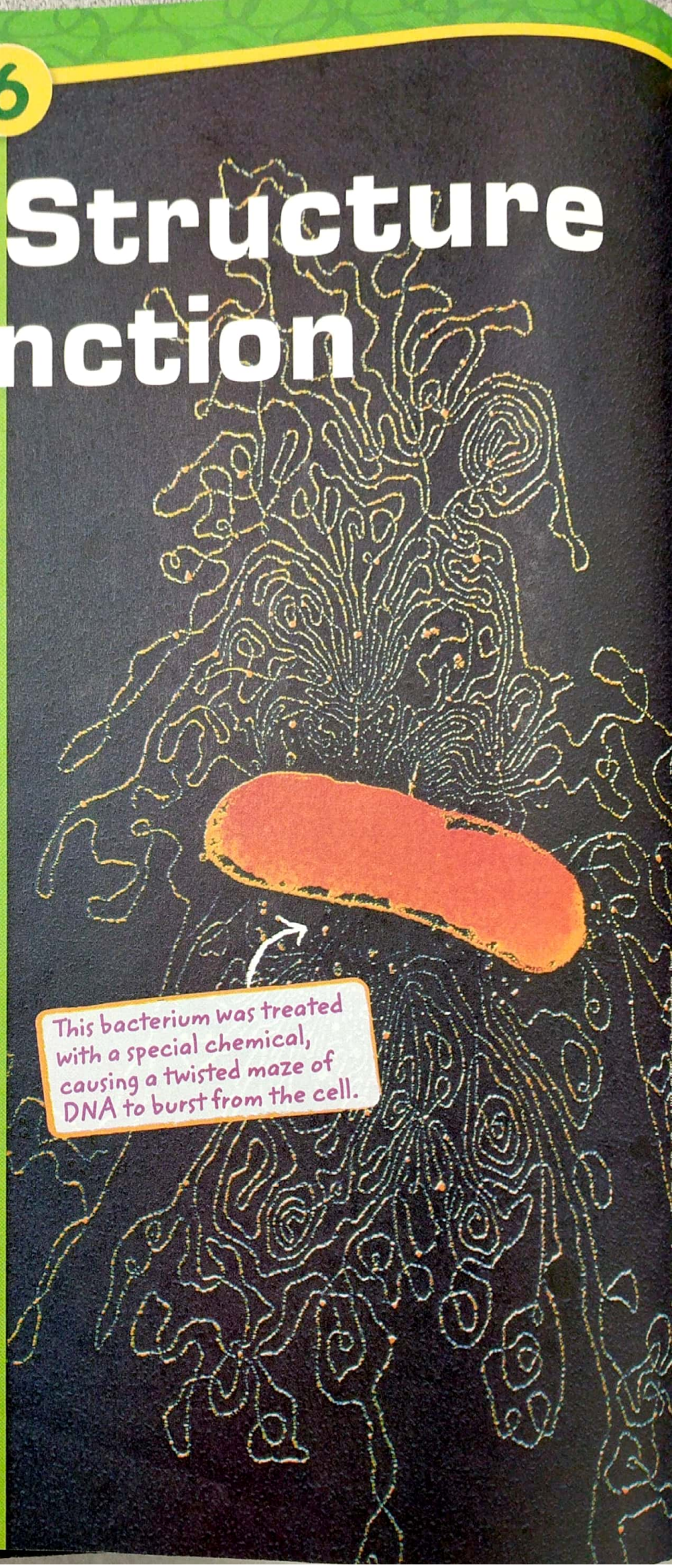
Lesson 6

DNA Structure and Function

ESSENTIAL QUESTION

What is DNA?

By the end of this lesson, you should be able to describe the structure and main functions of DNA.



Lesson Labs

Quick Labs
- Modeling DNA
- Building a DNA Sequence
- Mutations Cause Diversity

Exploration Lab
- Extracting DNA

Engage Your Brain

1 Predict Check T or F to show whether you think each statement is true or false.

T	F	
☐	☐	DNA is found in the cells of all living things.
☐	☐	All DNA mutations are harmful.
☐	☐	The cell can make copies of its DNA.

2 Describe DNA is sometimes called the *blueprint of life*. Why do you think that is?

Active Reading

3 Synthesize Many English words have their roots in other languages. Use the Latin words below to make an educated guess about the meanings of the words *replication* and *mutation*.

Latin word	Meaning
mutare	to change
replicare	to repeat

Example sentence
DNA can undergo mutation.

mutation:

Example sentence
Before cell division, DNA replication occurs.

replication:

Vocabulary Terms

- **DNA**
- **mutation**
- **nucleotide**
- **RNA**
- **replication**
- **ribosome**

4 Identify This list contains the key terms you'll learn in this lesson. As you read, circle the definition of each term.

Cracking the CODE

ATTAGCGATCACTAAATTAGC

Active Reading

5 Identify As you read, underline the meaning of the word *code*.

What is DNA?

The genetic material of a cell contains information needed for the cell's growth and other activities. It also determines the inherited characteristics of an organism. The genetic material in cells is contained in a molecule called deoxyribonucleic (dee•OK•see•ry•boh•noo•KLAY•ik) acid, or **DNA** for short. 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 or complete your favorite video game. The books, however, don't actually do any of those things—you do. Similarly, the "books" that make up the DNA "library" carry the information that a cell needs to function, grow, and 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.

