CHAPTER 5

Getting Ready to Learn

CONCEPT REVIEW

- Traits are controlled by genes on chromosomes.
- Genes can be dominant or recessive.
- Cells have DNA, RNA, and proteins.

VOCABULARY REVIEW

organelle p. 20

protein p. 43

gene p. 102

technology *See Glossary.*

CONTENT REVIEW
CLASSZONE.COM
Review concepts and vocabulary.

TAKING NOTES

SUPPORTING MAIN IDEAS

Make a chart to show main ideas and the information that supports them. Copy each blue heading; then add supporting information, such as reasons, explanations, and examples.

CHOOSE YOUR OWN STRATEGY

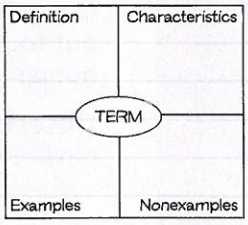
Take notes about new vocabulary terms using one or more of the strategies from earlier chapters —**four square, word triangle, frame game,** or **magnet word.** Feel free to mix and match the strategies, or use an entirely different vocabulary strategy.

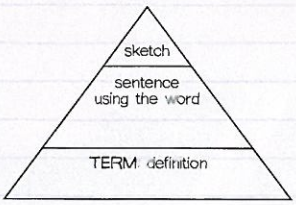
See the Note-Taking Handbook on pages R45–R51.

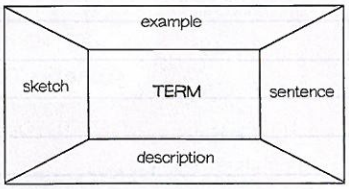
SCIENCE NOTEBOOK

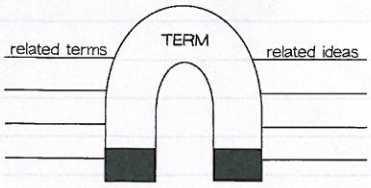
DNA sequences can change.

- Variations in DNA make one organism different from another.
- Human DNA has 6 billion base pairs; yeast DNA has 12 million base pairs.









KEY CONCEPT

5.1 DNA and RNA are required to make proteins.

BEFORE, you learned

- Traits pass from parents to offspring in predictable patterns
- Traits are passed on through genes
- In sexual reproduction, offspring get half their genes from each parent

NOW, you will learn

- How the structure of DNA stores information the cell needs
- How DNA is copied
- How RNA uses the information from DNA to make proteins

VOCABULARY

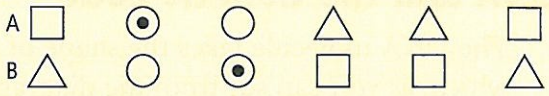
replication p. 137
RNA p. 138

EXPLORE Templates

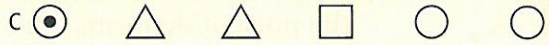
How does a template work?

PROCEDURE

1. Write a set of rules to describe how the characters in line A relate to the characters in line B.



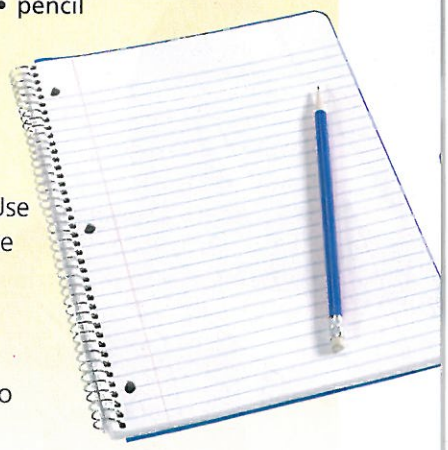
2. Place a piece of paper just under line C below. Use the rules from step 1 to produce a template—the corresponding pattern that goes with line C.



3. Give the rules and the template to a classmate to produce a copy of line C.

MATERIALS

- paper
- pencil

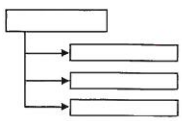


WHAT DO YOU THINK?

What is a template and how does it differ from a copy?

SUPPORTING MAIN IDEAS

Make a chart of information supporting the main idea: *DNA is the information molecule.*



DNA is the information molecule.

DNA is a molecule that stores information—that's all it does. You could compare the information in DNA to the books in your local library. You might find a book describing how to bake a cake, make a model sailboat, or beat your favorite computer game. The books, however, don't actually do any of those things—you do. The "books" in the DNA "library" carry all the information that a cell needs to function, to grow, and to divide. However, DNA doesn't do any of those things. Proteins do most of the work of a cell and also make up much of the structure of a cell.

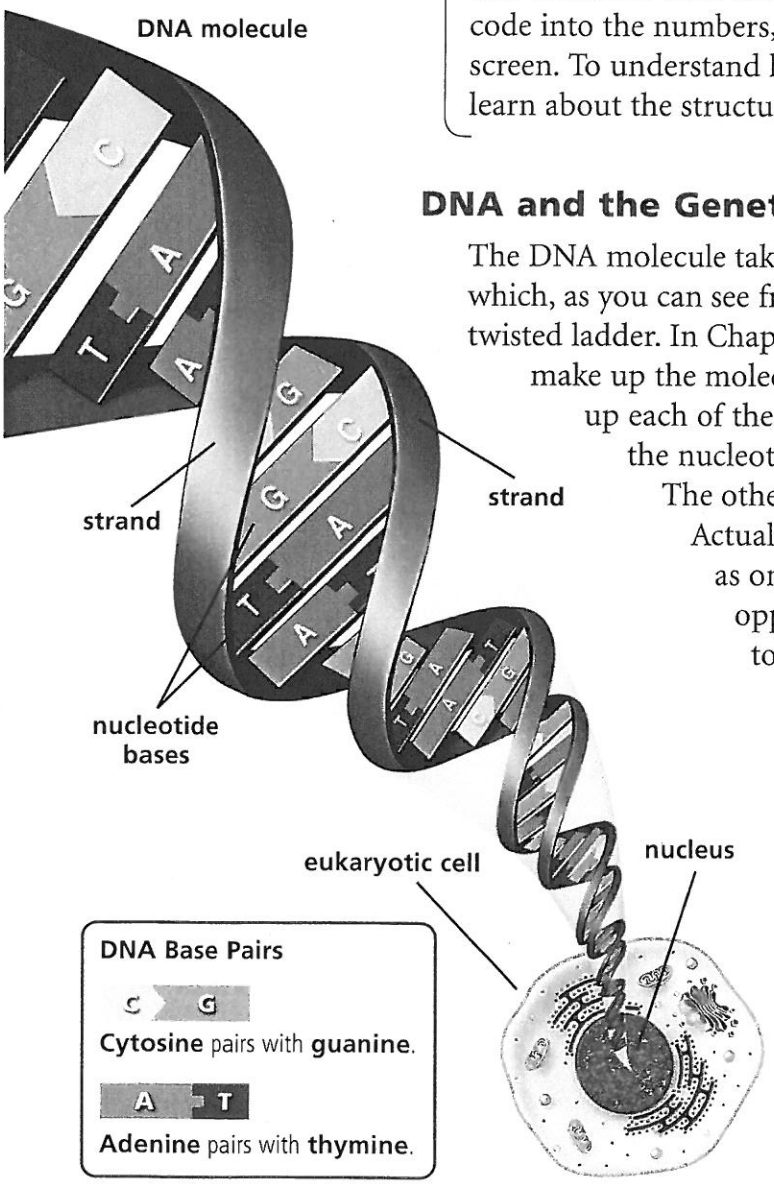
Proteins and Amino Acids

Proteins are large molecules that are made up of chains of amino acids. Twenty different amino acids come together in enough combinations to make up the thousands of different proteins found in the human body. Some proteins are small. For example, lysozyme is a digestive protein that is made up of a sequence of 129 amino acids. Some proteins are large. For example, dystrophin is a huge structural protein that is made up of 3685 amino acids.

RESOURCE CENTER
CLASSZONE.COM
Learn more about DNA.

CHECK YOUR READING What is the relationship between proteins and amino acids?

DNA stores the information that enables a cell to put together the right sequences of amino acids needed to produce specific proteins. Scientists describe DNA as containing a code. A code is a set of rules and symbols used to carry information. For example, your computer uses a code of ones and zeroes to store data and then translates the code into the numbers, letters, and graphics you see on a computer screen. To understand how DNA functions as a code, you first need to learn about the structure of the DNA molecule.



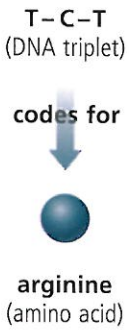
DNA and the Genetic Code

The DNA molecule takes the shape of a double-stranded spiral, which, as you can see from the diagram, looks something like a twisted ladder. In Chapter 2, you read about different subunits that make up the molecules found in cells. Nucleotide subunits make up each of the two strands of the DNA molecule. One part of the nucleotide forms the side rail of the DNA "ladder." The other part, the nucleotide base, forms the rung. Actually, two bases come together to form the rung, as one nucleotide base attaches to another from the opposite strand. You can see how the parts fit together in the diagram to the left.

There are four different nucleotides in DNA, identified by their bases: adenine (A), thymine (T), cytosine (C), and guanine (G). Because of differences in size and shape, adenine always pairs with thymine (A-T) and cytosine always pairs with guanine (C-G). The bases fit together like two pieces of a jigsaw puzzle. These bases are often referred to simply by their initials—A, T, C, and G. The phrase "all tigers can growl" may help you remember them.

