the cell. Most of the cell's activities occur in the cytoplasm, and nutrients are absorbed, transported, and processed here. Inside the cytoplasm are tiny tubes called microtubules. Microtubules allow movement of the organelles within the cell and provide support for the cell. **Centrioles** (Figure 1(b)) are organelles that are made of special microtubules. They are found in almost all animal cells, and they are active during cell division.

If you would like to learn more about cell structures, go to **www.science.nelson.com** GO

2.2 CHECK YOUR Understanding

1. Look at Figure 3. How are the functions of the cell membrane and the nuclear membrane similar?

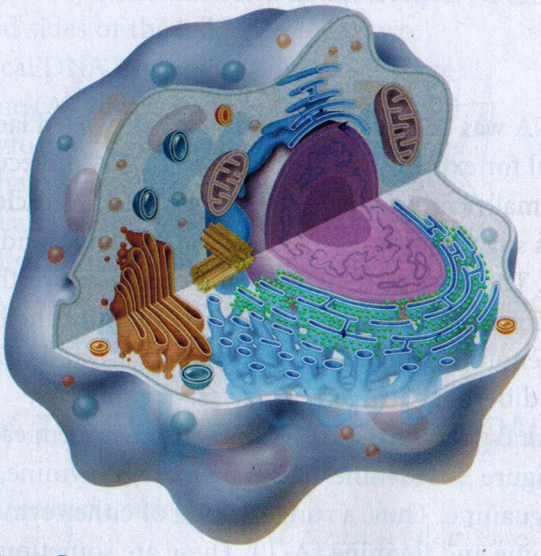


Figure 3

2. Explain how the nucleus and the nucleolus are different.
3. List the main structures that are found in the nucleus.
4. Describe the relationship between the nucleolus and the ribosomes.
5. List two different locations where ribosomes can be found.
6. How are some materials transported throughout the cell?
7. Explain the difference between rough and smooth endoplasmic reticulum.
8. What are chromosomes made of?
9. How many chromosomes are present in a normal human body cell?
10. Describe the shape of a DNA molecule.
11. Where is DNA located in the cell?
12. Identify structures A, B, and C in Figure 4.

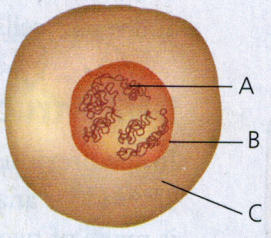


Figure 4

13. Compare plant and animal cells in terms of the organelles they contain.
14. (a) In which type of cells are you most likely to find centrioles?
    (b) When are centrioles the most active?
    (c) What are centrioles made of?
15. Identify structures A to E in Figure 5.

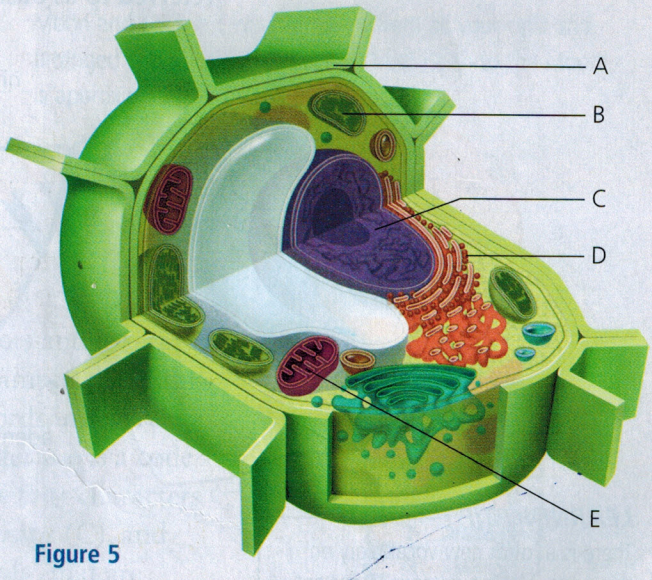


Figure 5

16. Where in a cell are the chromosomes located?
17. Describe two functions of the cytoplasm.

2.3 From DNA to Proteins

You have learned that the nucleus contains chromosomes, which contain DNA. DNA is a molecule that contains all the instructions to make, maintain, and repair cells. But how does DNA perform all these functions?

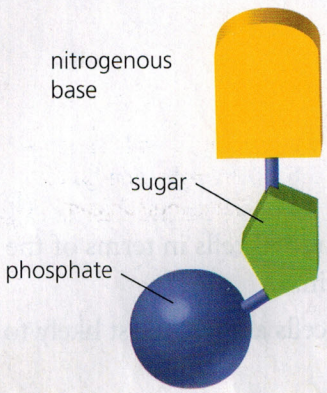


Figure 1 A nucleotide is composed of a sugar molecule, a phosphate molecule, and a nitrogenous base.

DNA Structure

In the previous section, DNA was described as looking like a twisted ladder. The ladder analogy is useful for explaining its structure. A DNA molecule is made of two strands of smaller molecules, called nucleotides. A **nucleotide** (Figure 1) is composed of a sugar molecule, a phosphate molecule, and a nitrogenous base molecule. The sides of the DNA ladder are made of the sugar and phosphate molecules joined to each other. The rungs of the ladder are made of pairs of nitrogenous bases, one from each of the strands. Each nucleotide has one of four different **nitrogenous bases**: adenine (A), thymine (T), cytosine (C), and guanine (G). Pairs of these bases form each rung of the DNA ladder (Figure 2). Adenine always pairs with thymine, and cytosine always pairs with guanine. Thus, a rung is made of either cytosine and guanine (C-G) or adenine and thymine (A-T). These are sometimes referred to as base pairs.

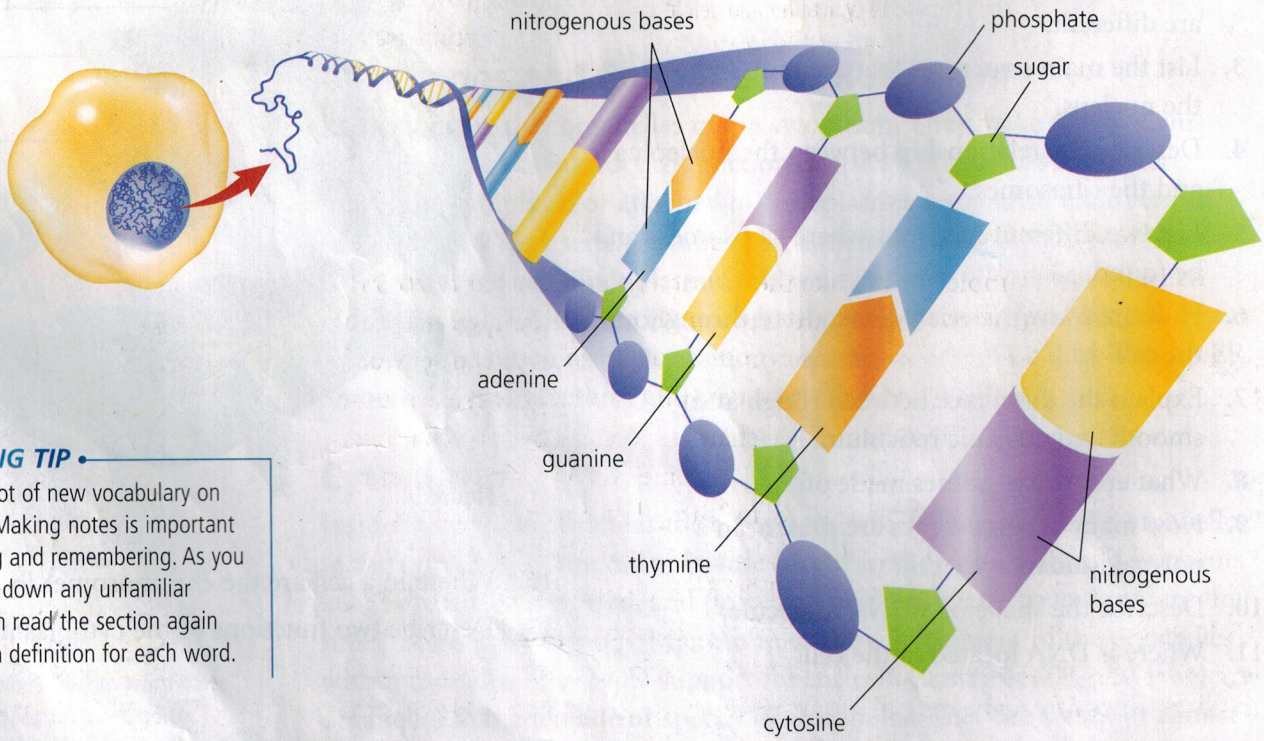


Figure 2 DNA molecules are made of two strands of nucleotides joined by their sugar and phosphate molecules and by their nitrogenous bases. The linked bases are called base pairs. A single chromosome can contain millions of base pairs.

LEARNING TIP

There is a lot of new vocabulary on this page. Making notes is important for learning and remembering. As you read, write down any unfamiliar words. Then read the section again and write a definition for each word.

One of the things that make DNA so amazing is its ability to replicate, or copy, itself. Before a cell divides, each DNA molecule makes a copy of itself. Each DNA molecule splits in many places between the pairs of bases, like a broken zipper. New bases join up with the bases on each of the opened sides of the ladder to form two identical DNA molecules (Figure 3). Since adenine (A) always pairs with thymine (T), and cytosine (C) always pairs with guanine (G), the two new DNA molecules are identical. Each new DNA molecule has an old strand and a new strand. GO

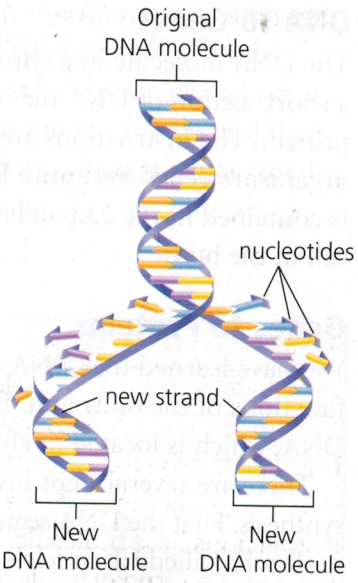


Figure 3 To replicate, a DNA molecule separates between the base pairs. Each separate side acts as a template for free nucleotides to join the opened strand.

If you would like to learn more about DNA replication, go to **www.science.nelson.com** GO

TRY THIS: Measuring Your DNA

Skills Focus: measuring, recording

Materials: calculator

The DNA in each human cell is coiled and fits inside the nucleus. If you stretched out the DNA from one typical human cell, it would measure about 2 m! There are about 100 trillion (100 000 000 000 000 or 1×10^{14}) cells in a human.

A. Calculate how many times your DNA would stretch to the Moon and back if it were removed from all your cells and arranged end to end. The distance from Earth to the Moon is approximately 380 000 km.

The Genetic Code

The bases in a DNA molecule are like the characters (numbers and letters) in a code. Think of codes that you are familiar with. For example, the Latin alphabet is a 26-character code that produces millions of words in several languages. The binary code (1 and 0) that computer languages use is a code that stores information. DNA has a four-character code. The four characters are DNA's nitrogenous bases: adenine (A), guanine (G), cytosine (C), and thymine (T). These bases combine to form "three-letter words" that are three bases long, for example, GGC or TAC (Figure 4). Each three-letter word codes for the production of one of 20 different amino acids. **Amino acids** are small molecules that are the building blocks of proteins. Different combinations of amino acids form different proteins. Proteins determine the characteristics of organisms. All the three-letter words in a cell's DNA form the instructions for all the body's cells to follow. This is the genetic code of all living organisms. It is sometimes called "the language of life." The genes of blue whales use the genetic code to produce blue whale characteristics. Human genes use the genetic code to produce human characteristics.