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 that is translated into numbers, letters, and graphics 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 Timeline

Review this timeline to learn about some of the important scientific contributions to our understanding of DNA.

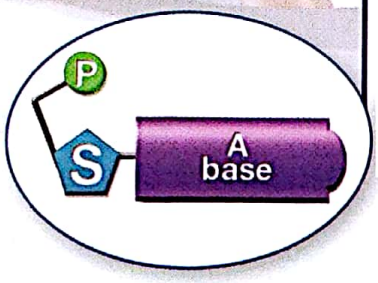
1875

1869 Friedrich Miescher identifies a substance that will later be known as DNA.

1900

1925

1919 Phoebus Levene publishes a paper on nucleic acids. His research helps scientists determine that DNA is made up of sugars, phosphate groups, and four nitrogen-containing bases: adenine, thymine, guanine, and cytosine. Bases are often referred to by their first letter: A, T, C, or G. Each base has a different shape.



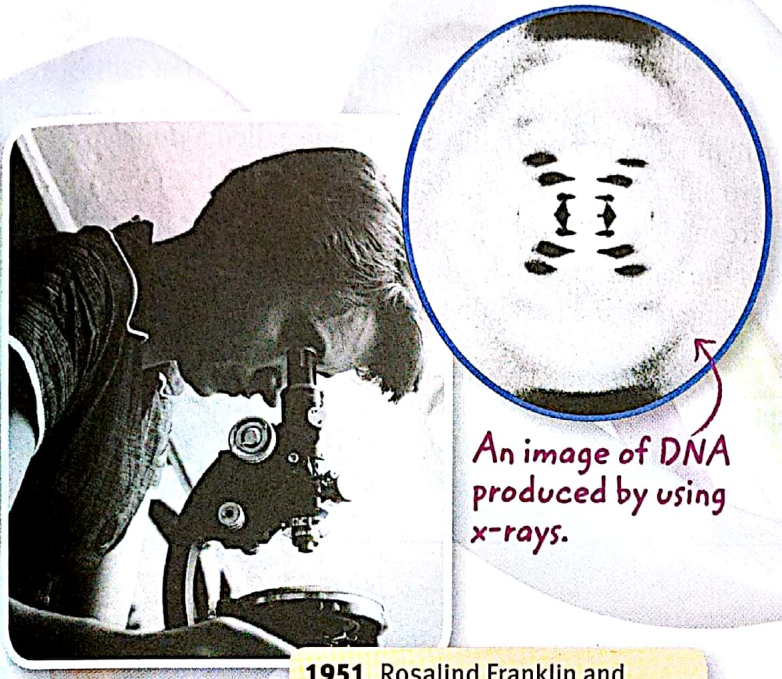
6 Analyze In this model, what do *P*, *S*, and *A bases* represent?

How was DNA discovered?

The discovery of the structure and function of DNA did not happen overnight. Many scientists from all over the world contributed to our current understanding of this important molecule. Some scientists discovered the chemicals that make up DNA. Others learned how these chemicals fit together. Still others determined the three-dimensional structure of the DNA molecule. The timeline below shows some of the key steps in this process of discovery.

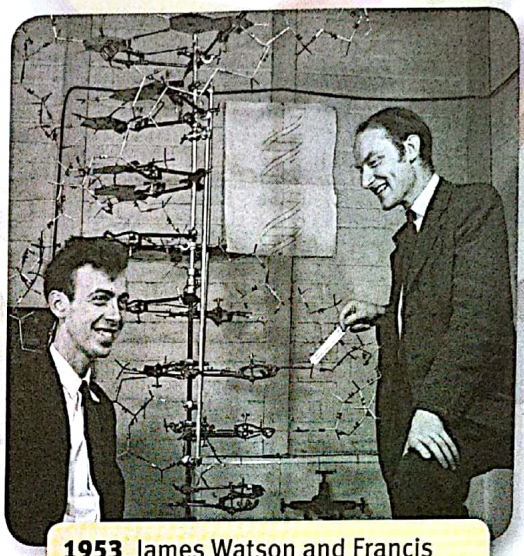
Think Outside the Book Inquiry

7 Research Use the Internet or library resources to research a scientist who contributed to the discovery of DNA. Then, create a poster about the scientist. Share your findings with your class.



An image of DNA produced by using x-rays.

1951 Rosalind Franklin and Maurice Wilkins make images of DNA using x-rays. When an x-ray passes through the molecule, the ray bends and creates a pattern that is captured on film.



1953 James Watson and Francis Crick use Chargaff's rules and the x-ray images of DNA to conclude that DNA looks like a long, twisted ladder. They build a large-scale model of DNA using simple materials from their laboratory.

1950 — 1975

1950 Erwin Chargaff observes that the amount of guanine always equals the amount of cytosine, and the amount of adenine equals the amount of thymine. His findings are now known as *Chargaff's rules*.

1952 Alfred Hershey and Martha Chase perform experiments with viruses to confirm that DNA, not proteins, carries genetic information.

Unraveling DNA

What does DNA look like?

The chemical components that make up DNA are too small to be observed directly. But experiments and imaging techniques have helped scientists to infer the shape of DNA and the arrangement of its parts.

