4 The DNA Connection

Reading Preview

Key Concepts

- What forms the genetic code?
- How does a cell produce proteins?
- How can mutations affect an organism?

Key Terms

- messenger RNA
- transfer RNA

Target Reading Skill

Sequencing A sequence is the order in which the steps in a process occur. As you read, make a flowchart that shows protein synthesis. Put the steps of the process in separate boxes in the flowchart in the order in which they occur.

Protein Synthesis

DNA provides code to form messenger RNA.

↓

Messenger RNA attaches to ribosome.

↓

Lab zone Discover Activity

Can You Crack the Code?

1. Use the Morse code in the chart to decode the question in the message below. The letters are separated by slash marks.

   • – – / • • • • / • / • – • / • / • – / • – • / • / – – • / • / – • / • / • • • / • – • • / – – – / – • – • / • – / – / • / – • • /

2. Write your answer to the question in Morse code.
3. Exchange your coded answer with a partner. Then decode your partner's answer.

Think It Over

Forming Operational Definitions Based on your results from this activity, write a definition of the word *code*. Then compare your definition to one in a dictionary.

A • –	N – •
B – • • •	O – – –
C – • – •	P • – – •
D – • •	Q – – • –
E •	R • – •
F • • – •	S • • •
G – – •	T –
H • • • •	U • • –
I • •	V • • • –
J • – – –	W • – –
K – • –	X – • • –
L • – • •	Y – • – –
M – –	Z – – • •

The young, white, ring-tailed lemur in the photograph below was born in a forest in southern Madagascar. White lemurs are extremely rare. Why was this lemur born with such an uncommon phenotype? To answer this question, you need to know how the genes on a chromosome control an organism's traits.

A white lemur and its mother ▶

The Genetic Code

The main function of genes is to control the production of proteins in an organism's cells. Proteins help to determine the size, shape, color, and many other traits of an organism.

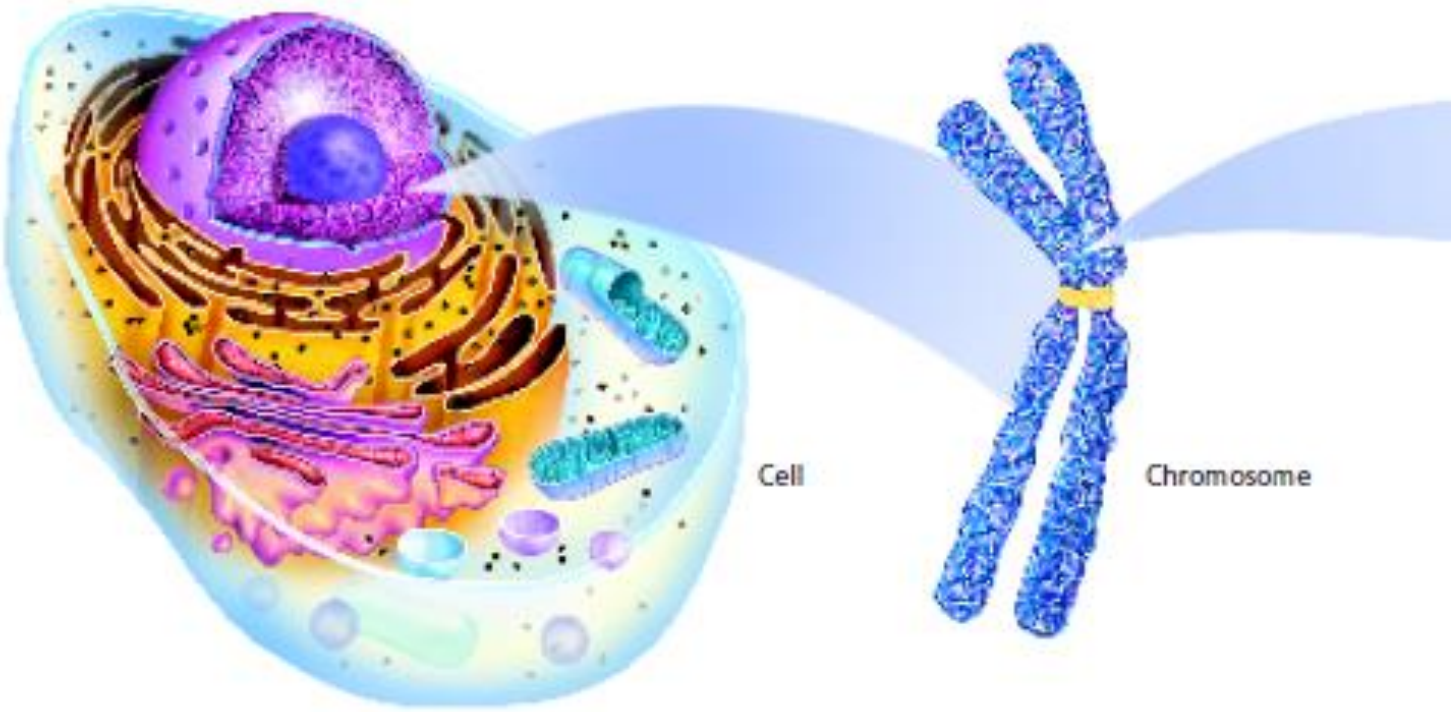
Genes and DNA Recall that chromosomes are composed mostly of DNA. In Figure 16, you can see the relationship between chromosomes and DNA. Notice that a DNA molecule is made up of four different nitrogen bases—adenine (A), thymine (T), guanine (G), and cytosine (C). These bases form the rungs of the DNA "ladder."