It is the sequence—the order—of bases in a strand of DNA that forms the code for making proteins. Like a list of ingredients in a recipe book, a set of bases specifies the amino acids needed to form a particular protein. The cookbook uses just 4 bases—A, T, G, and C—to code for 20 amino acids. A code of 2 bases to 1 amino acid gives only 16 possible combinations. However, a code of 3 bases to 1 amino acid gives 64 possible combinations.

The genetic code is, in fact, a triplet code. A specific sequence of 3 nucleotide bases codes for 1 amino acid. For example, the triplet T-C-T on a strand of DNA codes for the amino acid arginine. Some amino acids have two different codes. Others have three, and some have four. A gene is the entire sequence of the bases that codes for all the amino acids in a protein. Each gene is made up of a sequence of bases at a particular location on the DNA.



Replication

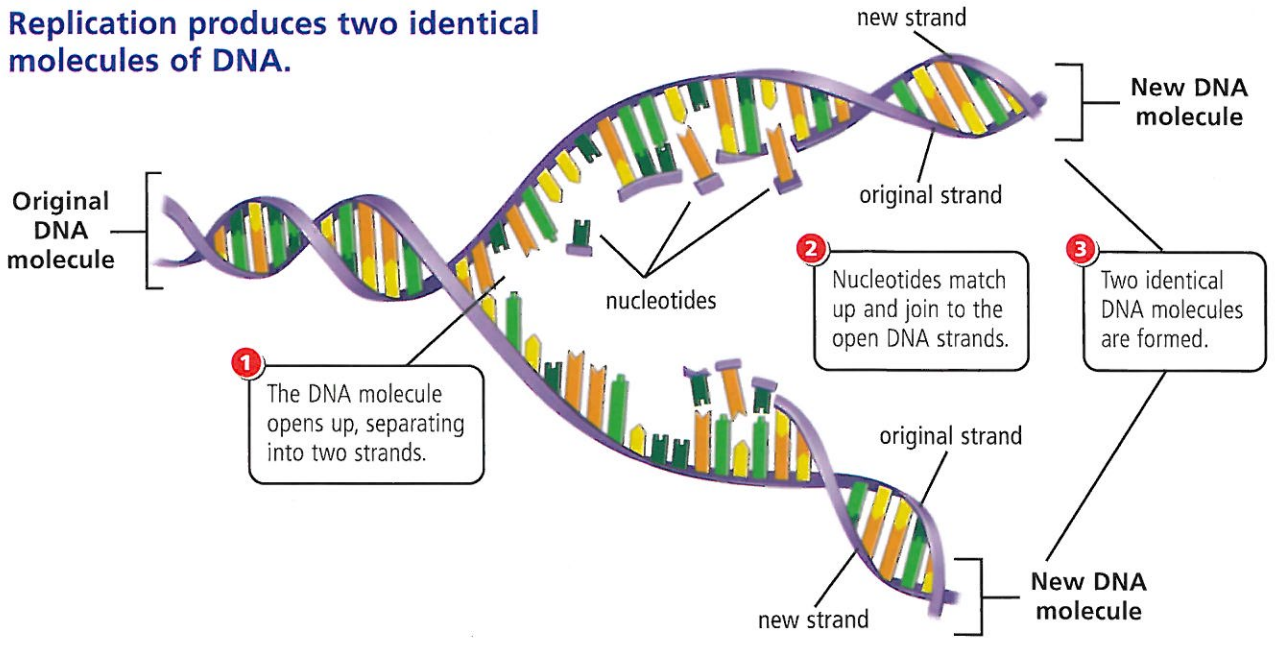
When a cell divides into two cells, each daughter cell receives an identical copy of the DNA. Before a cell divides, all of its DNA is copied, a process referred to as **replication.** Let's follow the process through for one DNA molecule. First, the two strands of DNA separate, almost like two threads in a string being unwound. Nucleotides in the area around the DNA match up, base by base, with the nucleotides on each DNA strand. C matches up with G, and A matches up with T. When replication is complete, there are two identical DNA molecules. Each molecule has one strand of old DNA and one strand of new DNA.

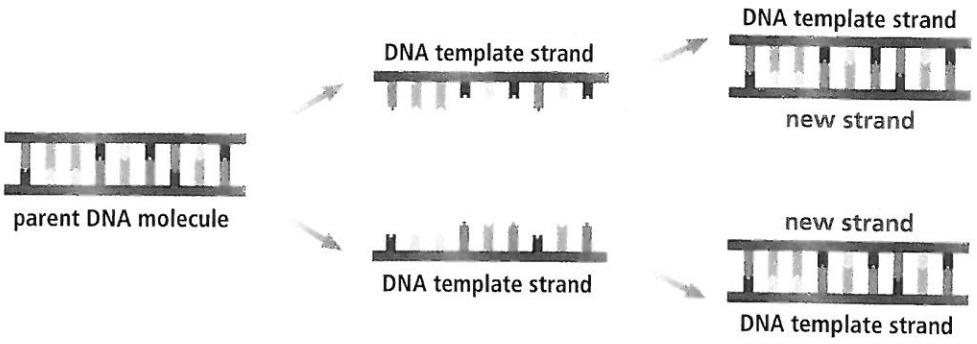
READING TiP

Replicate includes the root word meaning "to repeat."

Replication

Replication produces two identical molecules of DNA.





1. The parent DNA molecule is made up of two strands.
2. The two strands separate and are used as templates.
3. Two new identical DNA molecules are formed.

READING TiP

Complementary has a root that means "to complete."

During replication, each strand of DNA is used as a template to produce a copy of the other strand. A template is a pattern or shape that produces a matching, or complementary, product. If you've ever made a plaster model of your hand, you've worked with a template. You press your hand into a soft material that leaves a mold of your hand. You then pour liquid plaster into the mold to produce a copy of your hand. The mold is a template. Its shape allows you to make a complementary shape that matches your hand.

RNA is needed to make proteins.

VOCABULARY

Remember to choose strategies from an earlier chapter or some of your own to take notes on the term *RNA*.

DNA is not used to make proteins directly. Translating the genetic code of DNA involves another type of molecule, RNA. **RNA,** or ribonucleic acid, carries the information from DNA to a ribosome, where the amino acids are brought together to form a protein. DNA actually codes for RNA. Three different types of RNA are involved in making proteins. They are named for their functions:

- messenger RNA (mRNA)
- ribosomal RNA (rRNA)
- transfer RNA (tRNA)

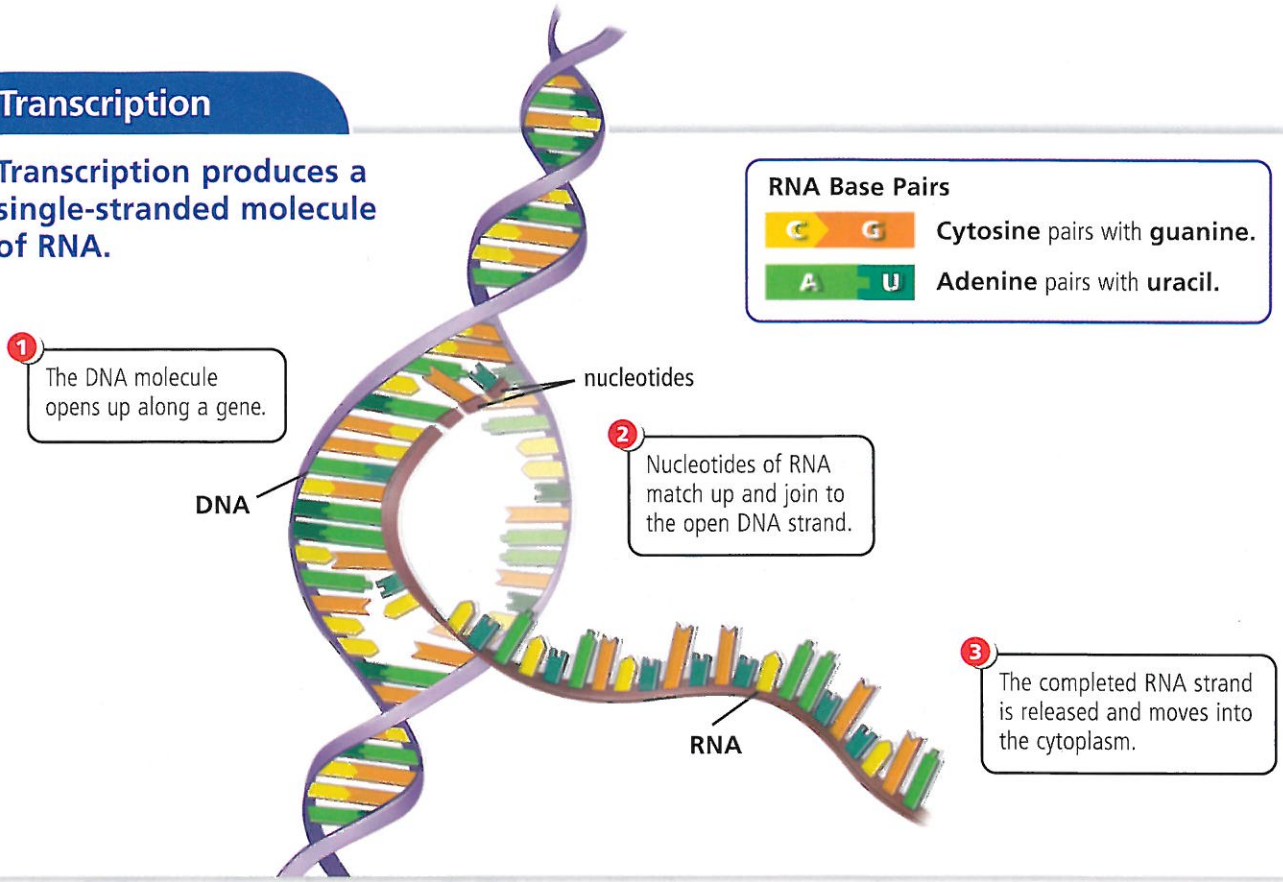
In prokaryotic cells, RNA and proteins are both made in the cytoplasm. In eukaryotic cells, DNA is copied in the nucleus, then RNA moves to the cytoplasm, where the proteins are made.