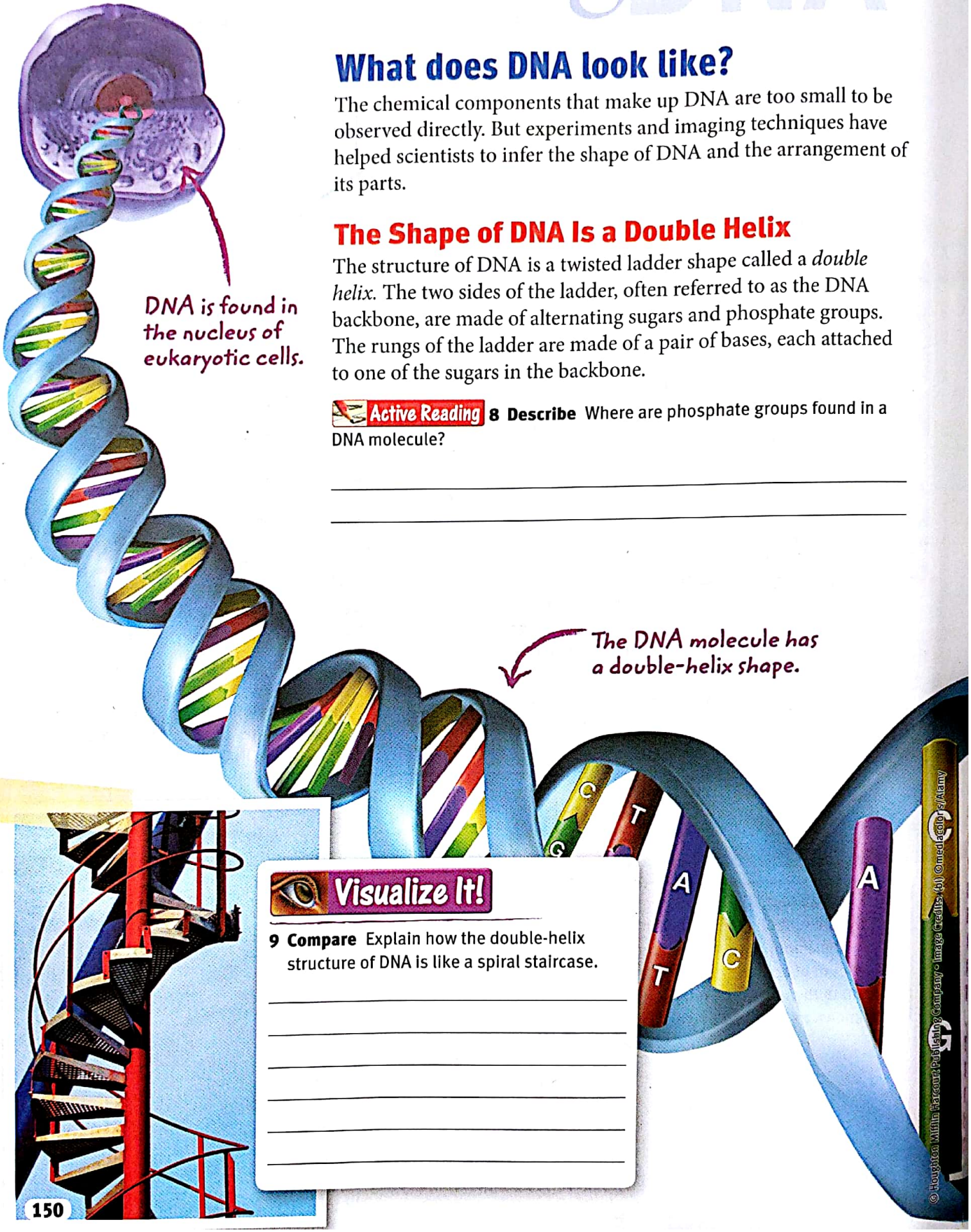
The Shape of DNA Is a Double Helix

The structure of DNA is a twisted ladder shape called a *double helix*. The two sides of the ladder, often referred to as the DNA backbone, are made of alternating sugars and phosphate groups. The rungs of the ladder are made of a pair of bases, each attached to one of the sugars in the backbone.

Active Reading **8 Describe** Where are phosphate groups found in a DNA molecule?

_____

_____



Visualize It!

9 Compare Explain how the double-helix structure of DNA is like a spiral staircase.

_____

_____

_____

_____

_____

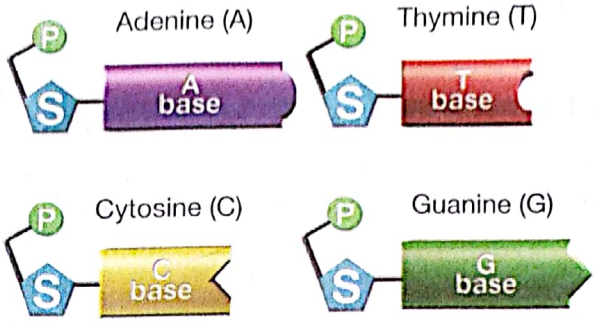
_____

DNA Is Made Up of Nucleotides

A base, a sugar, and a phosphate group make a building block of DNA known as a **nucleotide**. These repeating chemical units join together to form the DNA molecule. 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). These paired, or *complementary,* bases fit together like two pieces of a puzzle.

