2.1 The Importance of Cell Division

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

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.

Functions of Cell Division

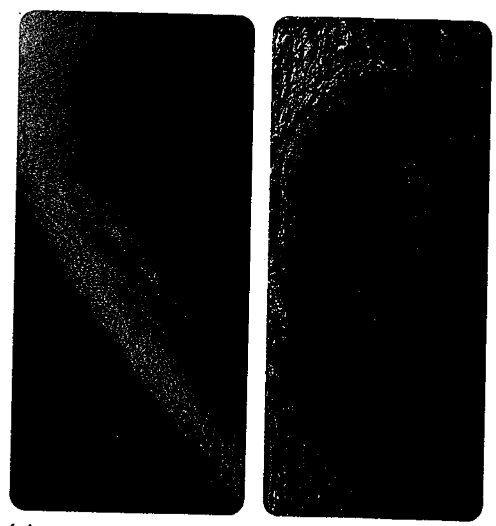
There are three main functions of cell division: growth, repair, and reproduction.

Growth

All living things are composed of one or more cells. All organisms begin life as a single cell. Multicellular organisms, such as dogwood trees and humans, undergo cell division to increase their size. Why don't cells simply increase in size to grow? Recall from Grade 8 science that there are limits to the size of a 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 multicellular organism has to use cell division. In a multicellular organism, after the body 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) use cell division to grow new cells over a cut. Where else would plants grow new cells to replace 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.

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.

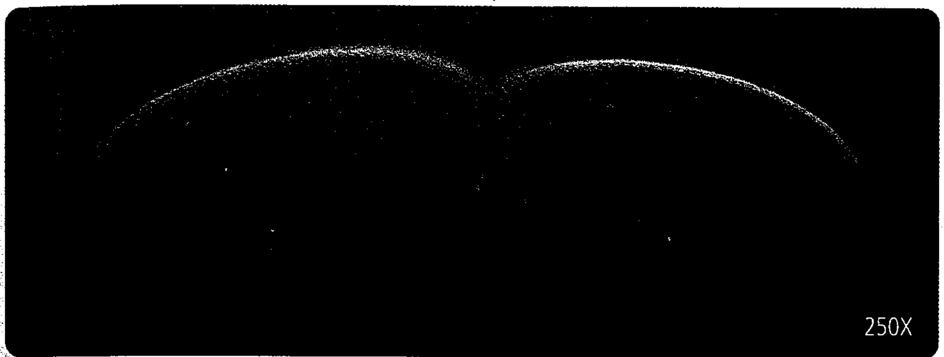


Figure 3 This single-celled paramecium is reproducing itself by cell division.

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.

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?

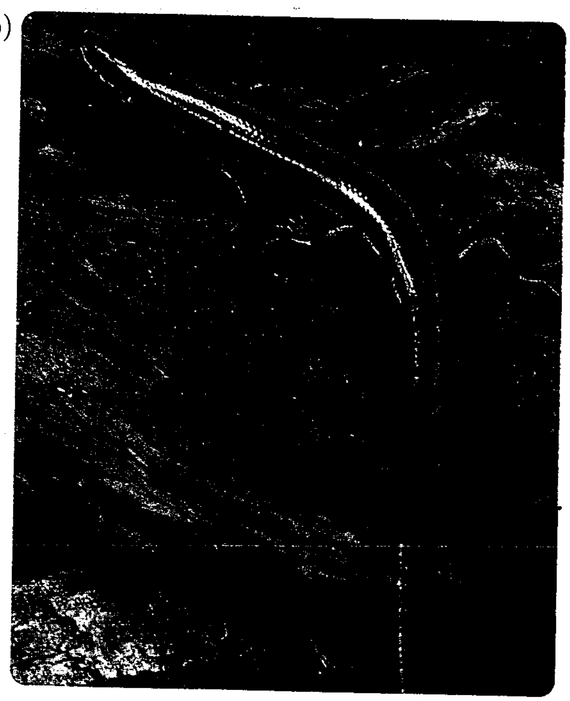
C. Make a prediction: How many cell divisions are needed to produce more than a trillion cells?