Transcription

The process of transferring information from DNA to RNA is called transcription. The chemical structure of RNA is quite similar to the structure of DNA. Both are made up of four types of nucleotide subunits. Three of the bases that make up RNA are the same as in DNA: guanine (G), cytosine (C), and adenine (A). However, the fourth base is uracil (U), not thymine.

Transcription

Transcription produces a single-stranded molecule of RNA.



During transcription, DNA is again used as a template, this time to make a complementary strand of RNA. Only individual genes are transcribed, not a whole DNA molecule. The DNA again opens up, just where the gene is located. As shown in the diagram above, RNA bases match up to complementary bases on the DNA template. Adenine pairs with uracil (A-U) and cytosine pairs with guanine (C-G).

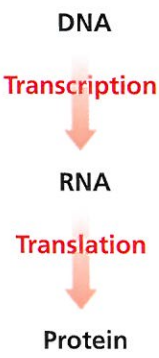
Transcription is different from replication in some important ways. Only one strand of DNA is transcribed, which means just a single strand of RNA is produced. When transcription is complete, the RNA is released, it does not stay attached to DNA. This means that many copies of RNA can be made from the same gene in a short period of time. At the end of transcription, the DNA molecule closes.

REMINDER

DNA base pairs:
C-G, A-T
RNA base pairs:
C-G, A-U

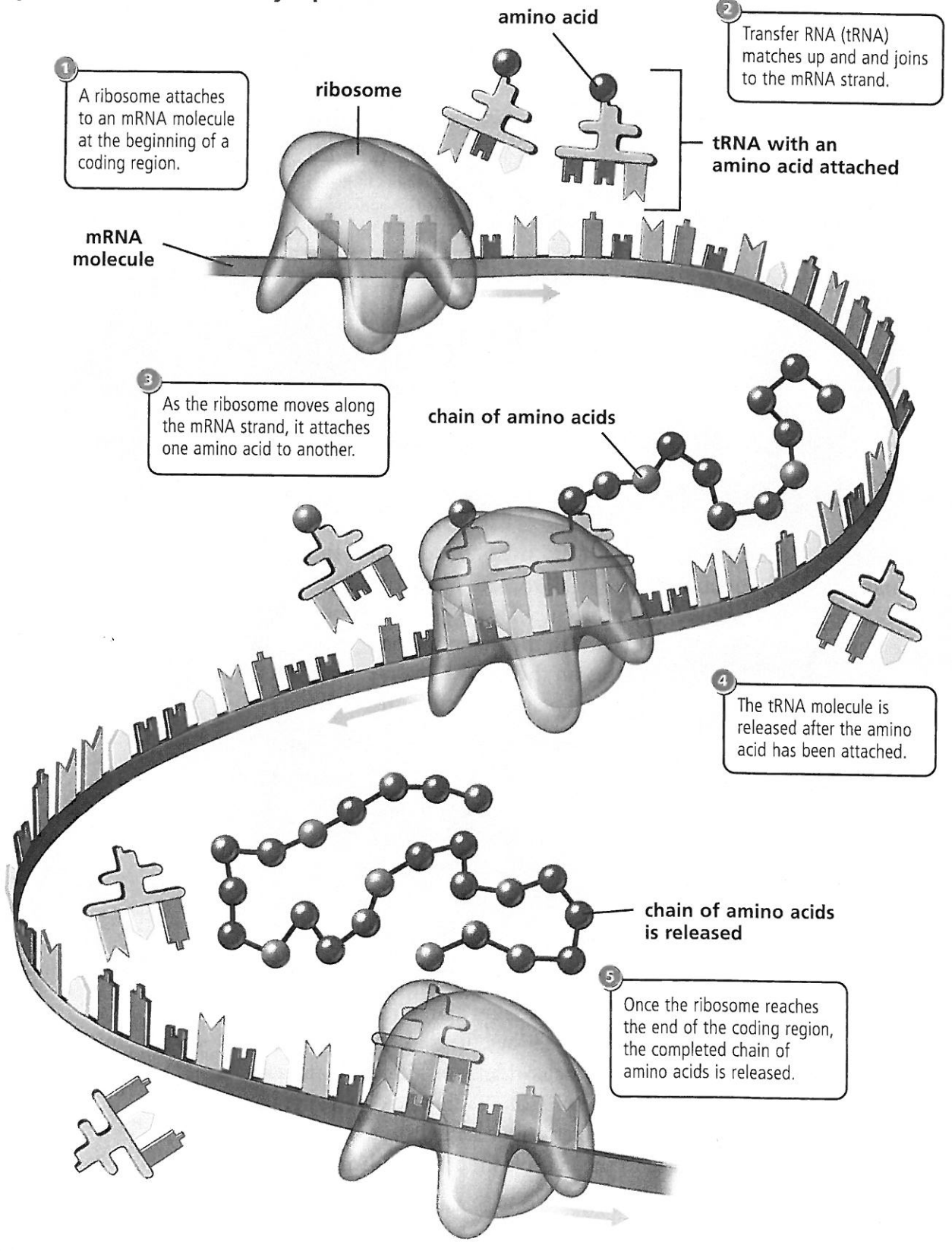
Translation

Replication and transcription involve passing along information that is coded in the language of nucleotide bases. To make proteins, cells have to translate this language of nucleotide bases into the language of amino acids. Three specific bases equal one amino acid. The actual assembly of the amino acids in their proper sequence is the translation. Translation takes place in the cytoplasm of a cell. It involves all three types of RNA.



Translation

The assembling of amino acids to form a protein occurs in the cytoplasm.



Proteins are made on ribosomes, structures that are made up of ribosomal RNA and proteins. If you think of DNA as a cookbook for making different proteins, and mRNA as a recipe for making a protein, then the ribosome is the place where the cooking gets done. In this analogy, tRNA gathers the ingredients, which are amino acids.

A tRNA molecule is shaped in such a way that one end of it can attach to a specific amino acid. The other end of tRNA has a triplet of bases that is complementary to a triplet of bases on mRNA. Transfer RNA does the actual translation of bases to amino acid when it matches up with mRNA. The diagram on page 140 shows the whole process.

READING TiP

Refer to the diagram on page 140 as you read the text. The numbers in the text match the numbers in the diagram.

1. Translation begins when a ribosome attaches to the beginning end of an mRNA molecule.
2. A tRNA molecule carrying an amino acid matches up to a complementary triplet on mRNA on the ribosome.
3. The ribosome attaches one amino acid to another as it moves along the mRNA molecule.
4. The tRNA molecules are released after the amino acids they carry are attached to the growing chain of amino acids.
5. The ribosome completes the translation when it reaches the end of the mRNA strand. The newly made protein molecule, in the form of a chain of amino acids, is released.

CHECK YOUR READING Describe how the three different types of RNA work together in protein synthesis.

VISUALIZATION
CLASSZONE.COM

Watch an animation of how proteins are made.

The process of making proteins is basically the same in all cells. The flow of information in a cell goes from DNA to RNA to protein.

5.1 Review

KEY CONCEPTS

1. Describe the shape of the DNA molecule and how nucleotide bases fit into that structure.
2. What is a protein and what is it made up of?
3. Identify three types of RNA involved in protein synthesis and briefly describe what they do.

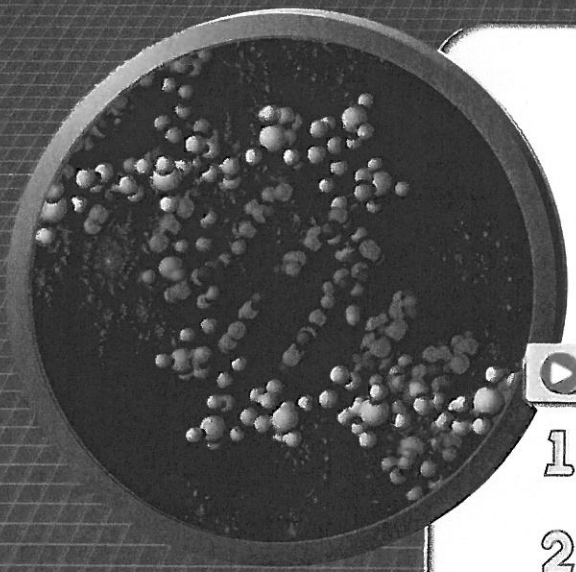
CRITICAL THINKING

4. **Infer** What might happen if the wrong amino acid is put on a tRNA molecule?
5. **Apply** Copy the following sequence of DNA bases: A-T-C-A-G-G. Write the complementary mRNA and tRNA sequences for this.

CHALLENGE

6. **Synthesize** Study the sequences you wrote for question 5. How does the tRNA sequence compare to the original DNA sequence?