The order of the nucleotides in DNA is a code that carries information. The DNA code is read like a book. *Genes* are segments of DNA that relate to a certain trait. Each gene has a starting point and an ending point, with the DNA code being read in one direction. The bases A, T, C, and G form the alphabet of the code. The code stores information about which proteins the cells should build. The types of proteins your body makes help to determine your traits.

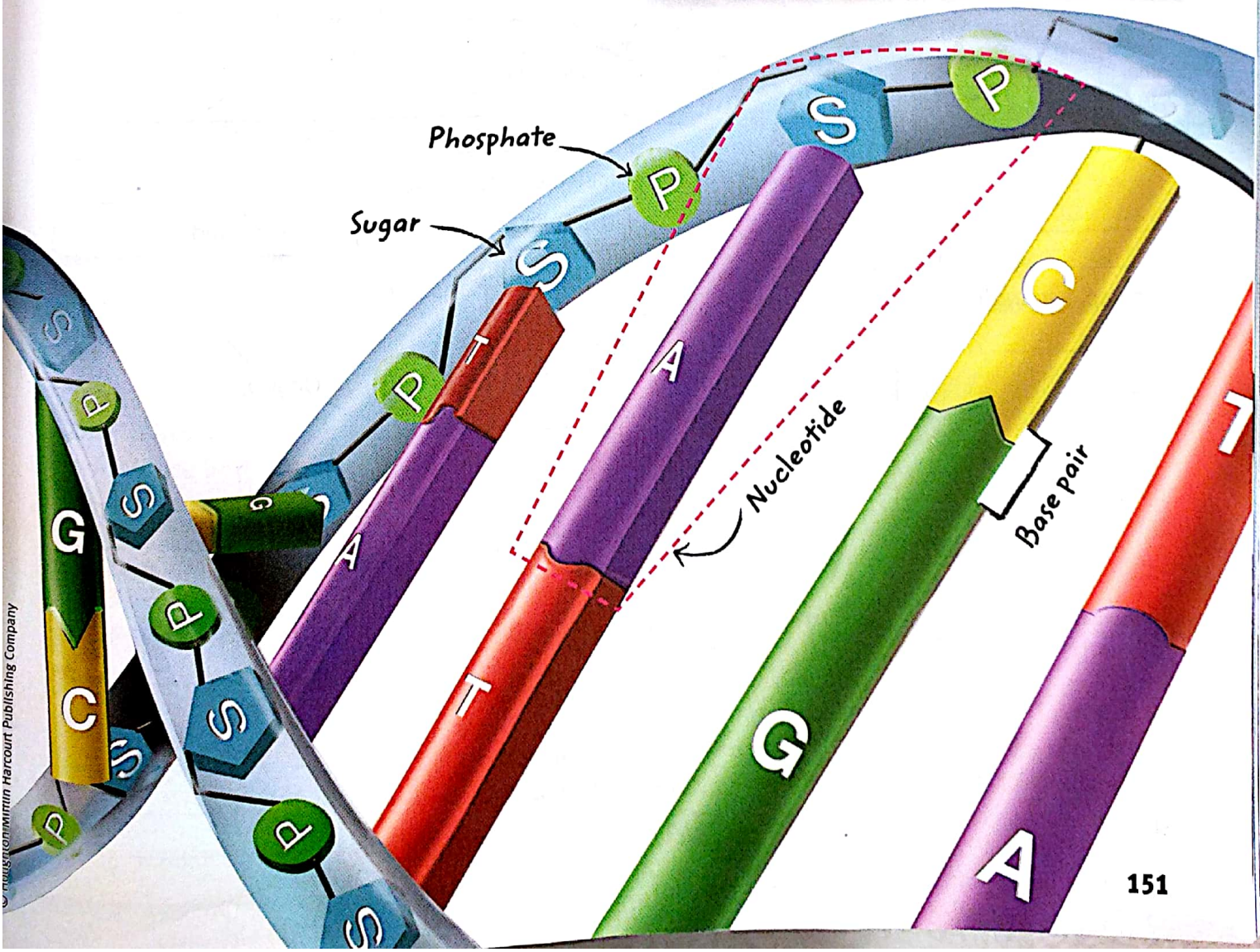
10 Apply Place boxes around the bases that pair with each other.



11 Devise The 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. Think of another phrase that uses words starting with A, T, C, and G that could help you remember the bases. Write your phrase below.