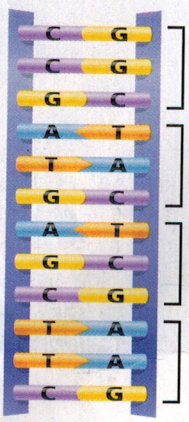


Figure 4 All the "words" of the genetic code, marked here by brackets, are three bases long. Most of the "words" code for an amino acid.

Did You KNOW?

The Human Genome

The Human Genome Project set out in 1990 to map all the genes in the human nucleus. The work was completed in 2003. Researchers now know that the human genome is made of approximately 3 billion DNA base pairs, which form 30 000 to 40 000 genes. Although researchers have identified many of the genes, they don't yet know the function of most of them, even some that have been identified and studied for years.

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DNA to Genes

The DNA molecule in a chromosome is organized into genes. A **gene** is a short section of DNA that contains the instructions to make a specific protein. The instructions are determined by the order of the bases. All of an organism's genes (its entire DNA) is called the **genome**. The human genome is contained in the 23 pairs of chromosomes in the nucleus of almost every cell in the body.

Genes to Proteins

You have learned that DNA controls all the cell activities, as well as all the functions of the body and the characteristics of each individual. How does DNA, which is located in chromosomes in the nucleus of the cell, do all this?

There are several steps involved in making a protein from DNA, or protein synthesis. First the DNA segment that makes up a gene is used to make another molecule, called ribonucleic acid (RNA). RNA is very similar in structure to DNA. DNA, however, has a double strand, whereas RNA has only one strand. Then, in a process that is similar to the replication of an entire DNA molecule, a gene segment of DNA separates and an RNA molecule is constructed from one half of the DNA (Figure 5). The RNA molecule then carries the code from the gene, out of the nucleus, to a ribosome in the cytoplasm. The ribosome "reads" the instructions on the RNA and assembles the appropriate amino acids in the correct order to make the protein.

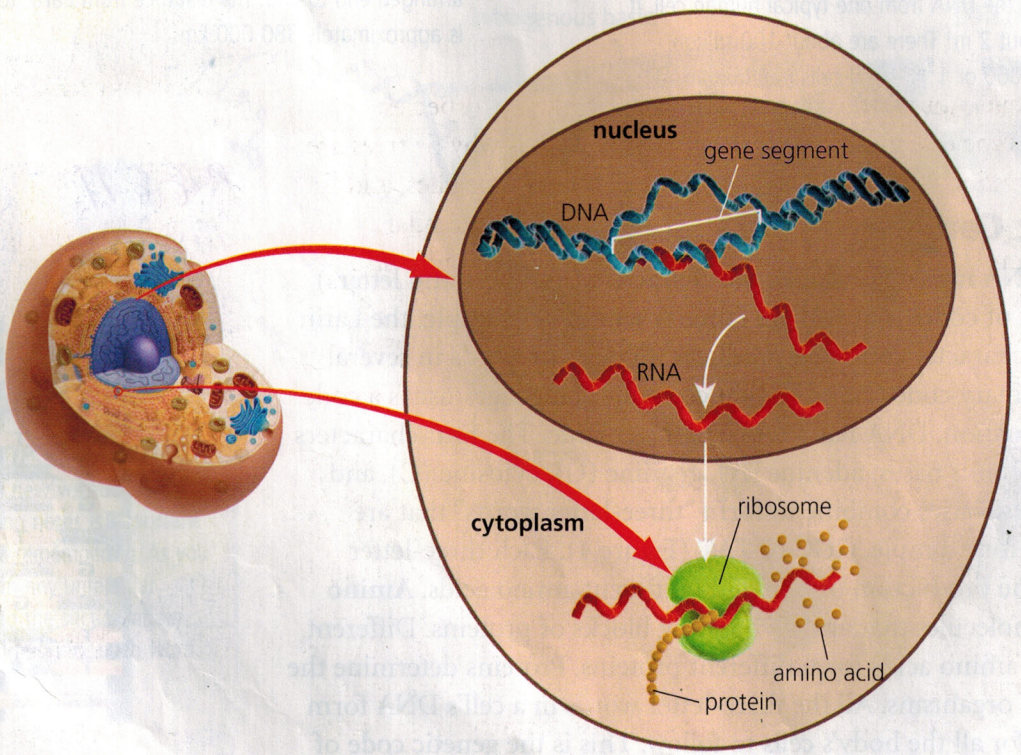


Figure 5 RNA acts as a messenger. It carries a gene's instructions from the nucleus to a ribosome in the cytoplasm.

Proteins have many functions. There is an enormous number of different types of proteins in the body. Enzymes are special proteins that control specific chemical reactions. Some hormones are made of proteins and act as messengers between cells. Table 1 shows several common proteins and their functions. The amino acids that make up proteins are either manufactured by your body or are obtained from the food you eat.

LEARNING TIP

After you finish reading the section called "Genes to Proteins," ask yourself, "How can I put what I have just read into my own words (paraphrase)?" Try explaining to a classmate how protein is made.

Table 1 Some common proteins and their functions

Protein	Function
hemoglobin	carries oxygen in red blood cells
insulin	controls the level of sugar in the blood
keratin	makes up hair and nails
collagen	holds tissue together, makes up bones
enzymes	control chemical reactions
antibodies	bind to foreign substances to protect the body against them
fibrinogen	helps blood clot
lactase	helps the body digest lactose (milk sugar)
growth hormone	stimulates growth (cell division)
prolactin	stimulates the production and release of milk from the mammary glands (see Chapter 4)
follicle stimulating hormone	stimulates egg and sperm production (see Chapter 4)

Genes and Variation

Genes are responsible for all the characteristics that make up a species. The number and type of genes differ among species. This is why fir trees are different from humans—humans don't have a gene to make needles, and fir trees don't have a gene to make hair. The DNA in organisms is similar, however. For example, 99.9 % of the DNA in the bacterium *E. coli* is also found in humans. Humans share 98 % of chimpanzee DNA and 35 % of daffodil DNA. The DNA that is unique to humans accounts for all the characteristics that are unique to humans.

All members of the same species have the same number and types of genes. We all have the genes that are responsible for making hair, nails, eyes, and every other human characteristic. If individuals from the same species have the same genes, why do they look different from one another? Why do some people have blue eyes and others have brown eyes? The answer is again in the genes. Within a species, there are different versions of the same gene. The different versions produce slightly different variations, or **traits**, for each characteristic. For example, in humans, one gene controls the characteristic of thumb shape. There are two different traits for this characteristic: straight or curved (Figure 6). Other characteristics, such as hair and eye colour, have several different versions. Also, some variations in characteristics are controlled by a number of different genes. Having different versions and

(a)

(b)

Figure 6 Thumb shape is a characteristic that is controlled by a single gene and has only two traits: the curved "hitch-hiker's thumb" (a) and the straight thumb (b).

LEARNING TIP

Think about the section called "Genes and Variation." Why do some people have curly hair and others have straight hair?

combinations of genes that control the characteristic partly explains why individuals, even close relatives, look so different. It is this unique combination of genes that you receive from your mother and your father that determines your characteristics. In the next two chapters, you will learn about the processes that produce the variations you see among all organisms. This variation allows individual organisms to adapt to changing environments.

TRY THIS: Human Traits Survey

Skills Focus: conducting, observing, recording, interpreting data

In this activity, you will survey your classmates to find out which of the following traits they have:

- Earlobes: Earlobes hang freely or are attached to the sides of the face (Figure 7).
- Thumb shape: Thumb curves when extended ("hitch-hiker's thumb") or is straight.
- Tongue: Tongue can be rolled like a U or cannot.
- Hair on middle section of fingers: Hair is present or absent.
- Dimples on face: present or absent
- Hairline: Hairline comes down into a widow's peak (a V) or is straight.

1. Create a table like Table 2 in your notebook. Use it to record your data for all the traits listed above.
2. Record whether each trait is present in each of your classmates.

A. Calculate the ratio for each trait.

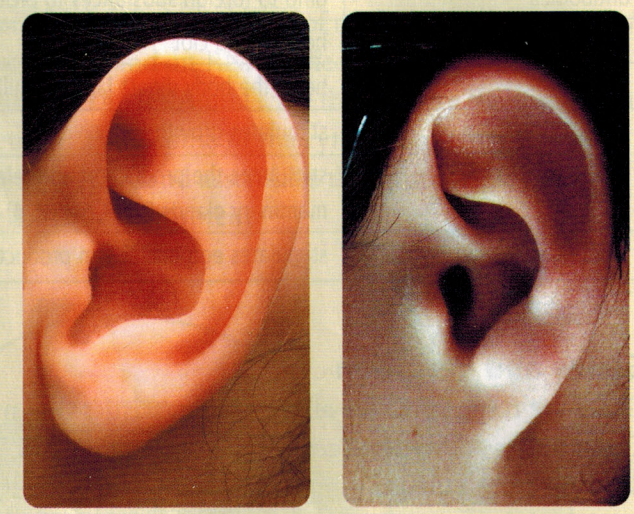
B. List the traits that more students have.

C. Do you think the ratios would be the same or different in another class? Explain.

D. If possible, compare your class results with results from other classes.

E. Calculate the ratios for the combined classes.

F. Do you see any patterns in the ratios?



(a) (b)

Figure 7 Free earlobes (a) and attached earlobes (b)

Table 2

Trait		Present	Number of students	Ratio
Earlobes	free			
	attached			
Thumb shape	hitch-hiker			
	straight			
Tongue	rolls			
	does not roll			

2.3 CHECK YOUR Understanding

1. Describe how chromosomes and DNA are related.
2. The DNA molecule is shaped like a twisted ladder.
   (a) What are the sides of the ladder made of?
   (b) What are the rungs made of?
   (c) Name each of the molecules that make up the rungs.
3. Describe how the DNA molecule replicates.
4. Which base joins with each base listed below?
   (a) cytosine
   (b) thymine
   (c) adenine
   (d) guanine
5. What part of the DNA molecule determines the genetic code of an organism?
6. What is the human genome?
7. Identify the numbered structures shown in Figure 8.