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)

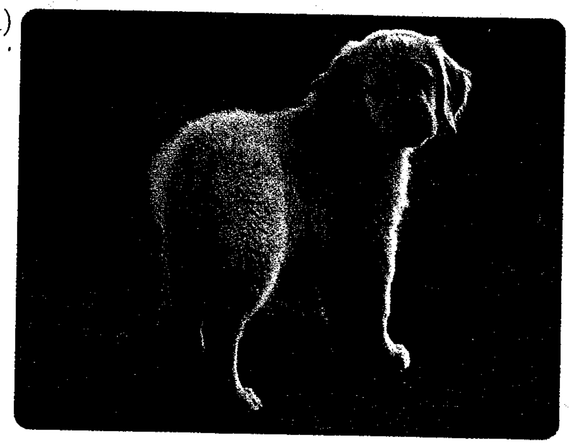


Figure 5

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?

2.3 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?

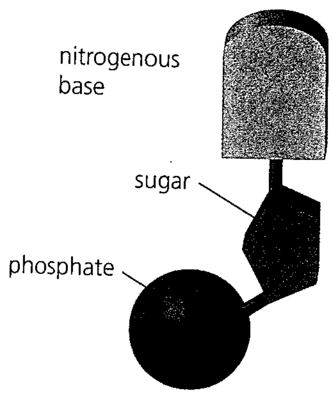
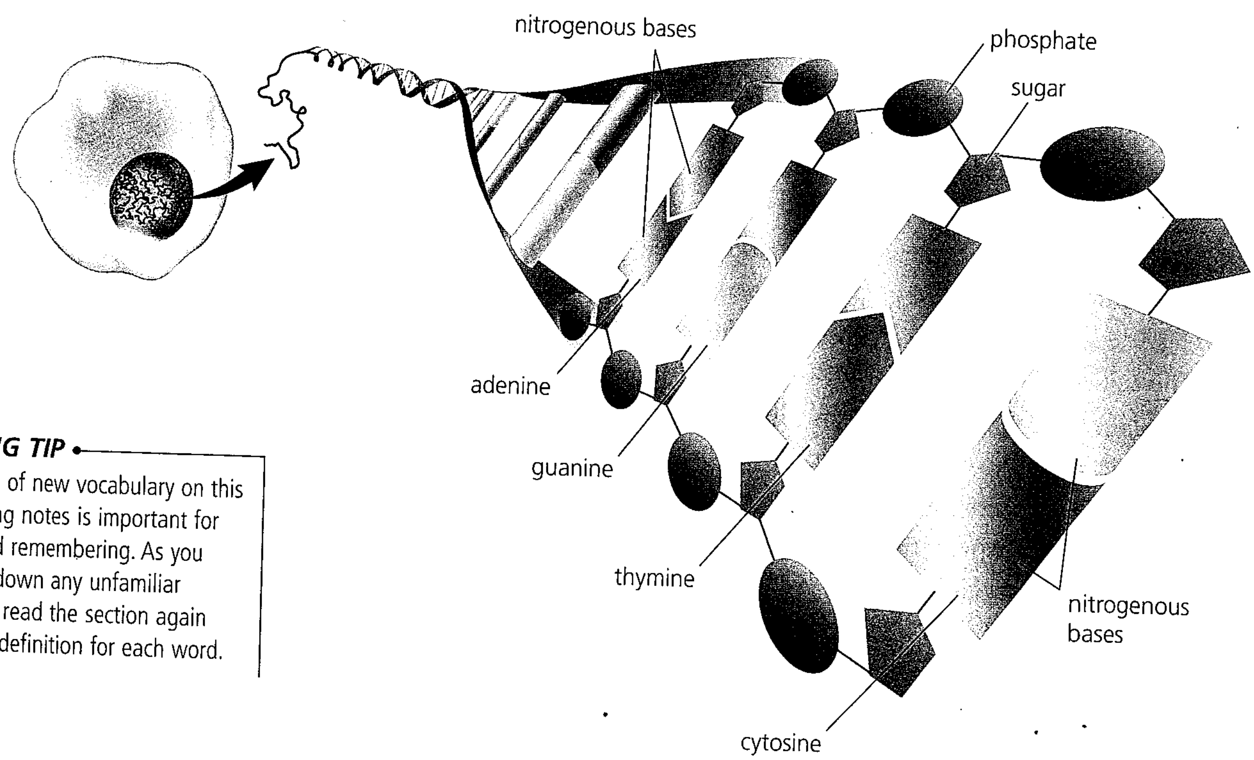


Figure 1 A nucleotide is composed of a sugar molecule, a phosphate molecule, and a nitrogenous base.