CHAPTER INVESTIGATION



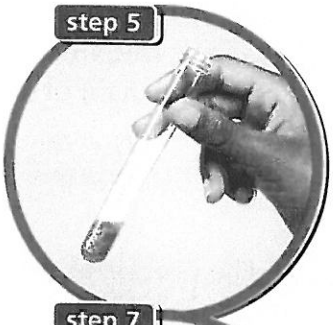
Extract and Observe DNA

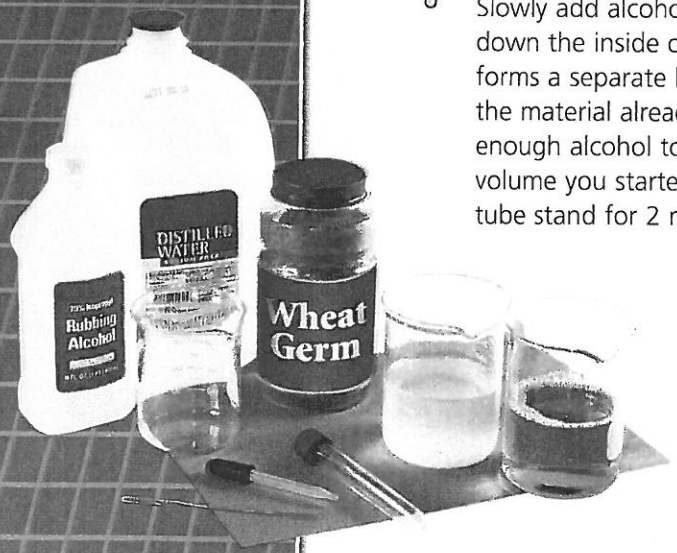
OVERVIEW AND PURPOSE In this activity, you will work with several simple chemicals that can break down the membranes of a cell. You will extract DNA from raw wheat germ. Then you will examine the properties of the extracted DNA.

Procedure

MATERIALS
- raw wheat germ
- scoop
- test tube
- warm distilled water
- detergent solution
- salt solution
- cold ethyl or isopropyl alcohol
- bent paper clip

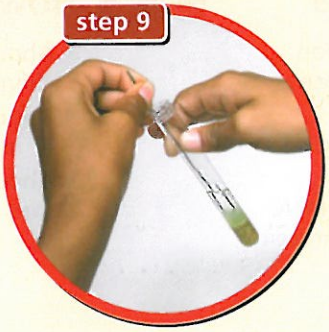
1. Make a table in your **Science Notebook** like the one shown on page 143.
2. Place a small scoop of wheat germ in a test tube. The wheat germ should be about 1 cm high in the test tube.
3. Add enough distilled water to wet and cover all of the wheat germ in the test tube.
4. Add 25–30 drops of detergent solution to the test tube.
5. For 3 minutes, gently swirl the test tube contents by rotating your wrist while holding the tube. Try not to make bubbles.
6. Add 25–30 drops of the salt solution to the test tube, and swirl for 1 more minute.
7. Hold the test tube tilted at an angle. Slowly add alcohol so that it runs down the inside of the test tube and forms a separate layer on top of the the material already in the tube. Add enough alcohol to double the total volume you started with. Let the test tube stand for 2 minutes.





8 Watch for stringy, cloudy material to rise up from the bottom layer into the alcohol layer. This is the DNA.

9 Use the bent paper clip to remove some DNA. Be careful to probe only the alcohol layer and not disturb the material at the bottom of the test tube.



10 Wash your hands after working with the chemicals.

Observe and Analyze

Write It Up

1. **OBSERVE** How do your observations of the DNA you just extracted compare with what you know about DNA. Record these comparisons in your notebook in a table similar to the one shown.
2. **INFER** What type of organism is wheat? Where is the DNA located in a wheat germ cell?
3. **INFER** What do you think was the purpose of using detergent in this experiment? Hint: How does soap work on greasy dishes?
4. **IDENTIFY LIMITS** What might happen if the wheat germ were not mixed properly with the detergent solution?

Conclude

Write It Up

1. **INFER** If you had used cooked or toasted wheat germ in this experiment, you would not have gotten good results. Why do you think this is the case?
2. **INFER** Would this experiment work with cells from other organisms, such as bananas, onions, or cells from your own cheek? Why or why not?
3. **INFER** Would DNA from a single cell be visible to the naked eye?
4. **APPLY** The procedure that you performed today is used by many people to obtain DNA for further study. Give some examples of how DNA information is used in the world today.

INVESTIGATE Further

CHALLENGE Repeat the experiment replacing the alcohol with water in step 7. Compare the results with the results you obtained using alcohol.

Extract and Observe DNA

Table 1. Properties and Observations

Properties of DNA	Observations

KEY CONCEPT

5.2 Changes in DNA can produce variation.

BEFORE, you learned

- DNA contains information in the form of a sequence of bases
- Genes code for RNA and proteins
- DNA is transcribed into RNA, which is used to make proteins

NOW, you will learn

- About mutations, any changes in DNA
- About the possible effects of mutations
- About pedigrees and how they are used

VOCABULARY

mutation p. 145
pedigree p. 147

EXPLORE Codes

What happens to a code if small changes occur?

PROCEDURE

1. Language is a type of code. Look at the English sentence below.

One day the cat ate the rat.

2. Insert an extra *a* into the word *cat* in the sentence above, but keep the spacing the same. That is, keep a space after every third letter.

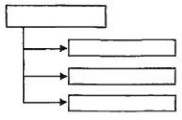
WHAT DO YOU THINK?

- Does the sentence still make sense? How were the rest of the words affected?
- How would other small changes affect the meaning of the sentence? Try substituting, removing, and switching letters.

MATERIALS

- pencil
- paper

SUPPORTING MAIN IDEAS
In your notebook, organize information that supports this main idea: *DNA sequences can change.*



DNA sequences can change.

Differences, or variations, in DNA are what make one organism different from another. The number of differences in the DNA sequences between two species is large. Each human cell, with its 46 chromosomes, contains an astounding 3 billion base pairs in its DNA. A yeast cell, by comparison, has 12 million base pairs in its DNA.

The number of differences between any two individuals of the same species is small. For example, about 99.9 percent of the DNA in the cells of two different humans is the same. Just 0.1 percent variation in DNA makes you the unique person you are. That averages out to one base in a thousand.

How can there be such great variety among people if their DNA is so similar? The reason is that of the 6 billion base pairs in human DNA, only 5 percent are in the genes that code for RNA and proteins. As you learned in Chapter 4, genes and their interaction with the environment are what determine the traits of a person.

Differences in genes affect the height of people or the color of their eyes, hair, or skin. Genes produce variation because the type or amount of the proteins they code for can vary from person to person. For example, skin color comes from a protein called melanin. The amount of melanin an individual produces affects the color of their skin.

Many traits, including skin tones, are affected by genes.

Given the huge number of base pairs in the DNA of any organism, it is not surprising that errors occur when DNA is copied. DNA is also affected by the environment. For example, exposure to ultraviolet radiation or x-rays can damage DNA. Both natural and human-made toxins, which are harmful chemicals, can also damage DNA.

Any change in DNA is called a **mutation.** Cells have different ways to repair mistakes in a DNA sequence. Certain enzymes actually proofread DNA, for example correcting mismatched base pairs. Other enzymes enable damaged DNA to be fixed.

VOCABULARY
Remember to choose a strategy from an earlier chapter or use one of your own to take notes on *mutation*.

CHECK YOUR READING What is a mutation?

When a mutation occurs in a gene, the coding region of DNA, the wrong amino acid might be placed in the amino-acid chain. If this happens, there are three possible outcomes.

1. **The mutation causes no effect.** Since some amino acids have more than one code, a mutation may not change the resulting protein. Also, since each cell has two sets of DNA, even if one gene is not working, enough protein may be produced.

2. **The effect of a mutation is minor.** A change in the genes that control the amount of melanin produced could affect not only how light or dark a person's skin is, it could also affect eye or hair color. The change, in this case, is a change in appearance.

3. **The effect of a mutation is great.** The effect can be good, such as a plant having an increased resistance to disease. Or the effect can be bad, causing a genetic disorder or disease.

RESOURCE CENTER
CLASSZONE.COM
Find out more about mutations.

Remember, only 5 percent of human DNA is in genes. If a mutation occurs in a noncoding region of DNA, then chances are that the mutation will have no effect. Such a mutation is neutral.

INVESTIGATE Neutral Mutations

SKILL FOCUS
Making models

MATERIALS
- newspaper
- pen
- paper-punch circles

TIME
15 minutes

How does a large number of noncoding sequences affect mutations?

PROCEDURE

1. Circle ten words on the page of a newspaper to represent genes. Place the newspaper on your desk.
2. Use a handful of paper-punch circles to represent mutations and scatter them onto the newspaper.
3. Count the number of paper-punch "mutations" that landed on "genes" and those that did not.

WHAT DO YOU THINK?

- What percentage of "mutations" affected gene sequences?
- What does this model suggest about the probability of mutations affecting genes that are only a small part of a DNA sequence?

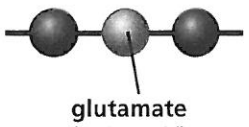
CHALLENGE Most of the sequences in bacterial DNA are genes. How could you use the same model to evaluate the effect of mutations on bacterial DNA?

Mutations can cause genetic disorders.

A genetic disorder is a disease or condition that results from mutations that affect the normal functioning of a cell. Sometimes these disorders are inherited, passed on from parent to offspring. Examples of inherited disorders include Tay-Sachs disease, cystic fibrosis, sickle cell disease, and albinism. Other genetic disorders result from mutations that occur during a person's lifetime. Most cancers fall into this category.