_____

_____



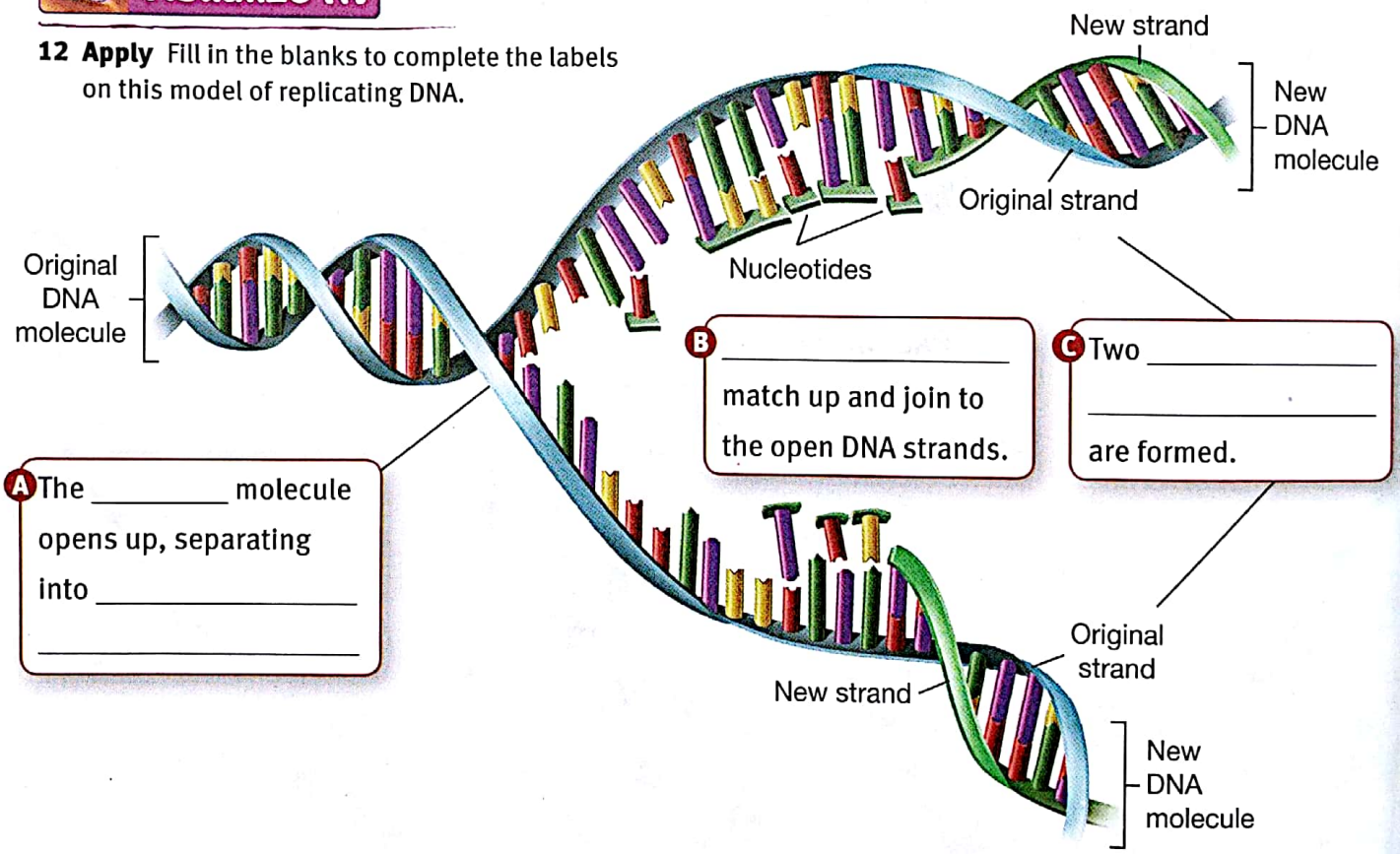
Replication and

How are copies of DNA made?

The cell is able to make copies of DNA molecules through a process known as **replication**. During replication, the two strands of DNA separate, almost like two threads in a string being unwound. The bases on each side of the molecule are used as a pattern for a new strand. As the bases on the original molecule are exposed, complementary nucleotides are added. For example, an exposed base containing adenine attaches to a nucleotide containing thymine. When replication is complete, there are two identical DNA molecules. Each new DNA molecule is made of one strand of old DNA and one strand of new DNA.

Visualize It!

12 Apply Fill in the blanks to complete the labels on this model of replicating DNA.



When are copies of DNA made?

Before a cell divides, it copies the DNA so that each new daughter cell will have a complete set of instructions. Our cells can replicate DNA in just a few hours. How? Replication begins in many places along the DNA strand. So, many groups of proteins are working to replicate your DNA at the same time.

Mutation

What are mutations?

Changes in the number, type, or order of bases on a piece of DNA are known as **mutations**. Sometimes, a base is left out. This kind of change is known as a *deletion*. Or, an extra base might be added. This kind of change is an *insertion*. The most common mutation happens when one base replaces another. This kind of change is known as a *substitution*.

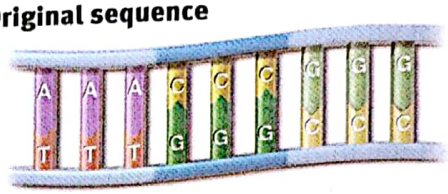
How do mutations happen? Given the large number of bases in an organism's DNA, it is not surprising that random errors can occur during replication. However, DNA can also be damaged by physical or chemical agents called *mutagens*. Ultraviolet light and the chemicals in cigarette smoke are examples of mutagens.

Cells make proteins that can fix errors in DNA. But sometimes a mistake isn't corrected, and it becomes part of the genetic code. Mutations to DNA may be beneficial, neutral, or harmful. A *genetic disorder* results from mutations that harm the normal function of a cell. Some of these disorders, such as Tay-Sachs disease and sickle-cell anemia, are *inherited*, or passed on from parent to offspring. Other genetic disorders result from mutations that occur during a person's lifetime. Most cancers fall into this category.

Visualize It!