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.



LEARNING TIP

There is lots 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.

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.

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.

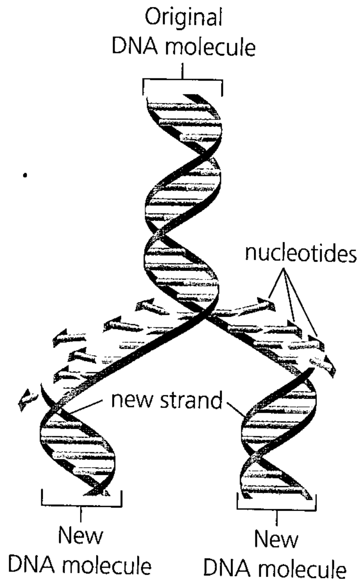


Figure 3 To replicate, a DNA molecule separates between the base pairs. Each separate side acts as a template for free nucleotides to join the opened strand.

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

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.

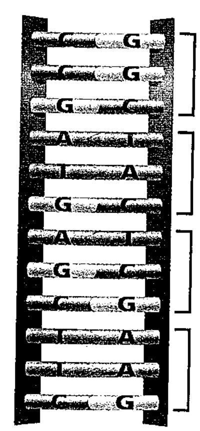


Figure 4 All the "words" of the genetic code, marked here by brackets, are three bases long. Most of the "words" code for an amino acid.

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.

www.nelson.science.com GO

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.

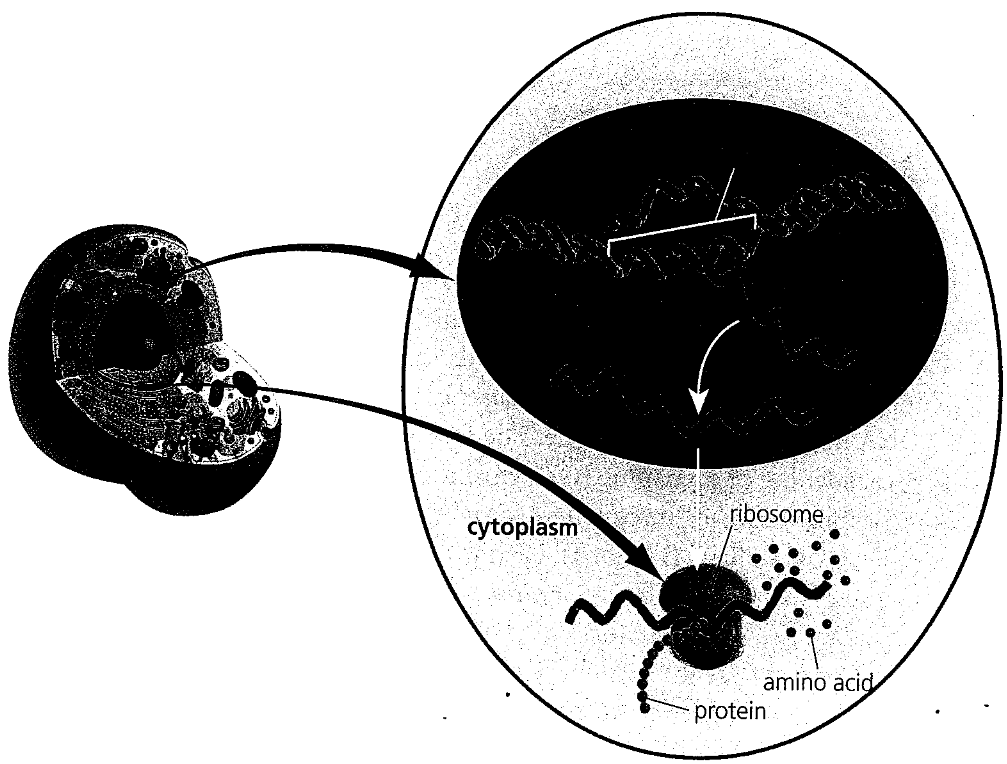


Figure 5 RNA acts as a messenger. It carries a gene's instructions from the nucleus to a ribosome in the cytoplasm.

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.