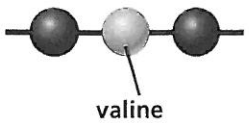
CHECK YOUR READING What is a genetic disorder?

normal hemoglobin
(protein)



glutamate
(amino acid)

sickle cell hemoglobin
(protein)

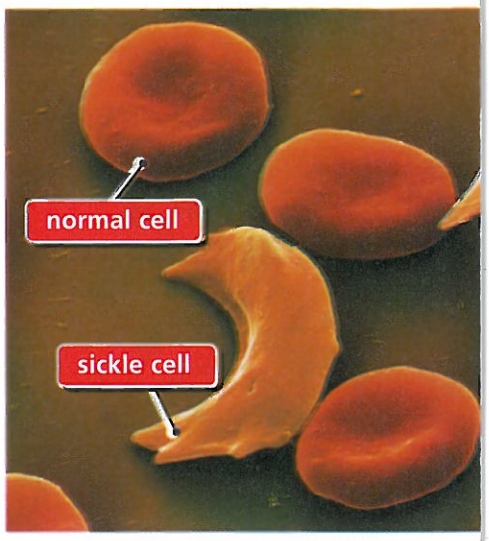


valine
(amino acid)

Sometimes a person carries a tendency for a disease, such as diabetes, glaucoma, Alzheimer's disease, or emphysema. In some cases, a person's behavior can help prevent the disease. Cigarette smoke is a leading cause of lung cancer. Smoke also greatly increases the risk of people with a genetic tendency for emphysema to develop that disease.

Sickle cell disease is an interesting example of how a mutation can have more than one effect. The mutation occurs in one of the genes that code for hemoglobin. Hemoglobin is a protein that carries oxygen in red blood cells. The mutation causes one amino acid to be replaced with another.

Sickle cell disease is a recessive disorder. Only people who carry two recessive alleles are affected. Recall that an allele is one form of a gene. Because of the amino acid change, some red blood cells can take on a sickle shape. See the photograph at the right. The pedigree below shows the pattern of inheritance of the sickle cell allele through three generations of a family. A **pedigree** is a diagram of family relationships that includes two or more generations.

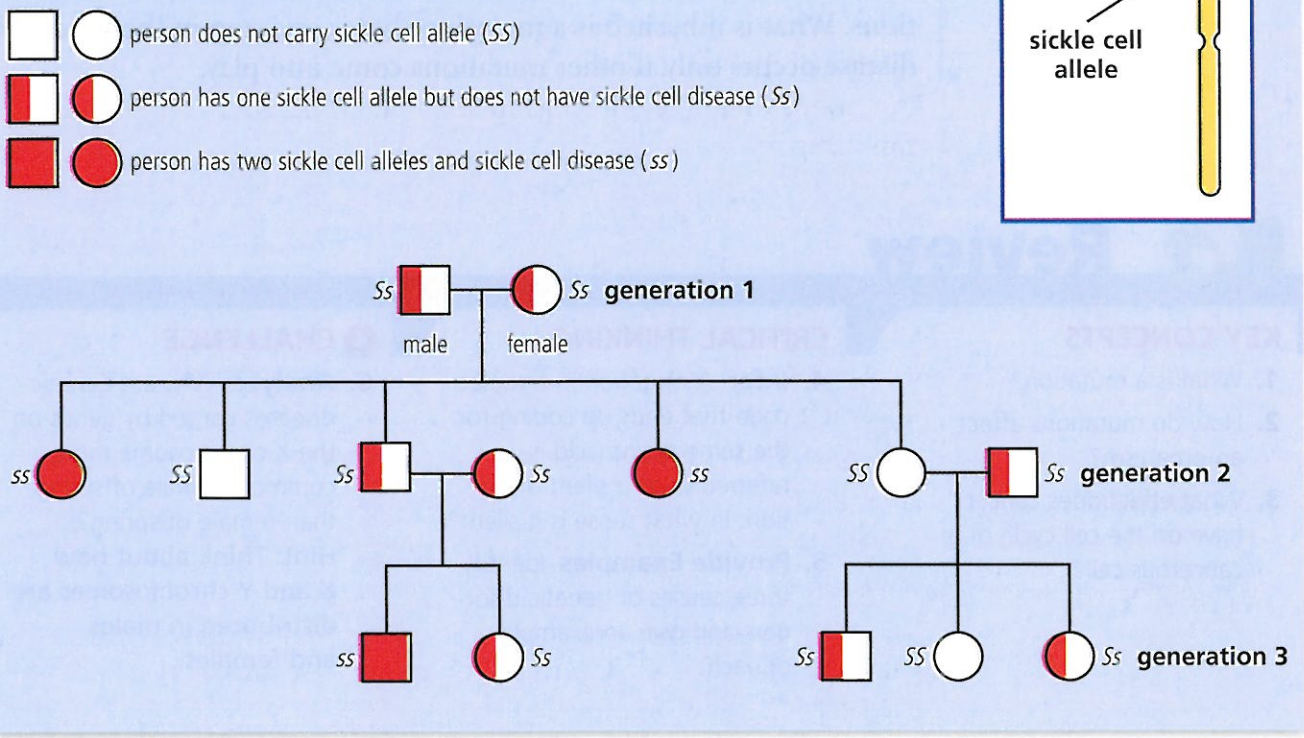


Sickle cell disease is a severe disease. Sickled red blood cells tend to break more easily than normal red blood cells. People with sickle cell disease do not get enough oxygen delivered to their body tissues, and the tissues become damaged. The disease is common in Africa and parts of India and the Middle East.

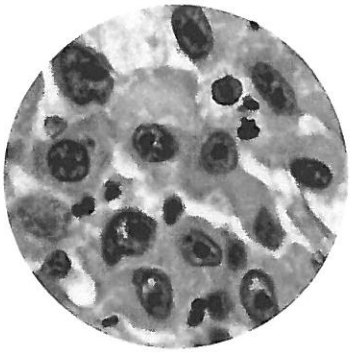
What is interesting about the sickle cell allele is that it provides protection against dying of malaria. Malaria is a severe disease, also common in Africa, India, and the Middle East. It is caused by microscopic organisms that reproduce in red blood cells. Scientists do not yet completely understand why people with the sickle cell allele are better able to survive malaria. However the effect of this protection is that the sickle allele remains common in populations that live in regions where malaria is common.

Pedigree for Sickle Cell Disease

Sickle cell disease is a recessive disorder.



Cancer is a genetic disorder that affects the cell cycle.



Cancer cells, such as the ones shown here, have abnormal shapes. Cancer cells reproduce uncontrollably and crowd out normal cells.

Cancer is not a single genetic disorder; but rather it is a group of disorders. All cancers are characterized by the uncontrolled division of cells. Normally, cells in a multicellular organism function to maintain the health of an organism. Cell division is controlled so that an organism has the number of cells it needs to function. Cancer cells are, in a way, "selfish" cells. Where normal cells stay within the same tissue, cancer cells spread quickly and can invade other tissues. A normal cell has a definite life span. Cancerous cells become "immortal"—they divide indefinitely.

CHECK YOUR READING What is a characteristic of all cancers?

Most cancers are caused by mutations to DNA that happen during a person's lifetime. Some mutations come from mistakes made during replication. But many are caused by harmful chemicals often referred to as *carcinogens* (kahr-SIHN-uh-juhnz). Many plants naturally produce carcinogens in their tissues. Nicotine is a carcinogen naturally found in tobacco leaves. There are other carcinogens in tobacco.

Ultraviolet and nuclear radiation as well as x-rays can also cause cancer. That is why, if you get an x-ray at the doctor's or dentist's office, the part of your body not being x-rayed is protected by a lead apron.

Some people may inherit a tendency for a particular cancer. That does not mean the cancer will occur. Cancer involves a series of mutations. What is inherited is a mutation that is one step in the series. The disease occurs only if other mutations come into play.

5.2 Review

KEY CONCEPTS

1. What is a mutation?
2. How do mutations affect an organism?
3. What effect does cancer have on the cell cycle of a cancerous cell?

CRITICAL THINKING

4. **Infer** A mutation in a triplet code that ends up coding for the same amino acid is referred to as a silent mutation. In what sense is it silent?
5. **Provide Examples** Identify three causes of genetic disorders and give an example of each.

CHALLENGE

6. **Analyze** Why are genetic diseases carried by genes on the X chromosome more common in male offspring than female offspring? Hint: Think about how X and Y chromosomes are distributed in males and females.

MATH in SCIENCE

SKILL: FINDING PERCENT OF A WHOLE

Percents and Populations

MATH TUTORIAL
CLASSZONE.COM
Click on Math Tutorial for more help with the percent equation.

Hemophilia is a genetic disorder in which blood does not clot properly. In any group of people who have hemophilia, approximately 80 percent have type A, which is caused by a mutation in one gene. Usually about 12 percent have type B, a different gene mutation.

To express what part of a population carries a gene mutation, scientists can use percentages. Once you know the percentage of a population, you can find out how many individuals that percent represents.

Example

Suppose a doctor is treating a group of people who have the disease hemophilia. The group has 400 people. About how many individuals would you expect to have hemophilia A?