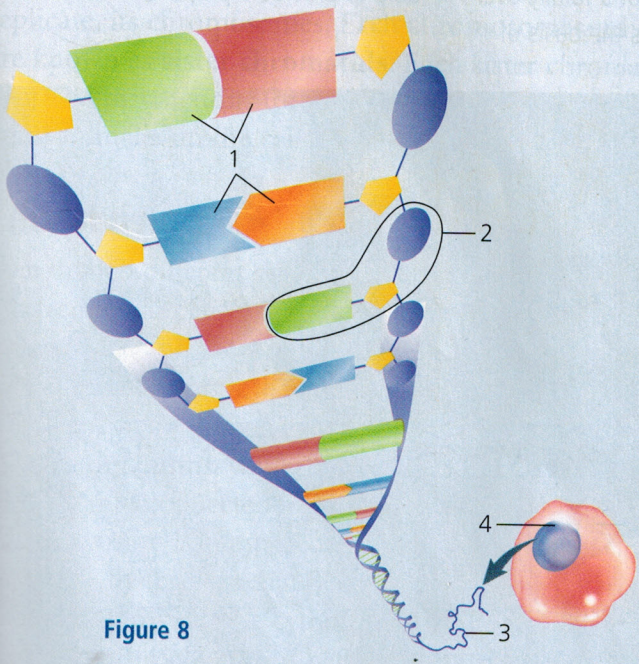


Figure 8

8. (a) Where are proteins made?
   (b) What are the building blocks of proteins?
9. What type of protein controls chemical reactions in your body?
10. (a) Name two types of structural proteins in your body.
    (b) Identify where each type of protein would be found.
11. Name and give the function of three proteins that are found in your blood.
12. Describe how DNA and genes are related.
13. How is the genetic code transferred from the nucleus into the cytoplasm?
14. How is RNA different from DNA?
15. Place the following events of protein synthesis in the correct order.
    (a) Ribosomes manufacture protein.
    (b) RNA is formed from a gene.
    (c) Part of a DNA molecule "unzips."
    (d) RNA carries the genetic code into the cytoplasm.
    (e) Amino acids attach to ribosomes.
16. Identify the structures labelled 1 to 3 in Figure 9.

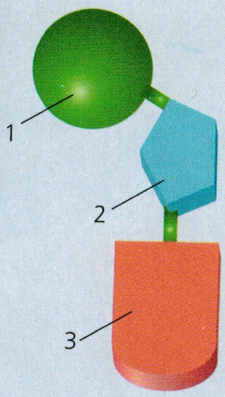


Figure 9

USING MITOCHONDRIAL DNA TO SOLVE MYSTERIES

Forensic scientists use the DNA found in mitochondria to help them identify human remains.

Dead bodies are not always easy to identify. For example, a body may have been burned or may have been left for a long time before being found. Often all that is left of a body is charred bits of bone, tangles of hair, or dried up patches of skin. The DNA in these samples is so damaged that regular DNA analysis is not possible. The only type of genetic material that can withstand extreme environmental conditions is found inside the mitochondria. Fortunately, there is technology that allows scientists to analyze mitochondrial DNA (mtDNA).

Mitochondria are tiny cellular organelles that use oxygen to break apart food molecules and release energy for the cell to use. When a cell undergoes cell division, the mitochondria divide and identical copies of the mitochondria are passed onto each of the resulting cells. This process is repeated over and over as an organism grows, so that all the cells in the organism have the same mtDNA.

During fertilization, when the egg and sperm join together, the mitochondria from the egg cell are retained but the mitochondria from the sperm cell are destroyed. Therefore, all mitochondria come from the mother. This means that all the fertilized egg's mitochondria are identical to the mother's mitochondria. As the fertilized egg divides, the cells produced have mitochondria that are identical to the mother's. The similarity of mtDNA in members of a family over many generations forms the basis of identifying human remains by forensic mtDNA techniques.

Scientists can identify victims by comparing mtDNA from the unidentified remains with mtDNA from possible female relatives. Panama, USA, Canada, Argentina, and Yugoslavia are just a few of the countries where human remains have been successfully identified using mtDNA analysis. In Panama, Yugoslavia, and Argentina, investigators from around the world worked together to identify the victims found in mass graves (Figure 1). While a lost relative can never be replaced, surviving family members get some degree of peace from knowing the fate of a family member and being able to provide a proper burial.

Figure 1 Forensic scientists investigate a mass grave.

2.4 The Cell Cycle

At this very moment, there are millions of cells undergoing cell division inside your body. But what about the rest of the trillions of cells in your body? What are they doing? Cells are not always dividing. The **cell cycle** is the sequence of events in the cell from one cell division to another (Figure 1). Just as you are growing and carrying out the normal functions of a human, most of the cells in your body are also growing in size or carrying out their normal functions. For example, muscle cells are using energy to contract. The cells that line your small intestine are absorbing nutrients from your digested food. This phase of growing and working is called **interphase**. A cell is in interphase for 90 % of the total time of the cell cycle. During interphase, the cell makes copies of each organelle in the cytoplasm. Once the cell is large enough, it will also make a copy of, or replicate, its chromosomes. Each chromosome and its copy are known as **sister chromatids**. Each sister chromatid carries identical instructions for the functions of the cell. Interphase and cell division make up the cell cycle.

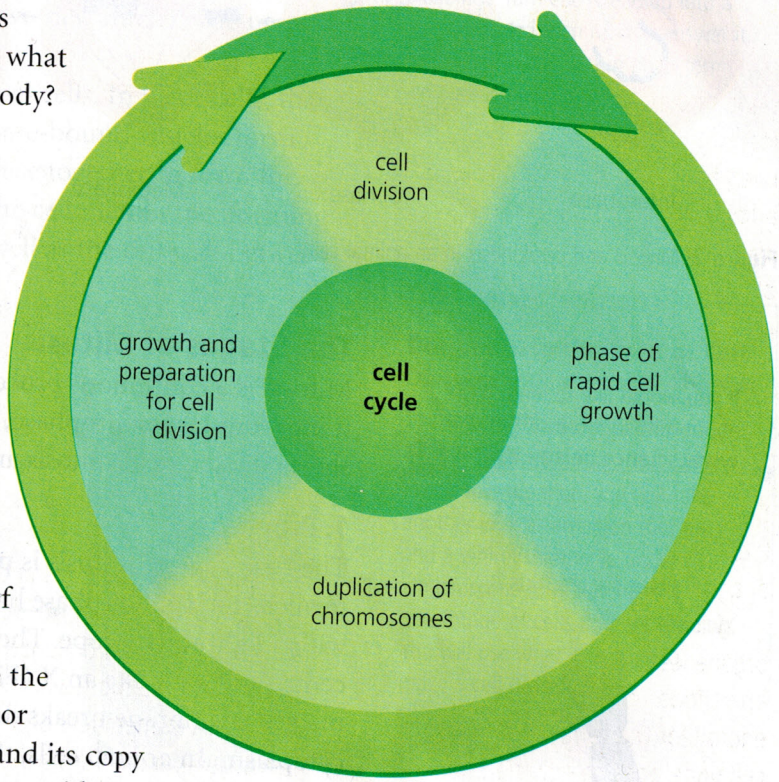


Figure 1 The circle represents the cell cycle of a eukaryotic cell. The light arrow represents the time the cell spends in interphase and the dark arrow represents the time in cell division. The labels indicate what is happening in the cell as the cycle progresses.

Cell Division

Even though different cells have different functions, the process of cell division is extremely similar in all cells and in all organisms. In both the unicellular paramecium and the giant blue whale, for example, one cell (called the **parent cell**) divides into two genetically identical cells (called **daughter cells**). The main difference is that the paramecia daughter cells become two separate organisms, while the blue whale daughter cells continue to divide and stay interconnected to make up the cells of various tissues and organs.

Cell division is composed of two processes: mitosis and cytokinesis. **Mitosis** is the process that divides the nuclear material. **Cytokinesis** is the process that divides the cytoplasm and the rest of the organelles in half. Cytokinesis usually begins before mitosis is finished. Each daughter cell receives approximately half the cytoplasm and organelles, and will be about half the size of the parent cell.

Did You KNOW?

Suicide Cells

Certain cells are genetically programmed to die after a certain number of cell divisions. For example, the eyelids of newborn puppies form an unbroken layer of skin. Shortly after birth, the eyelid cells across the middle of the eye die, allowing the top and bottom eyelids to separate and the eyes to open.

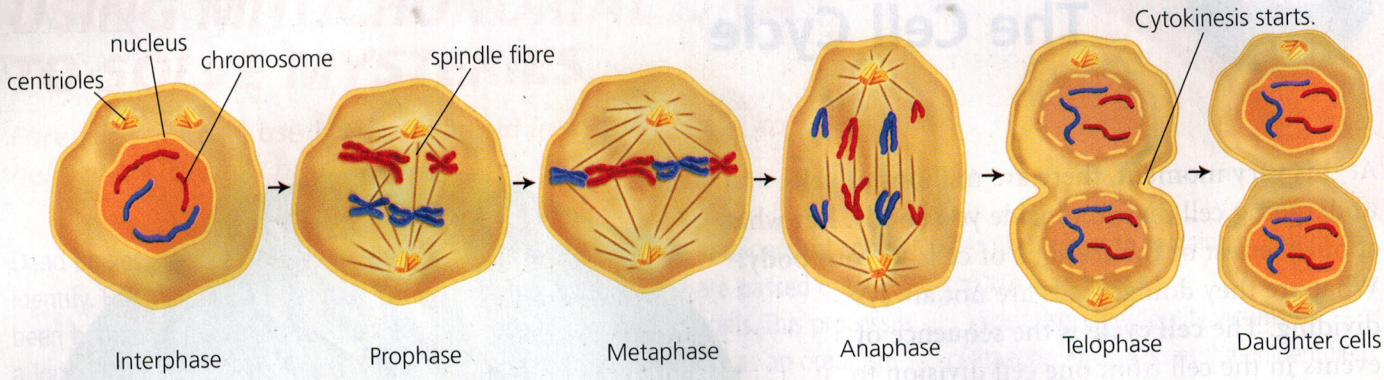


Figure 2 Mitosis and cytokinesis in an animal cell

If you would like to learn more about mitosis, go to **www.science.nelson.com** GO

Figure 3 A single duplicated chromosome is made of two sister chromatids joined at or near the centre.

The Stages of Mitosis

Mitosis is a continuous process, but, to make it easier to describe, we divide it into four stages: prophase, metaphase, anaphase, and telophase. Figure 2 shows the stages of mitosis and the process of cytokinesis in an animal cell. GO

1. Prophase

The first stage of mitosis is **prophase**. The sister chromatids that were formed during interphase have shortened and thickened, and are now visible with a light microscope. The sister chromatids become joined at or near the centre and look like an X (Figure 3). The nucleolus is no longer visible. The nuclear membrane breaks down and the chromosomes spread out in the cytoplasm. In animal cells, the centrioles, which were replicated during interphase, move to opposite poles of the cell and start to form spindle fibres. Spindle fibres are microtubules that grow toward the centre of the cell. The spindle fibres form the **spindle**, which moves the chromatids during the later stages of cell division.

2. Metaphase

The second stage of mitosis is **metaphase**. The spindle is completely formed, and the sister chromatids attach to the spindle fibres. The sister chromatids line up along the middle of the cell, halfway between the poles of the cell.

3. Anaphase

Anaphase is the third stage of mitosis. In anaphase, the sister chromatids are pulled apart by the spindle and move toward the opposite poles of the cell. The chromatids are now called chromosomes again.

4. Telophase

The last stage of mitosis is **telophase**. The new chromosomes have reached the opposite poles of the cell. During telophase, the events of prophase happen in reverse: two nuclear membranes form, the spindle disappears, the chromosomes lengthen and get thinner, and the nucleoli reappear. Mitosis is now complete. The original nucleus has divided into two genetically identical nuclei. 2A • *Investigation*

2A • *Investigation*

Observing Cell Division in Plant and Animal Cells

To perform this investigation, turn to page 64.

In this investigation, you will look at onion root tip and whitefish embryo cells under a microscope to observe the stages of cell division.