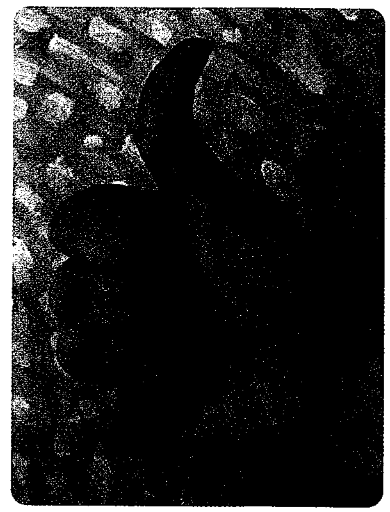
Table 1 Some common proteins and their functions

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)

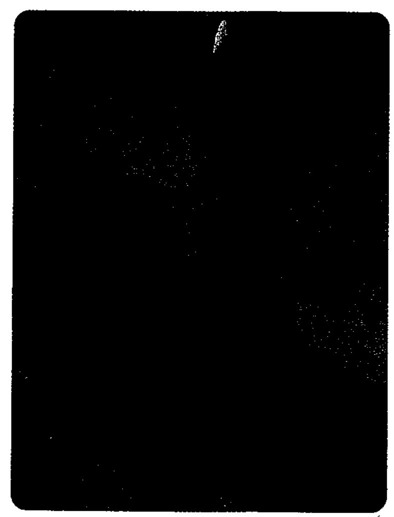
Genes and Variation

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.

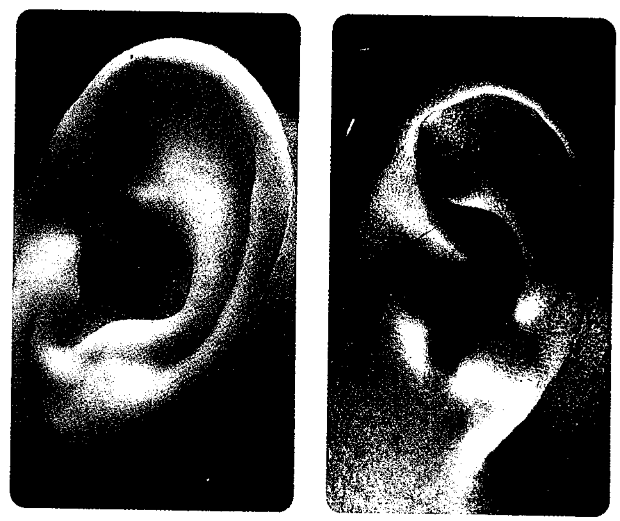
B. List the traits that more students have.

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.

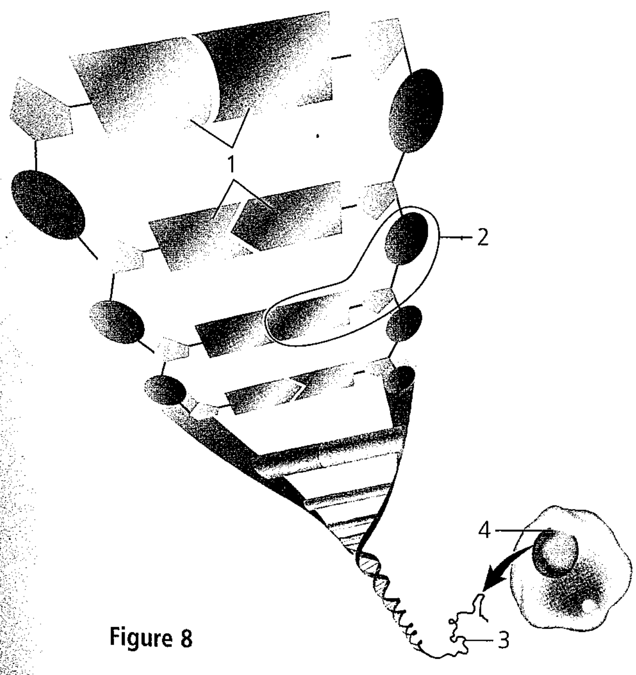


Figure 8

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.

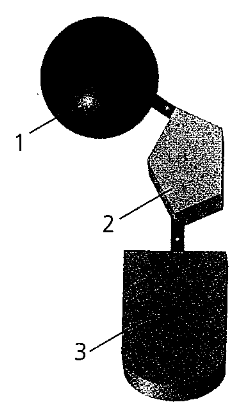


Figure 9