13 Apply Place a check mark in the box to indicate which type of mutation is being shown.

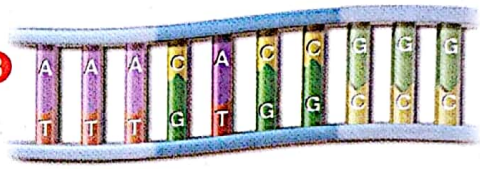
Original sequence



A

☐ deletion ☐ insertion ☐ substitution

B



☐ deletion ☐ insertion ☐ substitution

C

☐ deletion ☐ insertion ☐ substitution

This snake has albinism, a condition in which the body cannot make the pigments that give color to the skin and eyes.

14 Explain Albinism is an inherited genetic disorder. Explain what is meant by "inherited genetic disorder."

Protein Factory

What is the role of DNA and RNA in building proteins?

Imagine that you are baking cookies. You have a big cookbook that contains the recipe. If you take the book with you into the kitchen, you risk damaging the book and losing important instructions. You only need one page from the book, so you copy the recipe on a piece of paper and leave the cookbook on the shelf. This process is similar to the way that the cell uses DNA to build proteins. First, some of the information in the DNA is copied to a separate molecule called ribonucleic acid, or **RNA**. Then, the copy is used to build proteins. Not all the instructions are needed all the time. In eukaryotes, the DNA is protected inside the cell's nucleus.

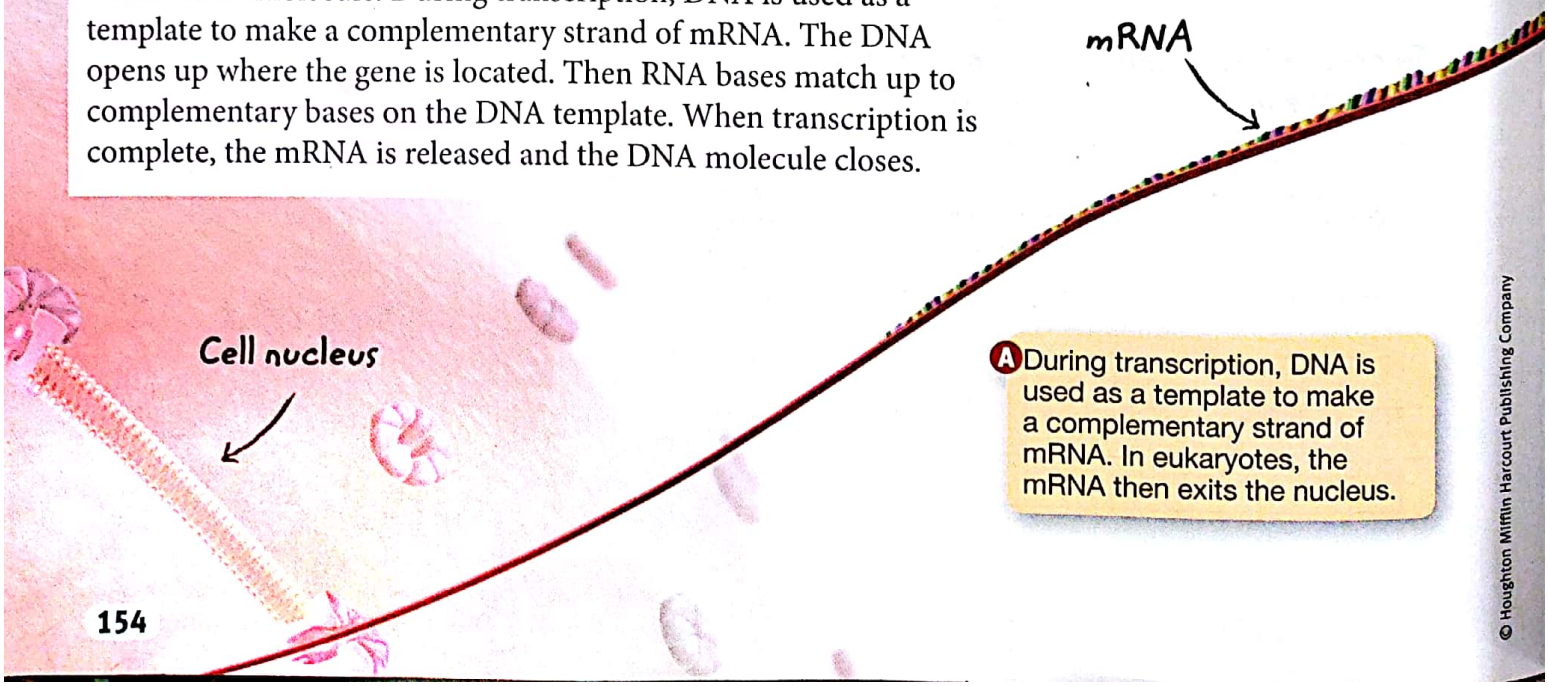
Like DNA, RNA has a sugar-phosphate backbone and the bases adenine (A), guanine (G), and cytosine (C). But instead of thymine (T), RNA contains the base uracil (U). Also, the sugar found in RNA is different from the one in DNA. There are three types of RNA: messenger RNA, ribosomal RNA, and transfer RNA. Each type of RNA has a special role in making proteins.

Active Reading **15 Identify** As you read, number the sentences that describe the steps of transcription.

RNA uses the genetic information stored in DNA to build proteins.