Cytokinesis

Cytokinesis is the second process in cell division. It begins at the end of mitosis, during telophase. Cytokinesis divides the cytoplasm into two daughter cells. It is visible in animal cells by an indentation or pinching of the cell membrane and cytoplasm between the two new nuclei. The new daughter cells are now in interphase.

Cytokinesis is different in plant cells and animal cells. In plant cells, there is no indentation in the cell membrane. Membrane-bound vesicles form between the two nuclei (Figure 4). The vesicles fuse together to form the cell plate. The cell plate grows outward toward the cell membrane, forming a new cell membrane for each daughter cell, as well as the cell wall between the two new membranes. 2B • *Investigation*

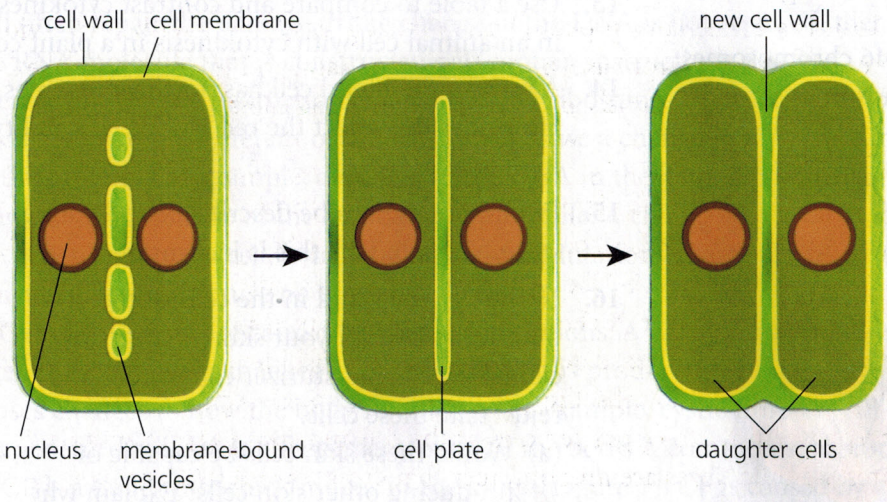


Figure 4 In plant cell cytokinesis, the cell plate forms new cell membranes and a new cell wall between the daughter cells.

LEARNING TIP

Making study notes is important for learning and remembering. Read this section again, and look at the headings. Turn each heading into a question, and then read to answer it. Record your answers in point form under each heading.

2B • *Investigation*

Determining the Rate of Cell Division in Plants and Animals

To perform this investigation, turn to page 66.

In this investigation, you will take another look at an onion root tip and a whitefish embryo under a microscope to determine the percentage of cells that are dividing. You will use what you learn to make a cell division clock.

TRY THIS: A Model of Cell Division

Skills Focus: creating models, observing, communicating

Materials: craft materials, such as modelling clay, pipe cleaners, wool, twist ties, string, rubber bands, and paper clips

This activity is intended to help you understand the continuous process of cell division.

1. Work with a partner to build a model of a cell. Your model must allow the chromosomes to be moved to show the stages of mitosis.
2. Your model must also be large enough to allow the chromosomes to move to the opposite poles of the cell.

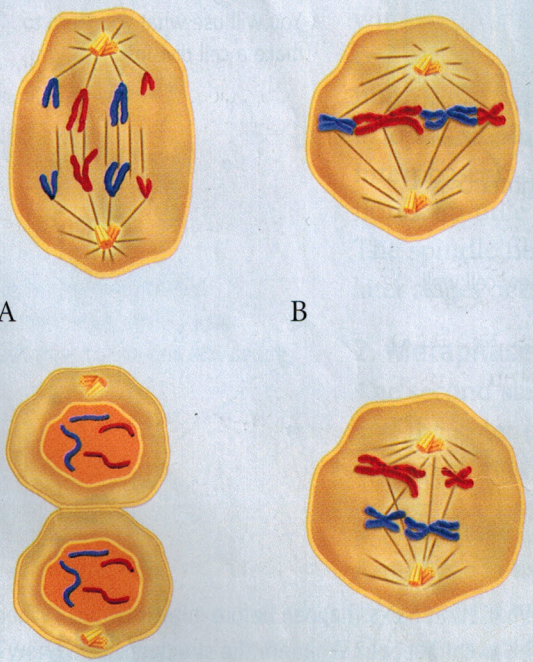
A. What event has to happen before mitosis begins? When does this event happen? What are the structures called now?

B. At each stage of mitosis, stop and describe to your partner what is happening.

C. Rearrange your cell model to show both animal cytokinesis and plant cytokinesis. Describe to your partner how each is different.

2.4 CHECK YOUR Understanding

1. What are the stages of the cell cycle?
2. When does the cell cycle start? When does it end?
3. Approximately what percentage of the cell cycle is interphase?
4. What event must occur before mitosis can begin?
5. How do the daughter cells compare with the parent cell?
6. What stage are the daughter cells in immediately following cell division?
7. A normal human body cell has 46 chromosomes. After mitosis, how many chromosomes should be in each daughter cell?
8. Identify the stages of mitosis, labelled A to D, in Figure 5.



A B C D

Figure 5

9. (a) List the stages of mitosis in their correct order.
   (b) Describe one feature that identifies each stage of mitosis.
10. Why is it necesary for a cell to duplicate its nuclear material?
11. What is the duplicated nuclear material called?
12. Why is telophase sometimes described as reverse prophase?
13. Use a table to compare and contrast cytokinesis in an animal cell with cytokinesis in a plant cell.
14. A human red blood cell has no chromosomes. How does this affect the red blood cell's ability to divide?
15. Interphase used to be described as a "resting stage." Explain why this is inaccurate.
16. No nuclei are found in the cells of the outermost layer of your skin. A company claims that its moisturizer can restore and rejuvenate these cells.
    (a) Would these skin cells be capable of producing other skin cells? Explain why or why not.
    (b) Evaluate the company's claim.
17. (a) Identify the dividing cells in Figure 6 as plant or animal cells.
    (b) Which of the processes involved in cell division is happening in each of the cells?

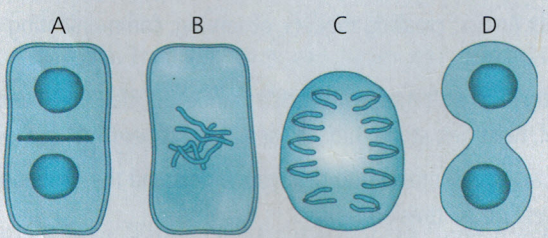


Figure 6

2.5 Changes to a Cell's DNA

The DNA that is found in almost every cell in your body forms your genetic code. It acts like the operating system of the cell, and it controls all your body's functions. What happens when the DNA is altered?

LEARNING TIP

Skim (read quickly) to get a general sense of Section 2.5. Examine the headings, and scan for words in bold. Ask yourself, "What information is important here?"

Mutations

In Section 2.3, you learned that the DNA in each gene provides the instructions to make a specific protein. The ribosomes in the cytoplasm assemble different amino acids in a specific order, according to the DNA's instructions. If the DNA in a gene has been changed in some way, the DNA's repair mechanism will often repair the damage. If the change in the DNA is not repaired, then the RNA molecule that is constructed will contain instructions that are altered. The altered instructions may direct the ribosomes to put the amino acids together in a different order, which will cause a change in the structure of the protein. For example, a change in the DNA in the hemoglobin genes may change the shape of the hemoglobin molecule. A change in the DNA, or the genetic code of a cell, is called a **mutation**. Mutations can be classified as beneficial, neutral (cause no effect), or harmful.

Genetic diseases are caused by harmful mutations. A harmful mutation in a gene's DNA causes changes in the protein that is produced, which in turn causes changes to how the body functions. For example, cystic fibrosis (CF) is a genetic disease that affects many parts of the body. A common symptom of CF is a buildup of thick mucus in the lungs (Figure 1). CF is caused by a mutation in a gene known as the CFTR gene. The normal CFTR gene codes for a protein that helps move certain chemicals into and out of the cell. When the gene has a mutation, the shape of the protein changes, and it no longer does its job properly. The change in the shape of the protein causes the many symptoms of CF.

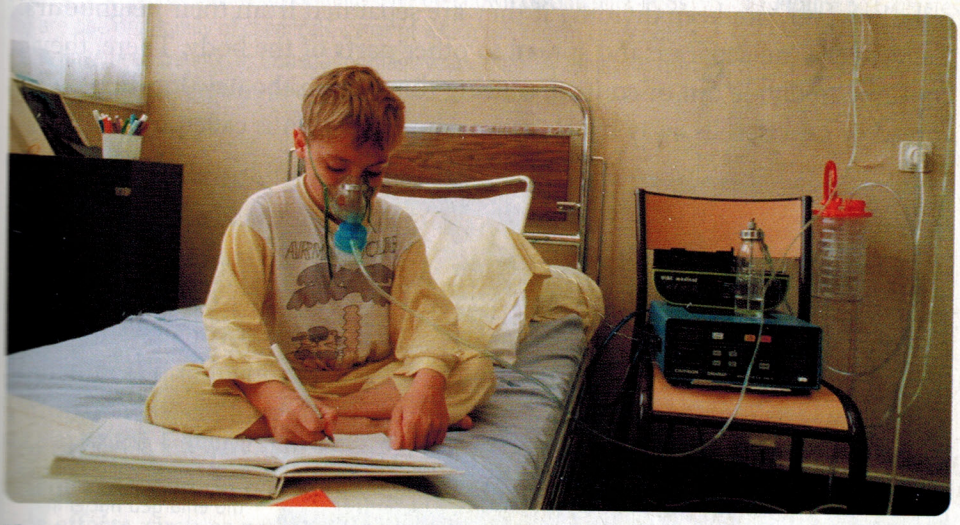


Figure 1 People with cystic fibrosis often get lung infections due to excess mucus in the lungs.

Did You KNOW?

A Beneficial Mutation

In Japan, a type of bacterium has been found that gets its nutrition from digesting nylon! This ability is caused by a beneficial mutation. Nylon was invented in 1935. Before that year, the mutation would not have been beneficial to the bacterium.

If you would like to learn more about mutations, go to **www.science.nelson.com**

LEARNING TIP

Make connections to your prior knowledge. Ask yourself, "What do I already know about cancer?" Consider the information you have learned in school, read on your own, or observed and experienced.

Insulin is a protein that the body needs to control the amount of sugar in the blood. It is produced by special cells in the pancreas. In people that have diabetes, the cells that produce insulin have either stopped producing it or produce insulin that doesn't work. Why does this happen? The DNA in the cells that produce insulin has been altered, so the instructions for making insulin have been altered. As a result, the cells cannot produce insulin from the instructions, or the instructions produce insulin molecules that do not work.

Cancer

Harmful mutations may cause cancer. **Cancer** is a disease in which cells divide very rapidly and uncontrollably. A mutation in the genes that control the cell-division process in the cell cycle causes cell division to go out of control. Some types of cells have a shorter cell cycle than others. The length of the cell cycle is unique to each type of cell and is determined by the DNA. If a mutation happens in the DNA that controls the cell cycle in a bone cell, the bone cell starts to divide much more quickly than normal bone cells do. The mutation gets passed on to the daughter cells, since the DNA of the parent cell is duplicated in the daughter cells. So the daughter cells divide uncontrollably as well.

Figure 2 A wart is a benign tumour on the skin. Benign tumours usually cause no harm.