(1) Write the percent as a decimal.

$$80\% = 0.80$$

(2) Multiply the decimal number by the total population.

$$0.80 \cdot 400 = 320.00$$

(3) Be sure the answer has the same number of decimal places as the total number of decimal places in the original factors.

$$0.80 \cdot 400 = 320.00$$

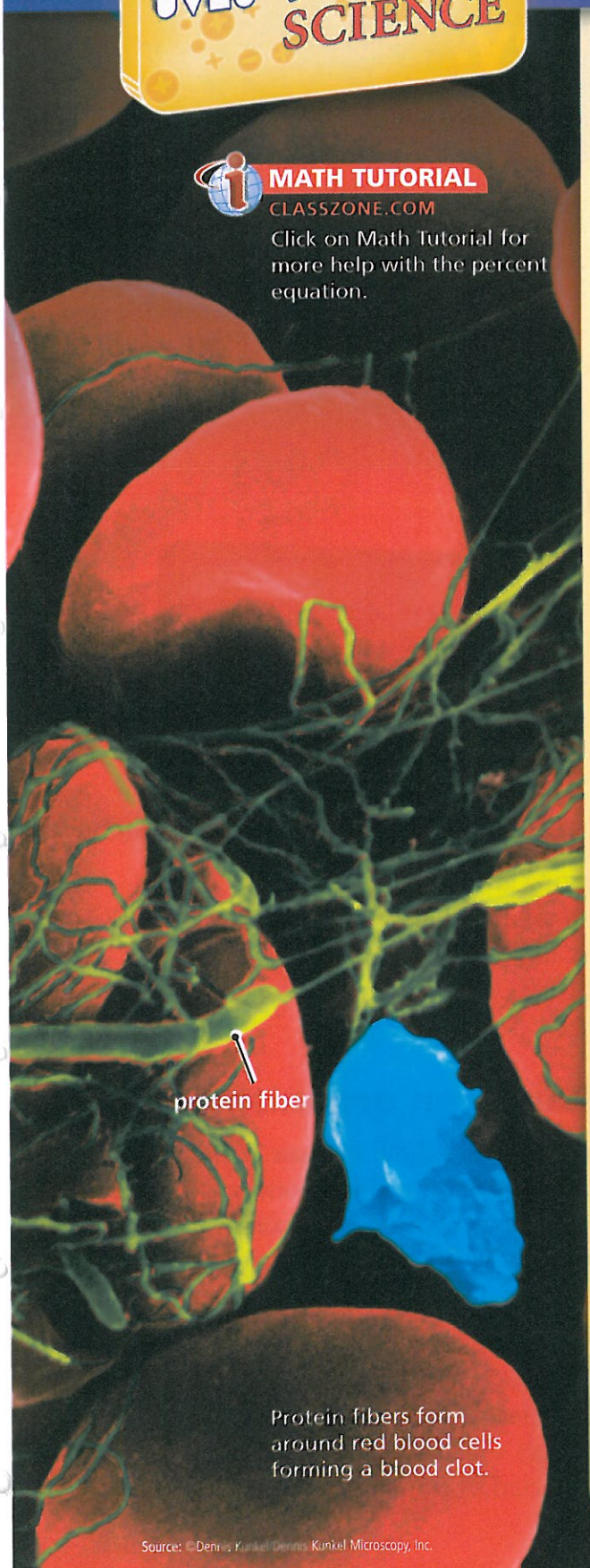
2 decimal places

ANSWER There are probably about 320 people with hemophilia A.

Answer the following questions for a group of 400 hemophilia patients.

1. How many patients are likely to have hemophilia B?
2. Suppose a new doctor begins treatment of 20 percent of the hemophilia A patients. How many individuals is that?
3. In as many as 30 percent of cases of hemophilia, there is no family history of the disorder. In the group of 400, how many individuals probably did not have a family history of hemophilia?

CHALLENGE Write a fraction in simplest terms equal to each percentage: 80 percent, 30 percent, 12 percent, 3 percent. When you multiply these fractions by 400, do you get the same or different results as when you multiply 400 by the percentages? Explain why the results may be different.



Protein fibers form around red blood cells forming a blood clot.

Source: © Dennis Kunkel Microscopy, Inc.

KEY CONCEPT

5.3 Modern genetics uses DNA technology.

BEFORE, you learned

- Mutations are changes to DNA
- Not all mutations have an effect on an organism
- Mutations can lead to genetic disorders

NOW, you will learn

- How scientists can change organisms by changing DNA
- About some applications of DNA technology
- About some issues surrounding the use of DNA technology

VOCABULARY

selective breeding p. 151
genetic engineering p. 151
genome p. 154
cloning p. 154

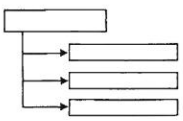
THINK ABOUT

What type of animal is this?

Look at the photograph of the animal to the right. The cells in this animal contain DNA from two different species. For a long time humans have been able to mix genes by breeding together animals of different but similar species. Now scientists have the technology to mix together genes from two very different species by inserting genes from one organism into the cells of another. What do the characteristics of this animal suggest about the source of its genes?

Changes in DNA can change an organism.

SUPPORTING MAIN IDEAS Begin a chart of information to support this main idea: *Changes in DNA can change an organism.*

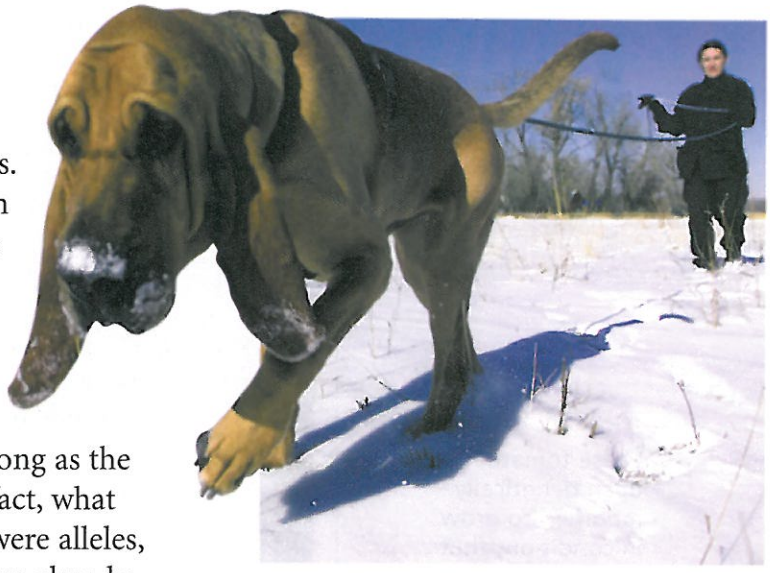


Organisms change over time. Changes come about because of mutations in DNA. Random changes in DNA may introduce new traits into an organism. Over time, certain traits may become more common in one group of organisms as they interact with the environment and each other.

Are all changes in a group of organisms random? There are dogs, such as bloodhounds, that are particularly well suited to tracking. There are cows that give large quantities of milk and crops that produce large quantities of grain. Changes such as these are not random, but result from careful breeding directed by humans.

Selective Breeding

For thousands of years, humans have been carefully selecting and breeding certain plants and animals that have desirable traits. As the years have passed, horses have gotten faster, pigs have gotten leaner, and corn has become sweeter. **Selective breeding** is the process of selecting and breeding parent organisms to pass on particular traits to the offspring.



Bloodhounds, with their strong sense of smell, are used in police work for tracking.

Selective breeding can be successful as long as the desirable traits are controlled by genes. In fact, what these early farmers were actually selecting were alleles, particular versions of a gene. The alleles were already present in some members of the population. People were not changing DNA, but they were causing certain alleles to become more common in a particular breed. The different dog breeds are a good example of this. All dogs share a common ancestor, the wolf. However, thousands of years of selective breeding have produced dogs with a variety of characteristics.

CHECK YOUR READING How does selective breeding affect DNA?

Genetic Engineering

Within the last fifty years it has become possible to directly change the DNA of an organism. **Genetic engineering** is the process in which a sequence of DNA from an organism is first isolated, then inserted into the DNA of another organism, changing that organism's DNA. The DNA that is engineered often codes for some particular trait of interest. Using technology, scientists can take a gene from one species and transfer it into the DNA of an organism from another species. The resulting organisms are referred to as genetically modified (GM), or transgenic.

READING TiP
The root *trans-* means "across." *Transgenic* refers to the movement of genes across species.

CHECK YOUR READING What are three steps involved in genetic engineering?

One application of genetic engineering across species involves making plants more insect-resistant. Genetic engineers have isolated genes in microorganisms that produce natural insect-killing chemicals, or pesticides. They have succeeded in transferring these genes into the DNA of crop plants, such as corn and soybeans. The cells of the genetically modified plants then produce their own pesticide, reducing the amount of chemical pesticide farmers need to use on their fields.

These tomatoes have been genetically modified to grow in conditions that would not support naturally occurring tomatoes.

Genetic engineering can address very specific needs. For example, in many parts of the world, soils are poor in nutrients. Or the soil may contain salts. Such soil is not good for growing food crops. Genetic engineers have inserted a gene from a salt-tolerant cabbage into tomatoes. The salt-tolerant tomatoes can grow in soil that natural tomatoes cannot grow in. These tomatoes can also be grown using brackish water, which is water with a higher salt content than fresh water.

There are risks and benefits associated with genetic engineering.

Genetic engineering offers potential benefits to society, but also carries potential risks. Probably most people in the United States have eaten foods made from genetically modified corn or soybeans. The plants have bacterial genes that make them more resistant to plant-eating insects. This increases food production and reduces the amount of chemical pesticides needed. Less chemical pesticide on the ground reduces the risk of environmental pollution.

However, many people worry that the natural pesticides produced by a genetically modified plant might have some effect on humans. What if genetically modified plants cross-breed with other plants, and give protection to plants that are considered weeds? There is also the question of how to let people know if the food they eat is genetically modified. Many people think that such food should be labeled.