Transcription: The Information in DNA Is Copied to Messenger RNA

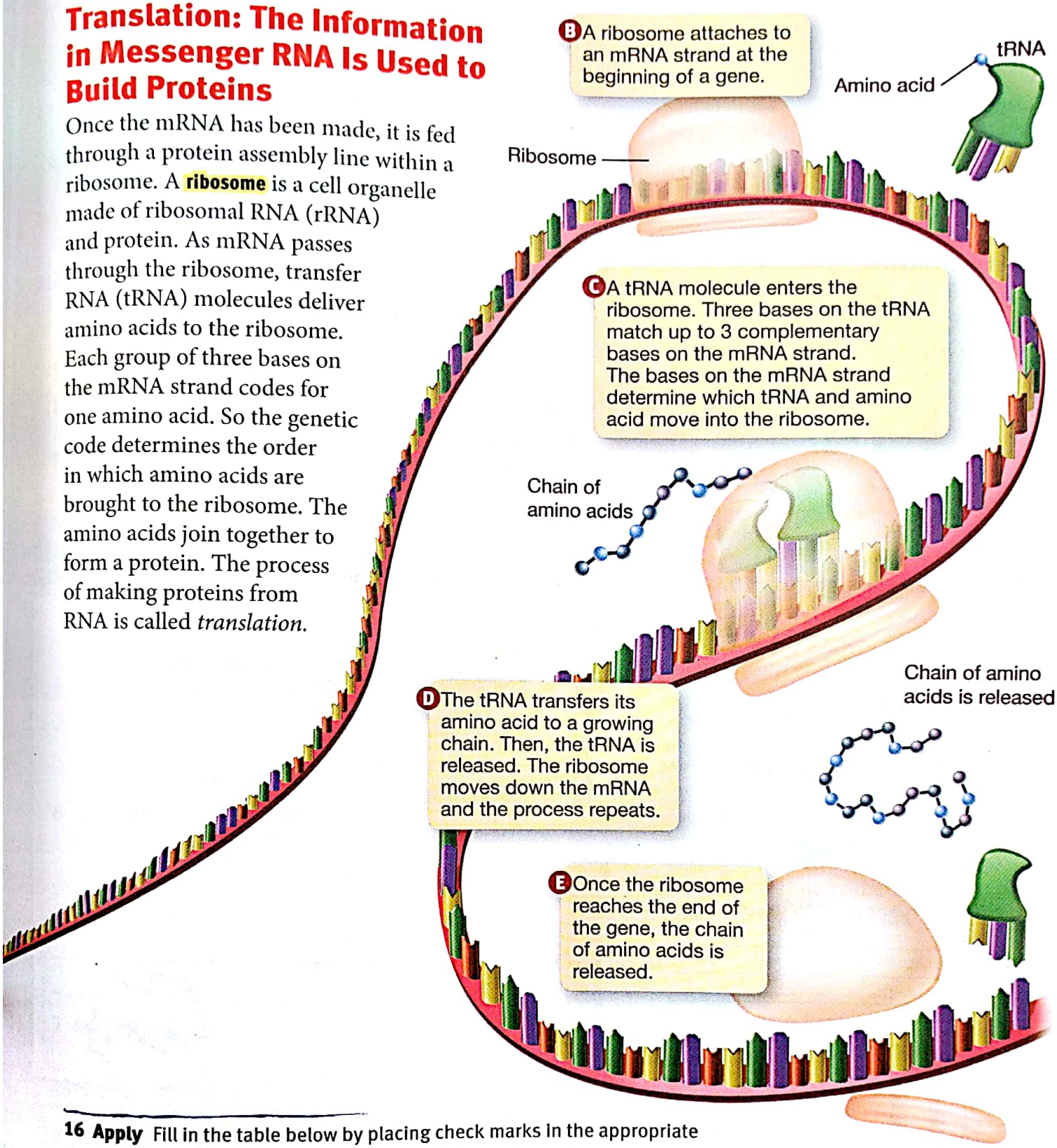
When a cell needs a set of instructions for making a protein, it first makes an RNA copy of the necessary section of DNA. This process is called *transcription*. Transcription involves DNA and messenger RNA (mRNA). Only individual genes are transcribed, not the whole DNA molecule. During transcription, DNA is used as a template to make a complementary strand of mRNA. The DNA opens up where the gene is located. Then RNA bases match up to complementary bases on the DNA template. When transcription is complete, the mRNA is released and the DNA molecule closes.



A During transcription, DNA is used as a template to make a complementary strand of mRNA. In eukaryotes, the mRNA then exits the nucleus.

Translation: The Information in Messenger RNA Is Used to Build Proteins

Once the mRNA has been made, it is fed through a protein assembly line within a ribosome. A **ribosome** is a cell organelle made of ribosomal RNA (rRNA) and protein. As mRNA passes through the ribosome, transfer RNA (tRNA) molecules deliver amino acids to the ribosome. Each group of three bases on the mRNA strand codes for one amino acid. So the genetic code determines the order in which amino acids are brought to the ribosome. The amino acids join together to form a protein. The process of making proteins from RNA is called *translation*.



16 Apply Fill in the table below by placing check marks in the appropriate boxes and writing the product of transcription and translation.