Characteristics of Cancer Cells

As the cancer cells keep dividing, they accumulate in abnormal masses called tumours. There are two types of tumours: benign and malignant. **Benign tumours** are masses of cells that grow but stay in one place and usually do not interfere with the normal functioning of the surrounding tissue or organ (Figure 2). Warts are benign tumours. Benign tumours can usually be removed by surgery. **Malignant tumours** invade the surrounding tissues and interfere with the normal functions of the tissues and organs.

Rapidly dividing cancer cells use up more nutrients than normal cells, but they do not carry out the functions of normal cells. Figure 3 shows normal cells and cancer cells. The cancer cells have highly visible enlarged nuclei because they are constantly dividing. Most normal cells stay in contact with neighbouring cells and cannot divide if they are separated from the neighbouring cells. Cancer cells, however, can keep dividing if they are separated from their neighbours. Cancer cells can separate and spread to other parts of the body. There, they continue to divide out of control, causing tumours in the new locations. The spread of cancer cells away from their original location is called **metastasis**.

Did You KNOW?

Not Just Humans Get Cancer

Many other organisms besides humans can get cancer. Sunflowers and tomatoes often develop a type of cancer called a gall. This is a plant tumour caused by viruses, bacteria, fungi, or insects. There is evidence of cancerous tumours in dinosaur bones as well as in the cells of linen (made from the flax plant) found wrapped around ancient mummies.

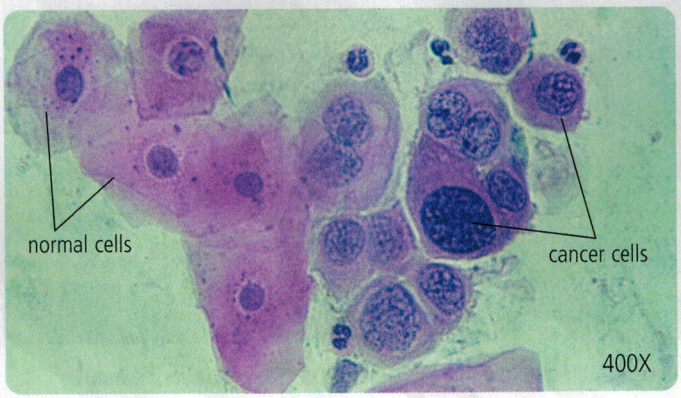


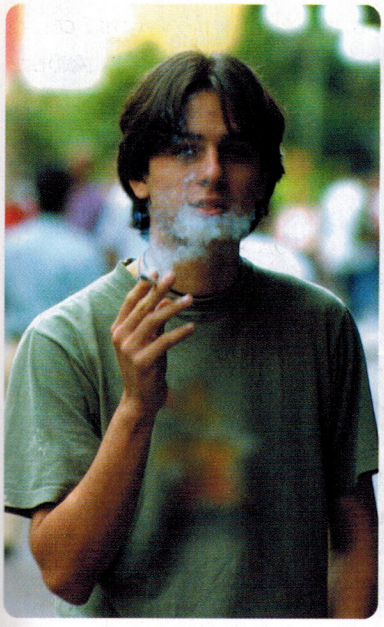
Figure 3 Normal cells, and cancer cells. Notice the enlarged nuclei in the cancer cells.

Causes of Cancer

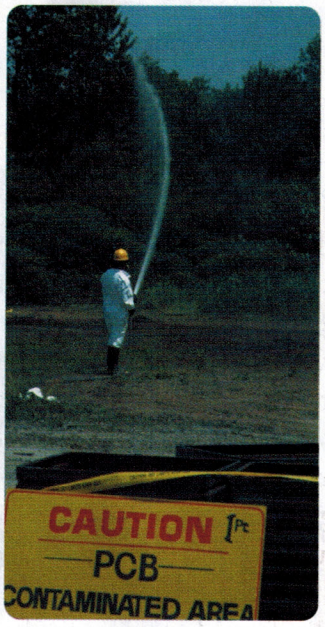
Any substance that can cause cancer is called a **carcinogen**. Scientists have discovered many carcinogens such as asbestos, certain pesticides, X-rays, some viruses, and many of the chemicals found in tobacco (Figure 4(a)). The environment contains a variety of carcinogens, many of which are by-products of industrial processes (Figure 4(b)). Many carcinogens, however, remain unknown. Avoiding known carcinogens decreases the chances of developing cancer. By not smoking and avoiding second-hand smoke, people reduce their exposure to the carcinogenic chemicals in tobacco smoke. By reducing time spent in the sun and/or wearing sunscreen, people reduce their exposure to the carcinogenic ultraviolet rays found in sunlight. Figure 5 shows risk factors that are associated with cancer. As well as these risk factors, your own genetic makeup influences your chances of getting cancer.

LEARNING TIP

Look at Figure 5. How do the parts of the circle graph relate to each other? How does the legend help to explain the information in the graph?



(a)



(b)

Figure 4 Cigarette smoke (a) contains over 60 known carcinogens. PCBs (b) are one of a family of chemicals, some of which are known carcinogens. PCBs have been banned in Canada for many years, but they remain in the environment for a very long time.

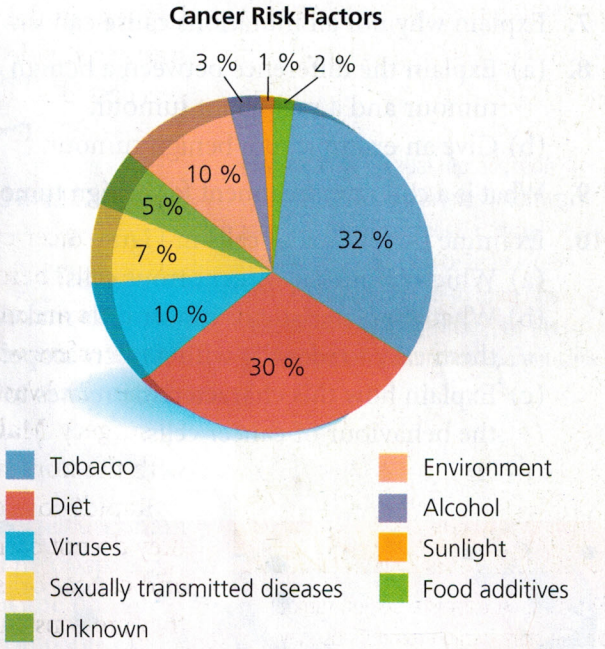


Figure 5 Estimates of risk factors are calculated in percentages.

Treating Cancer

Some cancers can be treated quite successfully if they are diagnosed early. Surgery can remove tumours before the cells metastasize. Radiation can be used to kill cancer cells by disrupting cell division in the rapidly dividing cancer cells. Chemotherapy involves using drugs to stop the cancer cells from dividing. Sometimes combinations of these treatments are used to treat a cancer patient. Unfortunately, chemotherapy and radiation also kill some fast-growing healthy cells, such as skin and hair cells, in addition to the cancer cells. This is why radiation therapy and chemotherapy can produce some unpleasant side effects, such as radiation burns, hair loss, nausea, and vomiting.

Did You KNOW?

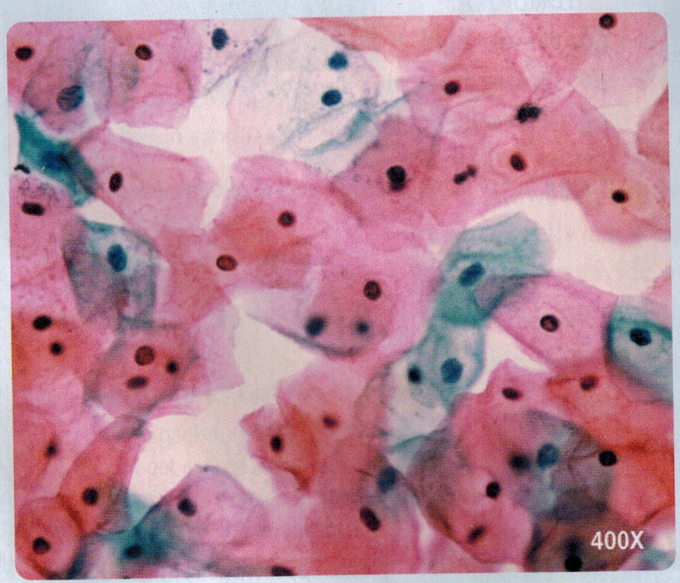
Sunburns

After repeated sunburns, it can take 10 to 30 years for skin cancer to develop. Take a sun-sense quiz and find out more about cancer.

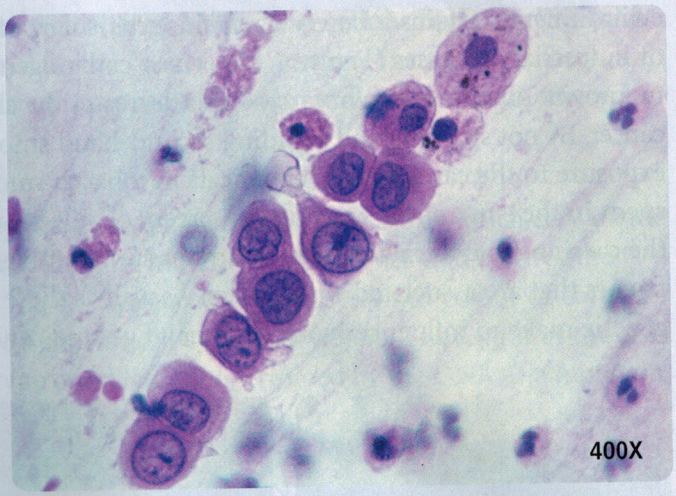
www.science.nelson.com GO

2.5 CHECK YOUR Understanding

1. What disease may result from a harmful mutation?
2. Which part of the cell does cancer affect?
3. Why do some normal cells have different lengths of cell cycles? Give two examples.
4. Describe two characteristics of cancer cells.
5. What characteristic of cancer cells allows cancer to spread to other areas of the body?
6. What is a carcinogen? Give two examples of known carcinogens.
7. Explain why not all mutations cause cancer.
8. (a) Explain the difference between a benign tumour and a malignant tumour.
   (b) Give an example of a benign tumour.
9. What is a common treatment for benign tumours?
10. Examine the photos of cells in Figure 6.
    (a) Which photo shows cancerous cells?
    (b) What characteristic of cancer cells makes them easy to identify with a microscope?
    (c) Explain how this characteristic relates to the behaviour of cancer cells.



A



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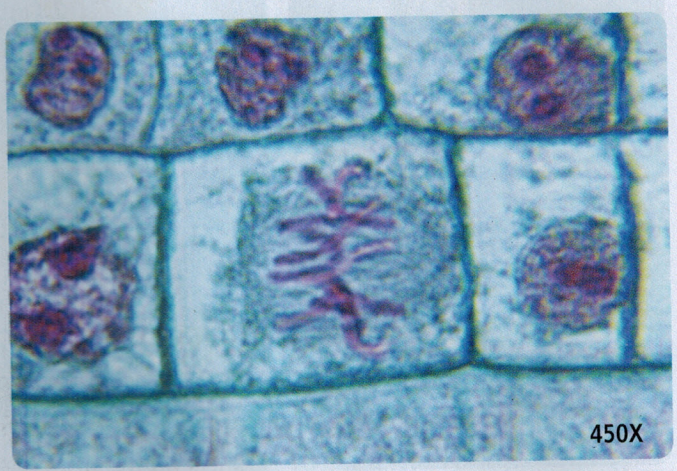


C

Figure 6

11. Why are cancers that metastasize more dangerous than cancers that do not?
12. Explain the differences between radiation and chemotherapy.
13. How does radiation affect cancer cells?
14. The percentage of people getting cancer is increasing. Considering the known causes, how can this increase be explained?
15. Explain why cancer treatment may cause burns and hair loss.