CHECK YOUR READING What are some risks and benefits associated with using genetic engineering in food crops?

There is uncertainty about how the DNA of genetically modified organisms might affect natural populations. For example, scientists are working with salmon that are genetically modified to grow more quickly. Fish are an important food source, and natural fish populations are decreasing. However, the salmon are raised in pens set in rivers or the sea. If the fish escape, they may breed with fish from wild populations. Government officials have yet to decide whether the benefit of having these fast-growing fish is worth the risk to wild populations.

ANALYZE How would the genetic material of wild salmon change if they were to breed with genetically modified salmon?

DNA technology has many applications.

DNA technology is used in many different ways. It can be used to add nutrients to foods to make them more nutritious. It can be used to produce new and better drugs for treating disease. DNA technology can also be used to determine whether a particular drug might cause side effects in an individual. And it can be used to screen for and perhaps treat genetic disorders.

DNA Identification

You may have seen news stories about how DNA evidence is used to solve a crime. Law enforcement specialists gather as much DNA evidence as they can from a crime scene—for example, skin, hair, or blood. In a laboratory, they scan about ten regions of the DNA that are known to vary from individual to individual. They use this information to produce a DNA profile—a DNA fingerprint. This fingerprint is unique to a person, unless that person has an identical twin. If DNA analysis of tissue found at the crime scene matches the DNA fingerprint of a suspect, then police know the suspect was at the scene.

The more matches found between crime-scene DNA and the suspect's DNA, the higher the probability that the suspect is guilty. Experts currently recommend that at least four to six DNA regions be matched to establish a person's guilt. The chances are very small that another person would have exactly the same DNA profile for all the DNA regions tested. Of course, the courts also take other forms of evidence into account before an individual is convicted of a crime.

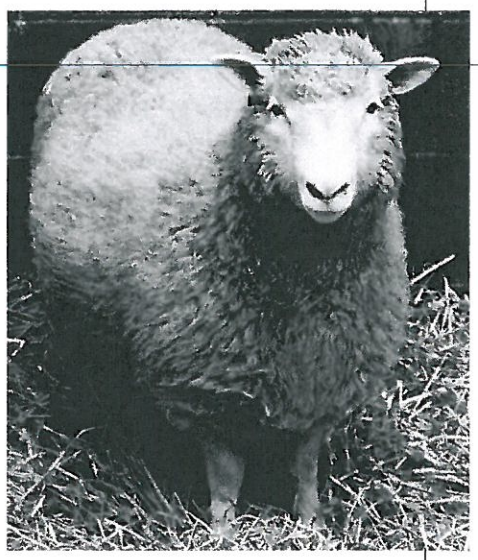
Learn more about DNA technology.

Studying Genomes

VOCABULARY
Don't forget to choose a strategy to take notes on the term *genome*.

One of the most challenging scientific projects ever undertaken was the Human Genome Project. A **genome** is all the genetic material in an organism. The primary goal of the project was to sequence the 3 billion nucleotide pairs in a single set of human chromosomes. The initial sequence was published in 2001. Scientists are now working to identify the approximately 30,000 genes within the human genome.

Scientists have completed sequencing the genomes of many organisms. These organisms, often referred to as model organisms, enable scientists to compare DNA across species. Many of the genes found in model organisms, such as the fruit fly and mouse, are also found in the human genome.



Dolly was the first successful clone of a mammal.

Scientists are aware that there are many ethical, legal, and social issues that arise from the ability to change DNA. We as a society have to decide when it is acceptable to change DNA and how to use the technology we have. **Cloning** is a technique that uses technology to make copies. It can be applied to a segment of DNA or to a whole organism. Cloning has been used in bacteria to produce proteins and drugs that help fight disease. Human insulin, which is used to treat people with a certain form of diabetes, is now produced in large quantities as the result of cloning techniques.

The same technology, which is so helpful in one application, can be a cause of concern when applied in a different way. In 1996, scientists produced the first clone of a mammal, a sheep named Dolly. All of Dolly's DNA came from a single body cell of another sheep. The ability to clone such a complex animal raised many concerns about future uses of cloning. This, as well as many other possible applications of technology, makes it important that people understand the science of genetics. Only then can they make informed decisions about how and when the technology should be used.

5.3 Review

KEY CONCEPTS

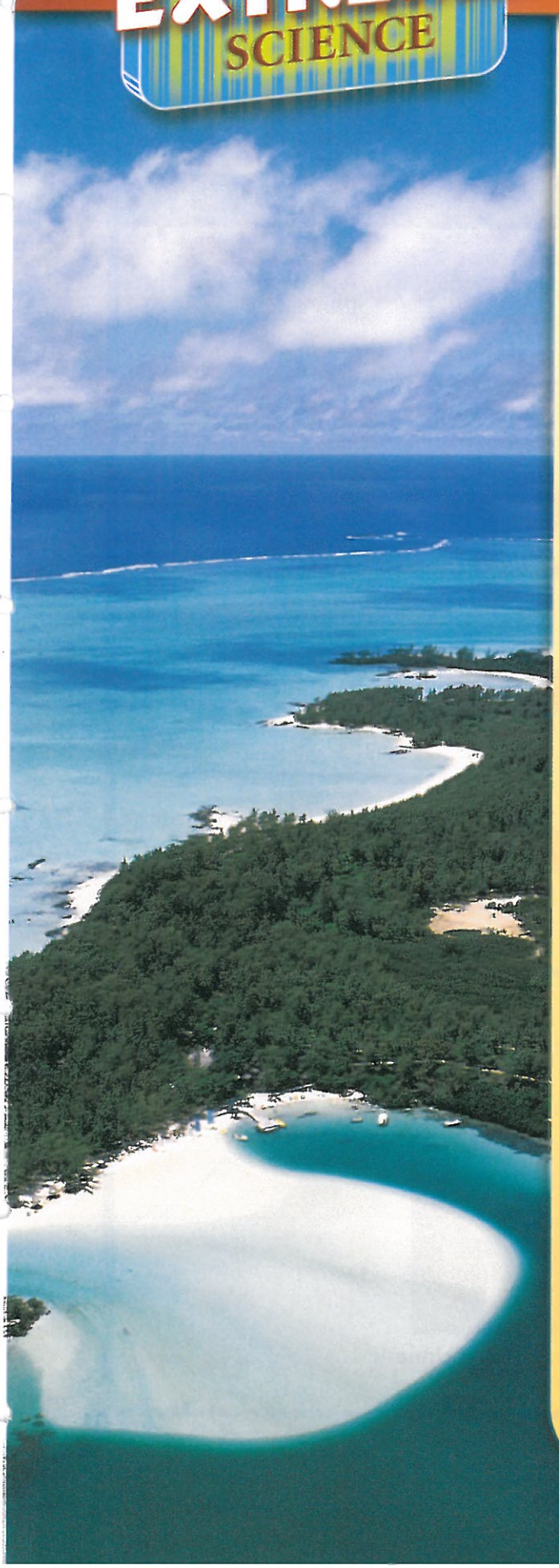
1. What is a genetically modified organism?
2. What is the Human Genome Project?
3. List three different applications of DNA technology.

CRITICAL THINKING

4. **Compare and Contrast** How is selective breeding different from genetic engineering? How is it the same?
5. **Analyze** Do you think a genetically modified trait in an organism can be undone? Why or why not?

CHALLENGE

6. **Analyze** Why might a genetically engineered drug, such as insulin, be better for treatment of disease than a drug that is manufactured chemically?



EXTREME SCIENCE

DNA OF EXTINCT ANIMALS

Modern Genetics Meets the Dodo and the Solitaire

Hunted to Extinction

The dodo bird was first sighted around 1600 by Portuguese sailors arriving on the shores of the island of Mauritius in the Indian Ocean. Portuguese sailors hunted the dodo, which was unable to fly, and used its meat for food. The bird, never having had contact with humans, did not run away. Only a mere 80 years later, the dodo was extinct.

DNA Evidence

Few bone specimens of the dodo bird remain today. Scientists collected and analyzed genetic material from preserved dodo specimens and specimens of another, similar extinct bird called the solitaire bird. The DNA evidence was compared with the genetic material of about 35 species of living pigeons and doves.

The model shows a solitaire bird, a close relative of the dodo.

The DNA had a story to tell. Evidence suggests that the dodo and solitaire bird were close relatives. Their nearest living relative is a species of pigeon found in nearby southeast Asia. From this evidence, scientists hypothesize that the dodo and solitaire birds species became separate almost 25 million years ago. In the geographic location of the island of Mauritius, the dodo developed its distinct characteristics, which eventually led to its extinction.

EXPLORE

1. **MAKE INFERENCES** How can scientists use what they know from analyzing dodo bones to help them form conclusions about the physical characteristics of the bird?
2. **CHALLENGE** Several factors contributed to the extinction of the dodo bird. Look online to find out more about these factors. How can learning about what happened to the dodo help save today's endangered species from extinction?

5 Chapter Review

the BIG idea

DNA is a set of instructions for making cell parts.

CONTENT REVIEW
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KEY CONCEPTS SUMMARY

1 DNA and RNA are required to make proteins.

DNA contains a code that enables a cell to make RNA and proteins. Replication copies the code before a cell divides.

- DNA's triplet code enables a cell to code for proteins
- mRNA, tRNA, and ribosomes translate the code into a sequence of amino acids.
- The amino acids form a protein needed for cell function.