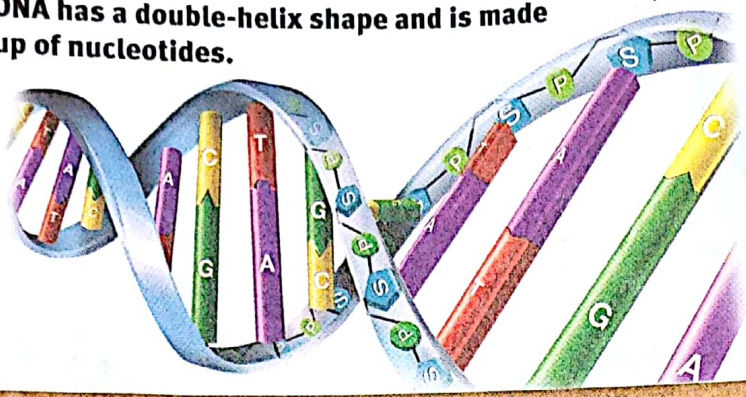
Process	What molecules are involved?				What is the product?
Transcription	☐ DNA	☐ mRNA	☐ tRNA	☐ ribosome	
Translation	☐ DNA	☐ mRNA	☐ tRNA	☐ ribosome	

Visual Summary

To complete this summary, fill in the blanks with the correct word or phrase. Then use the key below to check your answers. You can use this page to review the main concepts of the lesson.

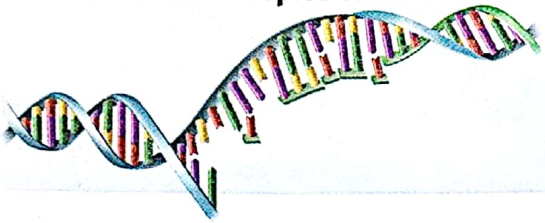
DNA Structure and Function

DNA has a double-helix shape and is made up of nucleotides.



17 The four bases in DNA nucleotides are _____

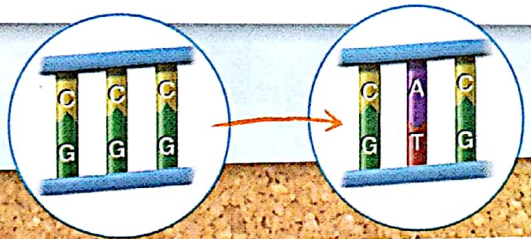
The cell can make copies of DNA.



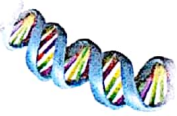
18 DNA replication happens before cells _____

DNA can mutate.

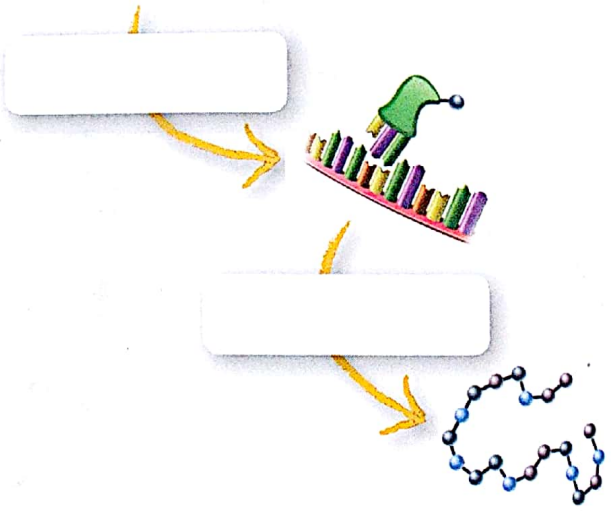
19 Three types of DNA mutations are _____



DNA and RNA are involved in making proteins.



20 The two processes involved in making proteins from the DNA code are _____



Answers: 17 adenine, guanine, cytosine, and thymine; 18 divide; 19 insertion, deletion, and substitution; 20 transcription; translation

21 **Explain** How could a mutation in the DNA affect what proteins are made by the cell?

Lesson Review

Lesson 6

Vocabulary

In your own words, define the following terms.

1 A(n) _____ of DNA consists of a sugar, a phosphate, and a nitrogen-containing base.

2 A(n) _____ is a change in the base sequence of a DNA molecule.

Key Concepts

Draw a line to connect the following scientists to their contributions to our understanding of DNA.

3 Erwin Chargaff	**A** took x-ray images of DNA molecule
4 Rosalind Franklin and Maurice Wilkins	**B** proposed a double-helix model of DNA
5 James Watson and Francis Crick	**C** found that the amount of adenine equals the amount of thymine and that the amount of guanine equals the amount of cytosine

6 Identify How does the structure of RNA differ from the structure of DNA?

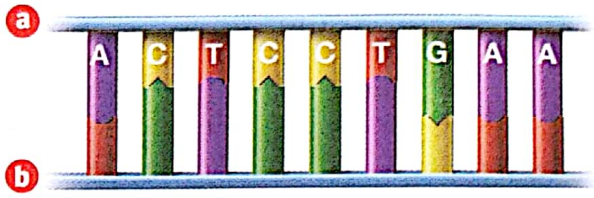
7 Identify When does DNA replication occur?

8 Describe Name the three types of RNA and list their roles in making proteins.

9 Identify What can cause DNA mutations?

Critical Thinking

Use this diagram to answer the following questions.



10 Describe What is the sequence of bases on DNA strand *b*, from left to right?

11 Apply This segment of DNA is transcribed to form a complementary strand of mRNA. The mRNA then undergoes translation. How many amino acids would the RNA code for?

12 Infer After many cell divisions, a segment of DNA has more base pairs than it originally did. Explain what has happened.

13 Explain Why must DNA replicate?