2.6 Cell Division and Asexual Reproduction

As you have learned, cell division plays a vital role in the life of all living things. All living things reproduce, and some use cell division as their method of reproduction.

There are two types of reproduction: sexual and asexual. In **sexual reproduction**, two separate organisms (parents) contribute genetic information, usually in specialized sex cells (an egg cell and a sperm cell). The sex cells combine to produce a **zygote**, the first cell of the new organism. **Asexual reproduction** involves only one parent. All the offspring that are produced by asexual reproduction are identical to the parent. Figure 1 compares sexual and asexual reproduction at the cellular level.

LEARNING TIP

Check your understanding of sexual and asexual reproduction. In your own words, explain to a partner how they are different.

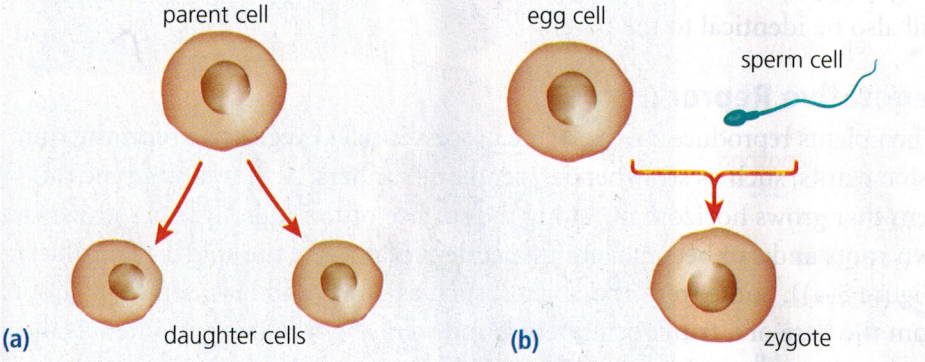


Figure 1 In asexual reproduction, (a), one parent cell divides into two identical daughter cells. In sexual reproduction (b), two cells, one cell from each parent, join to form one cell, called a zygote, which has the genetic material from both parent cells.

Types of Asexual Reproduction

From a simple bacterium to a daffodil plant, many different species use many different types of asexual reproduction to produce offspring. The offspring are clones. **Clones** contain DNA that is identical to the DNA of the parent and are therefore genetically identical. Ususally, the parent chromosomes and DNA are replicated in interphase. Cell division divides the genetic material and the cytoplasm between the two daughter cells.

Binary Fission

In **binary fission**, the parent undergoes cell division to produce two genetically identical daughter cells, or offspring (Figure 2). The offspring are smaller than the parent cell, but all the necessary structures are present. Only single-celled organisms (such as bacteria), some protists (such as amoebas), and some algae use binary fission to reproduce.

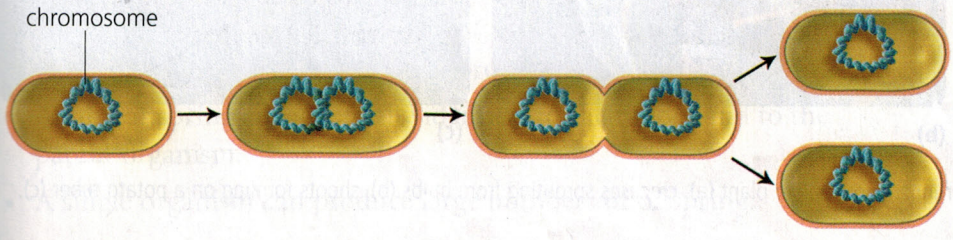


Figure 2 Binary fission in a bacterium

Figure 3 A population explosion of a protist called a dinoflagellate causes a red tide.

Figure 4 Budding in a hydra

Binary fission allows for rapid population growth under ideal conditions. Bacteria can double their population every 20 minutes. If the bacterium is one that causes a disease, this increase in numbers can produce an infection. Certain protists, called dinoflagellates, take advantage of good conditions in the ocean. The resulting population explosion is called a red tide (Figure 3). The dinoflagellates produce toxins that can kill fish, as well as humans, if the fish or humans consume clams or mussels that have eaten the dinoflagellates.

Budding

In **budding**, the offspring begins as a small growth on the parent, called a bud. The bud continues to undergo cell division and grow in size before breaking off from the parent. Budding occurs in single-celled organisms, such as yeast, as well as in multicellular organisms, such as the hydra (Figure 4), which is related to jellyfish and anemones. Since the initial daughter cells of the bud are genetically identical to the parent, the large bud that eventually breaks off will also be identical to the parent.

Vegetative Reproduction

When plants reproduce asexually, the process is called **vegetative reproduction**. Some plants, such as strawberries, send out runners. A runner is a type of stem that grows horizontally along the surface of the soil. A runner grows its own roots and can become an independent plant, like the spider plant shown (Figure 5(a)). Some trees and shrubs, such as aspen and lilac, send out shoots from the base of a trunk or underground stems, which grow into new plants. Cuttings from some plants can also grow their own roots and become new plants. Bulbs, from which daffodils and crocuses develop (Figure 5(b)), and tubers, such as potatoes (Figure 5(c)), are other forms of vegetative reproduction. The new plant clones are genetically identical to the parent plant.

(a)

(b)

(c)

Figure 5 Vegetative reproduction in plants: runners on a spider plant (a), crocuses sprouting from bulbs (b), shoots forming on a potato tuber (c).

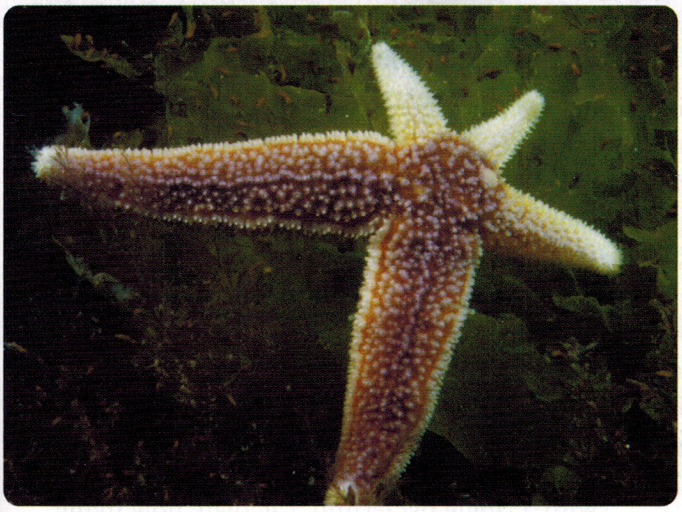
Fragmentation

In **fragmentation**, a small part of an animal breaks off and grows into a new organism. A fragment can grow into a complete animal. Whether an entire new animal grows from the fragment depends on how much of the original parent is contained in the fragment. The fragment of a sea star (Figure 6(a)), for example, must contain part of the central disk in order to produce a new organism. The original parent animal can regrow the lost fragment.

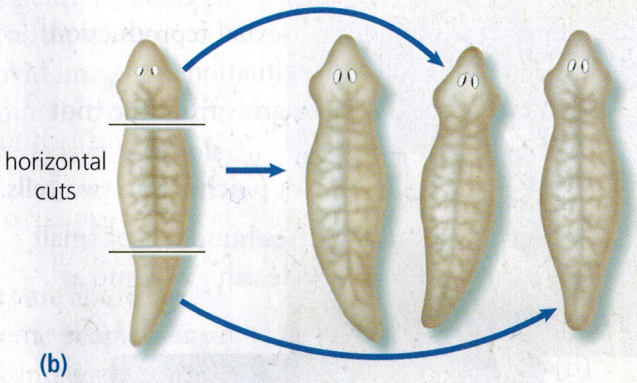
Reproduction after fragmentation cannot happen without regeneration. Regeneration is the ability to regrow a body part, a tissue, or an organ. Some flatworms, such as planaria (Figure 6(b)), can regenerate an entire organism from a small fragment. The genetic material of the new offspring is identical to the genetic material to the parent.

LEARNING TIP

Headings and subheadings act as a guide for your reading. To check your understanding as you read, turn each heading into a question and then answer it.



(a)



(b)

Figure 6 Fragmentation in a sea star (a) and a planarian (b). The sea star is growing three new legs from a fragment. Each section of the planarian will grow into a complete organism.

Spore Formation

Many fungi (such as moulds, puffballs, and mushrooms), algae, and non-flowering plants (such as ferns) reproduce by forming large numbers of spores (Figure 7). **Spores** are cells with thick cell walls. They are similar to seeds, but they are produced by cell division and grow into organisms that are genetically identical to the parent organism. Organisms that form spores may also reproduce sexually.

Figure 7 A magnified view of spore-bearing parts in the fungus *Penicillium*.

Characteristics of Asexual Reproduction

Even though there are different types of asexual reproduction, all of them have characteristics in common:

- Only one organism is needed to reproduce.
- All the offspring are genetically identical to each other and to the parent organism.
- A single organism can produce large numbers of offspring.

2.6 CHECK YOUR Understanding

1. At the cellular level, how is asexual reproduction different from sexual reproduction?
2. What is cloning? Why are all the offspring of asexual reproduction called clones?
3. What process must occur before asexual reproduction begins?
4. Explain why the population of an asexually reproducing organism can increase rapidly.
5. Use a Venn diagram to compare asexual reproduction with cell division.
6. Identify the method of asexual reproduction in each of the following situations.
   (a) A new tree begins to grow from the root of a nearby tree.
   (b) A single-celled protist pinches into two cells.
   (c) A mushroom disperses hundreds of small particles. Each particle can grow into a new mushroom.
   (d) 

   Figure 8
7. Use a dictionary to define "binary" and "fission." How do these definitions explain this type of asexual reproduction?
8. How are budding and vegetative reproduction similar?
9. (a) What is the difference between binary fission and budding?
   (b) How are these two types of asexual reproduction similar?
10. Describe two types of vegetative reproduction.
11. How is spore formation different than the other types of asexual reproduction?
12. (a) Explain the difference between fragmentation and regeneration.
    (b) Give an example of an animal that can do both.
13. Many organisms that reproduce asexually also reproduce sexually. What are some advantages of asexual reproduction?
14. Why is having only one parent both an advantage and a disadvantage of asexual reproduction?
15. Under certain conditions, bacteria can reproduce every 20 minutes. If a population started off with a single bacterium, calculate how many bacteria would be present in six hours.
16. Oysters are a major part of the diet of sea stars. Oyster harvesters used to try to kill sea stars by cutting them up and throwing them back into the ocean. Why did this practice not reduce the number of sea stars?
17. Some lizards easily lose pieces of their tails, which they can later regenerate. Explain how this process benefits the lizard.