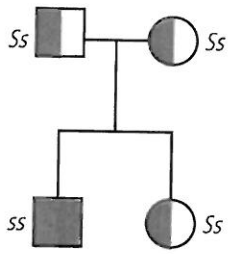
DNA → RNA → Proteins

VOCABULARY
replication p. 137
RNA p. 138

2 Changes in DNA can produce variation.

Differences in DNA produce variations. Any change to DNA is a mutation. Many mutations have little or no effect. However, some mutations can change the way a cell works—sometimes helping an organism, sometimes hurting it.

Genetic disorders are caused by mutations in DNA. Some are inherited and can be followed through different generations of a family by using a pedigree. Other genetic disorders, such as cancer, are caused by mutations that occur during a person's lifetime.



pedigree

VOCABULARY
mutation p. 145
pedigree p. 147

3 Modern genetics uses DNA technology.

Changes in DNA can change an organism. Selective breeding changes organisms by choosing desired traits already coded for by DNA.

Genetic engineering introduces changes to the DNA of an organism. It can be used to

- introduce new traits into an organism
- produce medicines and other products
- identify individuals
- clone genes as well as organisms
- sequence the genome of an organism

DNA technology raises important issues for society.


Dolly was the first clone of a mammal.

VOCABULARY
selective breeding p. 151
genetic engineering p. 151
genome p. 154
cloning p. 154

Reviewing Vocabulary

Copy the chart below and write the definition for each word. Use the meaning of the word's root to help you.

Term	Root Meaning	Definition
1. replication	to repeat	
2. mutation	to change	
3. genome	relating to offspring	
4. cloning	to branch off	

Reviewing Key Concepts

Multiple Choice *Choose the letter of the best answer.*

5. Genes are sequences of DNA, which are made up of
- **a.** nucleotides
- **b.** chromosomes
- **c.** phosphates
- **d.** ribosomes

6. What happens during replication?
- **a.** DNA is copied.
- **b.** RNA is copied.
- **c.** Ribosomes are made.
- **d.** Proteins are made.

7. Which base is found only in RNA?
- **a.** thymine
- **b.** guanine
- **c.** adenine
- **d.** uracil

8. The main function of mRNA in protein synthesis is to
- **a.** transfer amino acids to a ribosome
- **b.** carry proteins to the ribosome
- **c.** transcribe genes from DNA
- **d.** connect nucleotides together

9. Proteins are made up of a sequence of
- **a.** chromosomes
- **b.** amino acids
- **c.** nucleotides
- **d.** base pairs

10. Mutations are changes in
- **a.** DNA
- **b.** the cell cycle
- **c.** tRNA
- **d.** proteins

11. Which is a known cause of genetic mutations?
- **a.** poor nutrition
- **b.** malaria
- **c.** ultraviolet radiation
- **d.** cancer

12. A pedigree shows
- **a.** how proteins are synthesized
- **b.** how genes are inherited in a family
- **c.** where mutations are located in a sequence of DNA
- **d.** which triplet of bases matches up with a particular amino acid

13. The main goal of the Human Genome Project was to
- **a.** find cures for genetic diseases
- **b.** find all mutations in human DNA
- **c.** count the number of genes in human DNA
- **d.** sequence all DNA on human chromosomes

14. Genetic engineering involves
- **a.** inserting changed DNA into an organism
- **b.** cross-breeding plants
- **c.** testing new medicines for genetic diseases
- **d.** using x-rays to change DNA

Short Answer *Write a short answer to each question.*

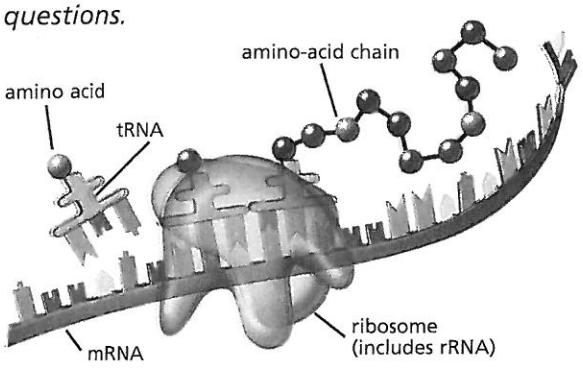
15. DNA is described as the information molecule. What is the information that DNA carries?

16. What is the difference between selective breeding and genetic engineering?

17. List three applications of DNA technology and how these uses benefit humans.

Thinking Critically

Use the diagram to answer the next three questions.



18. **ANALYZE** How does the mRNA strand above compare with the DNA template that produced it? Use the words *guanine, cytosine, thymine, adenine, and uracil* in your answer.

19. **SUMMARIZE** Three types of RNA are needed for protein synthesis. What are the three types and what is the function of each?

20. **APPLY** A protein contains 131 amino acids. How many bases will there be on the mRNA strand corresponding to these amino acids and how do you know?

21. **ANALYZE** A cell contains two sets of DNA. If the gene on one molecule of DNA has a mutation, how will that affect the gene on the other molecule of DNA?

22. **SYNTHESIZE** A mutation occurs during DNA replication. The following sequence

A-T-T-A-C-A-G-G-G

is copied as,

A-T-A-C-A-G-G-G

with one base missing. How does that affect the triplet code?

23. **SEQUENCE** List the steps in making a protein. Start with a gene on a DNA molecule. Include the chemical subunits involved in each step.

24. **EVALUATE** A person who carries a gene for a genetic disorder may not get the disorder. How can that be?

25. **INFER** How might a scientist determine if a neutral mutation has occurred in an organism?

26. **PREDICT** A mutation in an Arctic hare causes brown spots to appear on normally white fur. Explain how the mutation might affect the ability of the hare to survive.

27. **EVALUATE** Doctors can sometimes cure cancer by removing cancerous cells from a person's body. Why is it important for the doctors to remove all the cells?

28. **EVALUATE** How might selective breeding of a type of animal limit genetic diversity within the breed?

29. **EVALUATE** If a scientist compares the genome of a mouse to that of a human and discovers that the two organisms have many of the same genes, what can the scientist infer about how the cells in the two organisms function?

the BIG idea

30. **DRAWING CONCLUSIONS** Look again at the photograph on pages 132–133. How have models helped scientists understand the function of DNA?

31. **CONNECT** A local newspaper has written an editorial against the use of genetic engineering. The writer argues that humans should never change the DNA in an organism, even though they have the technology to do so. Write a response to the editorial, stating whether you think the benefits humans get from genetic engineering are worth the risks.

UNIT PROJECTS

Evaluate all the data, results, and information from your project folder. Prepare to present your project. Be ready to answer questions posed by your classmates about your results.

Standardized Test Practice

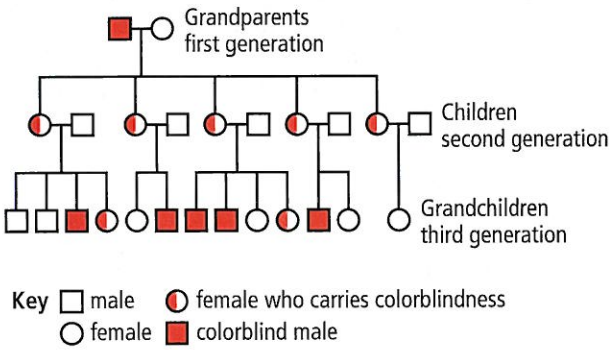
For practice on your state test, go to . . .
TEST PRACTICE
CLASSZONE.COM

Analyzing Data

Use the following information and the pedigree chart to answer the questions.

Red-green colorblindness is one of the most common genetic conditions in the human population. About 5 percent of males are red-green colorblind. A male receives just one allele for this trait, on the X chromosome he inherits from his mother. If he receives the allele for red-green colorblindness, he will be colorblind. His genotype will be cb/Y.

Females inherit two alleles for the trait. Colorblindness (cb) is recessive and the allele for regular color vision (Cb) is dominant. A female with both the recessive allele and the dominant allele will have normal color vision. Her genotype would be Cb/cb. However, if the female has a male child, her child may be colorblind. The pedigree chart shows colorblindness in three generations.



1. How many individuals in the first generation are colorblind?
   - **a.** two
   - **b.** one
   - **c.** none
   - **d.** three
2. How many individuals in the second generation are female?
   - **a.** none
   - **b.** one
   - **c.** two
   - **d.** five
3. Which statement describes the pattern of inheritance for colorblindness?
   - **a.** Grandmother and granddaughter are both colorblind.
   - **b.** Grandmother and son are both colorblind.
   - **c.** Grandfather and granddaughter are both colorblind.
   - **d.** Grandfather and grandson are both colorblind.
4. What are the genotypes of the males in the third generation?
   - **a.** Cb/Y, Cb/Y, Cb/Y, cb/Y, cb/Y, cb/Y, cb/Y
   - **b.** cb/Y, cb/Y, cb/Y, cb/Y,cb/Y, cb/Y, cb/Y
   - **c.** Cb/Y, Cb/Y, Cb/Y, Cb/Y, Cb/Y, Cb/Y, CbY
   - **d.** Cb/Y, Cb/Y, cb/Y, cb/y, cb/y ,cb/Y, cb/Y

Extended Response

5. Write a paragraph explaining why a color-blind man who has three daughters and one son with normal color vision might have two grandsons who are color-blind. Use the terms in the vocabulary box in your answer. Underline each term.

genotype	phenotype	allele
recessive	dominant	generation

6. The same color-blind man has four granddaughters. Would you predict the granddaughters to be colorblind? Explain why or why not. Use the terms in the vocabulary box.