2.7 Explore an Issue

DECISION MAKING SKILLS

- ○ Defining the Issue
- ● Researching
- ● Identifying Alternatives
- ● Analyzing the Issue
- ● Defending a Decision
- ● Communicating
- ● Evaluating

Beyond Dolly—Cloning Mammals

Humans have long been interested in cloning living things. Cloning is a type of asexual reproduction in which a single cell or part of an organism is used to grow a new, genetically identical organism. This new organism is a clone of the parent organism. As you have learned, cloning happens naturally in organisms that reproduce asexually. All their offspring are genetically identical.

There are many science fiction stories that have cloning as the central theme. While most science fiction is a mix of science and vivid imagination, recent scientific advances have made cloning possible in animals that cannot naturally form clones of themselves. Dolly the sheep (Figure 1) is an example of a successful clone of a mammal.

Figure 1 Dolly was the first mammal to be successfully cloned from a body cell.

The Issue: Reproductive Cloning of Mammals

Because of advances in reproductive technologies, scientists are able to clone mammals from a single body cell of an existing mammal. Some people believe that this has the potential to solve many medical problems and diseases for humans. Scientists might also be able to clone animals with organs that humans would not reject. The organs could be harvested and used for transplants. As well, scientists might be able to produce clones of endangered species. These clones could be produced and introduced into their natural habitats. Cloning livestock could help to solve the shortage of food in some countries.

Not everyone agrees with cloning, however. Some people believe that this technology could create more problems than it would solve. New diseases could result. Animals with harmful mutations could be born. Animals would be discarded after their valuable parts were harvested. There have been claims that humans have been successfully cloned, although there is no direct evidence that this has happened. These claims have generated a lot of media attention. Evidence of human cloning, however, has not been properly reported to the scientific community.

Statement

Scientists should not be permitted to clone mammals because this will lead to attempts to clone humans.

Background to the Issue

In 1952, scientists first developed techniques that allowed them to clone tadpoles. In 1958, Frederick Stewart excited the scientific world by growing the first complete carrot plant from a single root cell. Even though scientists

could clone frogs, they were unable to develop techniques to clone mammals. Then, in 1997, Scottish scientist Ian Wilmut cloned a sheep, which he named Dolly. Even though Dolly died in 2003, she is probably the most famous clone to date. Dolly was a normal female sheep, grown from a single cell of another sheep. She even gave birth to several lambs conceived in the normal way. Since then, other mammals have been cloned.

The Cloning Process

Dolly was created through a process that involved several steps (Figure 2). First, Wilmut and his team removed a body cell from the udder of one adult female sheep and an egg cell from another adult female sheep. They removed the nucleus from the egg cell and replaced it with the nucleus of the udder cell. They then used an electric shock to stimulate cell division in the new cell. Once the new cell had divided several times, they inserted the new embryo (developing organism) into the uterus of a third sheep. (The uterus is the organ in which the embryo develops.) The embryo continued to develop, and the sheep gave birth to Dolly.

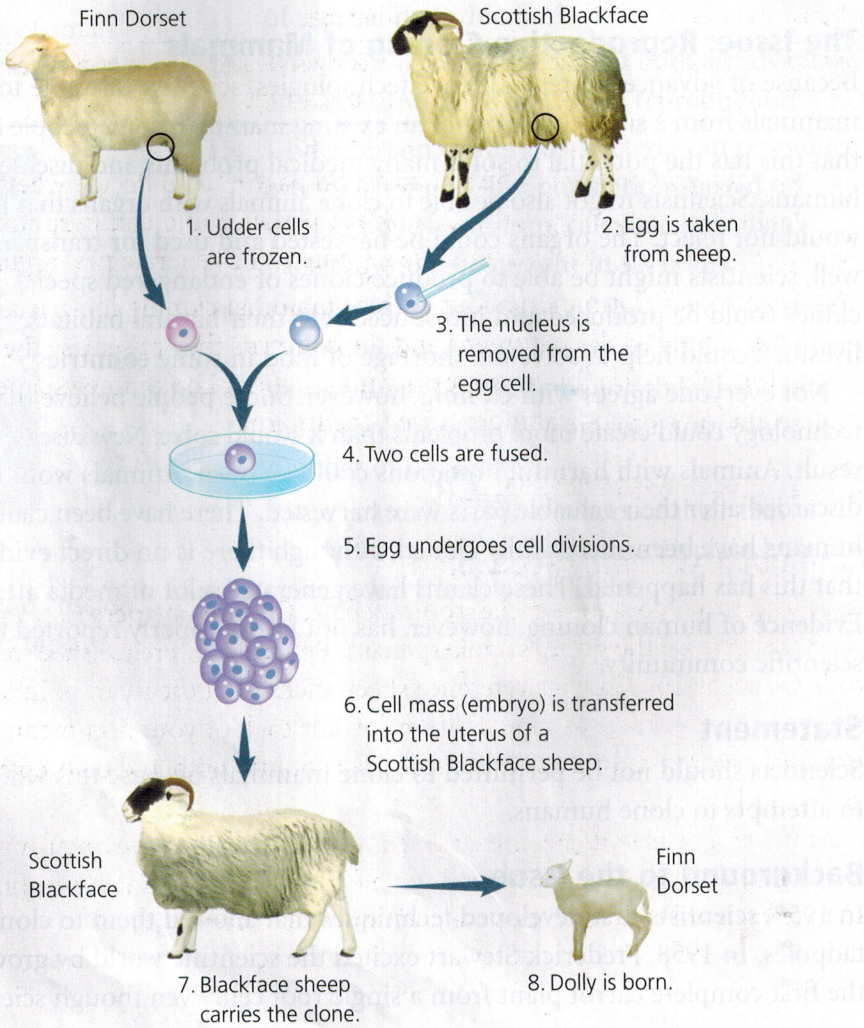


Figure 2 The cloning process involves combining the nucleus of a body cell with the cytoplasm of an egg cell.

LEARNING TIP

A concept map (Figure 2) is a collection of words or pictures, or both, connected with lines or arrows. For more information on concept maps, refer to the Skills Handbook.

The cloning process appears to be quite simple. Cloning a sheep, however, posed many biological and technical challenges. It took years of research and technical innovations to develop a process that could produce a sheep clone.

Make a Decision

1. Carefully read the statement and the background information. Consider each of the sample arguments provided in Table 1.

Table 1 Arguments on Reproductive Cloning of Mammals

Point	Counterpoint
Cloning mammals is not natural, and any artificial production of animals could cause problems, such as diseases, for the natural environment.	Other types of artificial cloning occur all the time, and diseases have not been introduced into the natural environment.
The time and money spent on research into cloning mammals could be better used to discover cures and treatments for existing human diseases.	Cloning could save money and time by reproducing valuable domestic mammals, such as cows that produce high yields of milk.
Successful cloning of mammals could lead to attempts to clone humans.	Scientists would only use human clones to save lives.

2. In your group, discuss the statement on page 61 and decide whether you agree or disagree with it. Look at the points and counterpoints in Table 1. You can expand on these arguments or generate new arguments.
3. Search for information about current mammal cloning in agriculture or attempts to clone humans and the concerns they raise. Use the information you find to support your position. Look in newspapers, in a library periodical index, or on the Internet.

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Communicate Your Decision

Your teacher will organize a classroom debate. Choose one person from your group to be the group's spokesperson. Prepare a reference sheet for your spokesperson. In your reference sheet, include all the main points that you want your spokesperson to make. For each of your arguments, consider arguments that the other side may counter with and be prepared to respond to them.

At the end of the debate, the class will vote on the issue. Be open-minded and willing to change your position. Vote for the most convincing arguments. Your teacher will conduct the vote and announce the results.

2A • Investigation •

Observing Cell Division in Plants and Animals

INQUIRY SKILLS

○ Questioning	● Conducting	● Evaluating
● Hypothesizing	● Recording	● Synthesizing
● Predicting	● Analyzing	● Communicating
○ Planning		

In Sections 2.1 and 2.4, you learned why and how cells undergo cell division. In this investigation, you will observe cell division using prepared slides and compare the process of mitosis in plant and animal cells.

Question

Are there differences between plant and animal cell division?

Prediction

Predict any differences you may observe between plant and animal cell division.

Experimental Design

The dividing plant cells you will examine are from onion root tips. The animal cells are from whitefish embryos. The prepared slides show cells in various stages of cell division. Since the cells have been "frozen in time," you will not be able to observe the continuous process from prophase to telophase in any one cell.

Materials

- prepared slide of an onion root tip
- microscope
- prepared slide of a whitefish embryo

LEARNING TIP •

To review how to use your microscope or how to make biological drawings, refer to the Skills Handbook.

Procedure

1. Obtain a prepared slide of an onion root tip, and place it on the microscope stage.
2. Focus the image under low power using the coarse-adjustment knob. Find cells that appear to be dividing. These will be toward the root cap, the narrower end of the specimen (Figure 1).

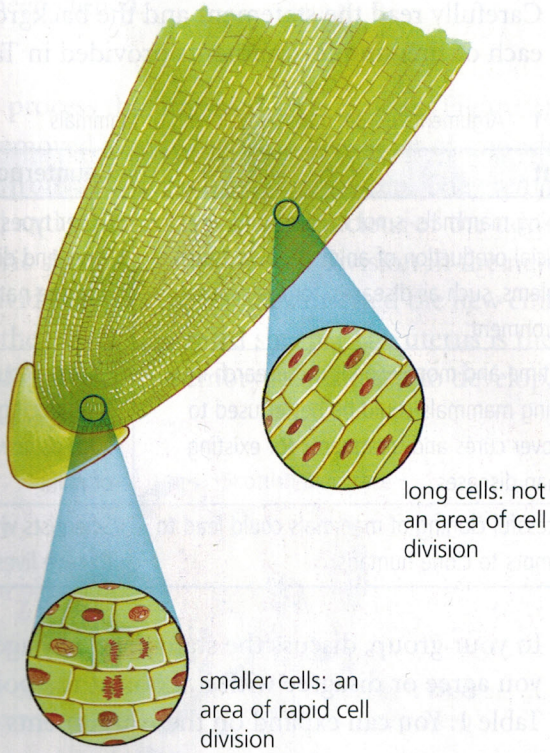
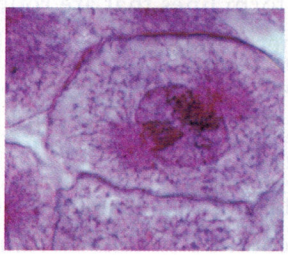


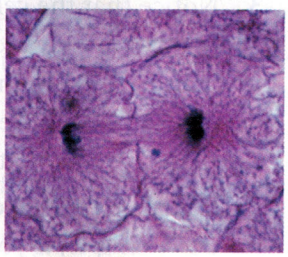
Figure 1 Step 2

3. Once you have centred the dividing cells in the field of view, rotate the nosepiece to the medium-power lens. Focus the image using the fine adjustment knob. Locate cells that are dividing. What do you observe that identifies the dividing cells?
4. Carefully rotate the high-power lens to above the specimen. Focus the image using the fine adjustment knob. Move the slide to locate cells in each phase of mitosis.
5. Draw and label a cell in each phase of mitosis. Label the structures that you can identify. These may include the nucleus, chromosomes, spindle, cell plate, and cell wall. Draw and label only the cell structures that you actually observe under the microscope. Write the name of the mitotic phase below each cell drawing.

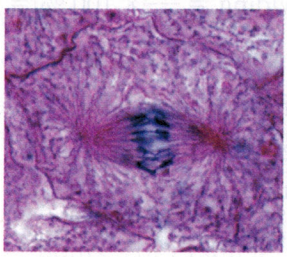
6. Rotate the nosepiece to the low-power objective lens, and remove the slide.
7. Place the whitefish embryo slide on the stage. Focus the image using the coarse-adjustment knob. Use the photographs in Figure 2 to help you.
8. Once you have located cells that are dividing, repeat steps 3, 4, and 5.
9. Compare your diagrams with your classmates' drawings. Explain to each other any stages that one of you included but the other did not. Try to find any stages or structures that you could not locate on your own slide on your classmates' slides.
10. Rotate the low-power objective lens into place, and remove your whitefish slide.



A. prophase

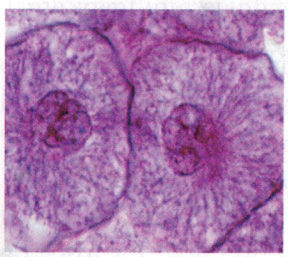


B. metaphase



C. anaphase

D. telophase



E. daughter cells

Figure 2 Cell division in a whitefish embryo (magnification: 450X)

Analysis

(a) What differences did you observe between plant and animal cell division? Use a table to compare the appearance of the dividing plant cells with the appearance of the dividing animal cells.

(b) Did your observations support your prediction? Explain.

(c) Were any stages of mitosis easier or more difficult to identify? Explain why.

(d) Which cell structures were the easiest to locate?

Evaluation

(e) Why did you use plant root tips and animal embryos to view cell division?

(f) Explain why the cells you viewed did not continue to divide.

(g) How are the differences in cell division in plant and animal cells related to the differences in the structures of plant and animal cells?

(h) List one feature of each stage of mitosis that you observed that helped you identify the stage.

Synthesis

(i) Where else in plants and animals would you expect to observe rapidly dividing cells?

(j) Why do biologists use dividing cells to determine the number of chromosomes in an organism?

(k) How can knowing the stages of mitosis help scientists?

(l) If a cell has 12 chromosomes, how many chromosomes will each daughter cell contain?

CHAPTER 2

Review

Cell Growth and Reproduction

Key Ideas

The functions of cell division are growth, repair, and reproduction.

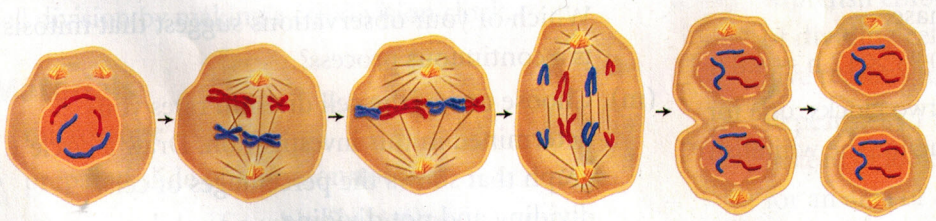
- Cell division produces new cells to increase the size of the organism.
- Cell division produces new cells to replace damaged and old cells.
- Cell division is the method that some organisms use to reproduce.

DNA in the nucleus plays a key role in normal cell functions and in cell division.

- The nucleus contains the nucleolus and the chromosomes.
- DNA is contained in the chromosomes in the nucleus of each cell and carries the genetic information to direct all the activities in the organism.
- Genes are segments of DNA on a chromosome. They carry the instructions to make proteins. This information results in individual characteristics.
- RNA is a copy of a gene segment of DNA. RNA carries the instructions from genes in the nucleus to the ribosomes, where proteins are made.
- Once a cell is large enough to divide, DNA replicates before cell division begins.

The cell cycle includes the normal cell functions and cell division.

- Cells spend most of their time in interphase, growing and performing their specific functions.
- Cell division includes mitosis and cytokinesis.
- The stages of mitosis are prophase, metaphase, anaphase, and telophase.
- Cytokinesis divides the cytoplasm in two and is different in animal and plant cells.
- The products of cell division are two genetically identical daughter cells.

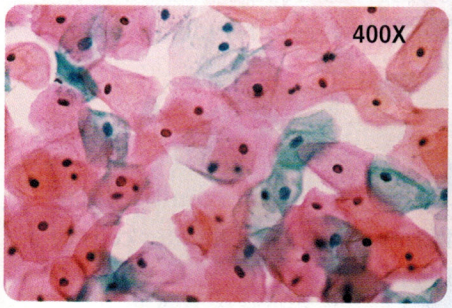


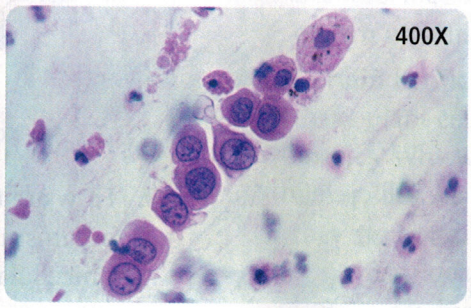
Vocabulary

nuclear membrane, p. 39
DNA, p. 39
nucleolus, p. 40
centrioles, p. 40
nucleotide, p. 42
nitrogenous bases, p. 42
amino acids, p. 43
gene, p. 44
genome, p. 44
traits, p. 45
cell cycle, p. 49
interphase, p. 49
sister chromatids, p. 49
parent cell, p. 49
daughter cells, p. 49
mitosis, p. 49
cytokinesis, p. 49
prophase, p. 50

Mutations in a cell's DNA can cause diseases, including cancer.

- Certain factors can cause mutations in a cell's DNA. Mutations in genes change the instructions that the genes contain. This can cause diseases such as cystic fibrosis and diabetes.
- Mutations in the genes that control cell division can cause cancer.
- Out-of-control cell division produces masses of cells, called tumours, that can interfere with normal body functions.
- Treatments for cancer include surgery, radiation therapy, and chemotherapy.





Some organisms reproduce asexually through cell division.

- Asexual reproduction involves only one parent.
- The offspring of asexual reproduction are genetically identical to the parent and to each other.
- Different types of asexual reproduction include binary fission, budding, vegetative reproduction, fragmentation, and spore formation.

spindle, p. 50
metaphase, p. 50
anaphase, p. 50
telophase, p. 50
mutation, p. 53
cancer, p. 54
benign tumours, p. 54
malignant tumours, p. 54
metastasis, p. 54
carcinogen, p. 55
sexual reproduction, p. 57
zygote, p. 57
asexual reproduction, p. 57
clones, p. 57
binary fission, p. 57
budding, p. 58
vegetative reproduction, p. 58
fragmentation, p. 59
spores, p. 59

Review Key Ideas and Vocabulary

1. Cells are constantly being replaced by new cells. Why are cells replaced, and where do the new cells come from?
2. Which process is responsible for increasing the number of cells in your body?
   (a) interphase
   (b) respiration
   (c) cell division
   (d) cell growth
3. Which type of asexual reproduction is used by bacteria?
   (a) budding
   (b) fragmentation
   (c) regeneration
   (d) binary fission
4. Which list gives the stages of the cell cycle in the correct order?
   (a) interphase, cytokinesis, prophase, metaphase, anaphase, telophase
   (b) prophase, anaphase, metaphase, telophase, cytokinesis, interphase
   (c) interphase, prophase, metaphase, anaphase, telophase, cytokinesis
   (d) cytokinesis, prophase, metaphase, anaphase, telophase, interphase
5. Which of the following terms refers to a substance that can cause cancer?
   (a) tumour
   (b) carcinogen
   (c) mutation
   (d) metastasis
6. Which of the following terms refers to the number of genes in an organism?
   (a) genome
   (b) chromosome
   (c) zygote
   (d) protein number
7. Which of the following lists gives the steps of protein production in the correct order?
   (a) RNA → DNA → ribosome → cytoplasm → protein
   (b) DNA → RNA → cytoplasm → ribosome → protein
   (c) ribosome → RNA → DNA → cytoplasm → protein
   (d) DNA → RNA → protein → ribosome → cytoplasm
8. What parts of your body undergo cell division more often than other parts? Explain your answer.
9. Identify the parts of the DNA molecule, labelled A to C, in Figure 1.

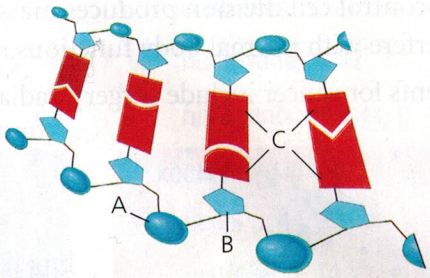


Figure 1

10. How are the daughter cells of a multicellular organism different from the daughter cells of a unicellular organism?
11. What occurs at the cellular level to cause cancer?
12. How is asexual reproduction different from sexual reproduction?
13. Why is the genetic material of a cell duplicated before cell division begins?
14. Identify the type of asexual reproduction in each of the following situations
    (a) A multicellular marine alga is broken up by a wave. Each piece of the alga grows into a new organism.

(b)

Figure 2

(c)

Figure 3

(d)

Figure 4

Use What You've Learned

15. An organism is composed of 280 cells. If each cell divides, how many cells would be present after eight divisions?
16. The following cells all divide faster than other average cells. Explain why.
    (a) the roots of a pine seedling
    (b) a tadpole developing into a frog
    (c) human cheek cells
    (d) white blood cells in the blood of a person with chicken pox
17. Use the circle graph in Figure 5 to answer the following questions.

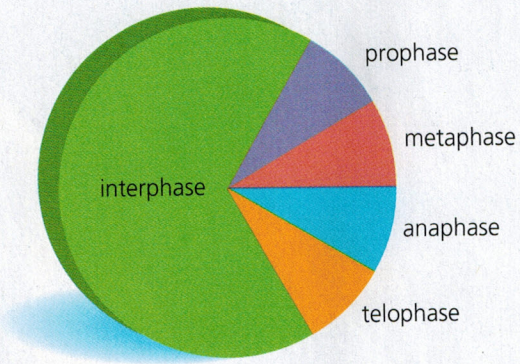


Figure 5

    (a) In which stage does growth occur?
    (b) In which stage do double-stranded chromosomes become single-stranded chromosomes?
    (c) During which stages is the cell undergoing cell division?
    (d) When does the genetic material get replicated?
    (e) During which stage would cytokinesis begin?
    (f) During which stage would the cell plate begin to form?
18. (a) If a parent cell has 12 chromosomes, how many chromosomes will each daughter cell have following mitosis?
    (b) Predict a possible outcome for each daughter cell if all the chromosomes moved to only one pole of the cell during anaphase.
19. Explain how a plant nursery could make use of one type of asexual reproduction.
20. Compare RNA and DNA molecules in terms of their structure, function, and location.
21. Explain how genes can cause a range of eye colours.

Think Critically

22. Your body does not have all the cells you had when you were a baby. What has happened to those cells?
23. Describe several ways in which industries could use information on the rate of cell division in certain organisms.
24. Certain herbicides (chemicals that kill plants) make plant cells divide faster than normal for a species. Why would these herbicides kill weeds? (Hint: Think about what cells are doing when they are not dividing.)
25. Why do some pesticides cause cancer?

Reflect on Your Learning

26. Cloning of mammals is a scientific and technological achievement, but it raises many concerns. Did the discussion of reproductive cloning of mammals change your opinion about the pros and cons of using this technology? Explain why or why not.
27. The stages of mitosis are named so they can be more easily discussed. Cells do not stop between stages. What observations did you make in your investigations to suggest that mitosis is a continuous process?

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