A gene is a section of a DNA molecule that contains the information to code for one specific protein. A gene is made up of a series of bases in a row. The bases in a gene are arranged in a specific order—for example, ATGACGTAC. A single gene on a chromosome may contain anywhere from several hundred to a million or more of these bases. Each gene is located at a specific place on a chromosome.

Order of the Bases A gene contains the code that determines the structure of a protein. **The order of the nitrogen bases along a gene forms a genetic code that specifies what type of protein will be produced.** Remember that proteins are long-chain molecules made of individual amino acids. In the genetic code, a group of three DNA bases codes for one specific amino acid. For example, the base sequence CGT (cytosine-guanine-thymine) always codes for the amino acid alanine. The order of the three-base code units determines the order in which amino acids are put together to form a protein.

FIGURE 16
The DNA Code

Chromosomes are made of DNA. Each chromosome contains thousands of genes. The sequence of bases in a gene forms a code that tells the cell what protein to produce. Interpreting Diagrams *Where in the cell are chromosomes located?*



How Cells Make Proteins

The production of proteins is called protein synthesis. **During protein synthesis, the cell uses information from a gene on a chromosome to produce a specific protein.** Protein synthesis takes place on the ribosomes in the cytoplasm of a cell. As you know, the cytoplasm is outside the nucleus. The chromosomes, however, are found inside the nucleus. How, then, does the information needed to produce proteins get out of the nucleus and into the cytoplasm?

The Role of RNA Before protein synthesis can take place, a "messenger" must first carry the genetic code from the DNA inside the nucleus into the cytoplasm. This genetic messenger is called ribonucleic acid, or RNA.

Although RNA is similar to DNA, the two molecules differ in some important ways. Unlike DNA, which has two strands, RNA has only one strand. RNA also contains a different sugar molecule from the sugar found in DNA. Another difference between DNA and RNA is in their nitrogen bases. Like DNA, RNA contains adenine, guanine, and cytosine. However, instead of thymine, RNA contains uracil (YOOR uh sil).

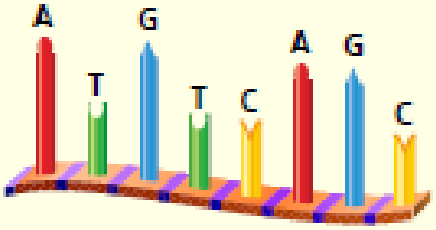
Types of RNA There are several types of RNA involved in protein synthesis. **Messenger RNA** copies the coded message from the DNA in the nucleus, and carries the message to the ribosome in the cytoplasm. Another type of RNA, called **transfer RNA,** carries amino acids to the ribosome and adds them to the growing protein.

Reading Checkpoint **How is RNA different from DNA?**

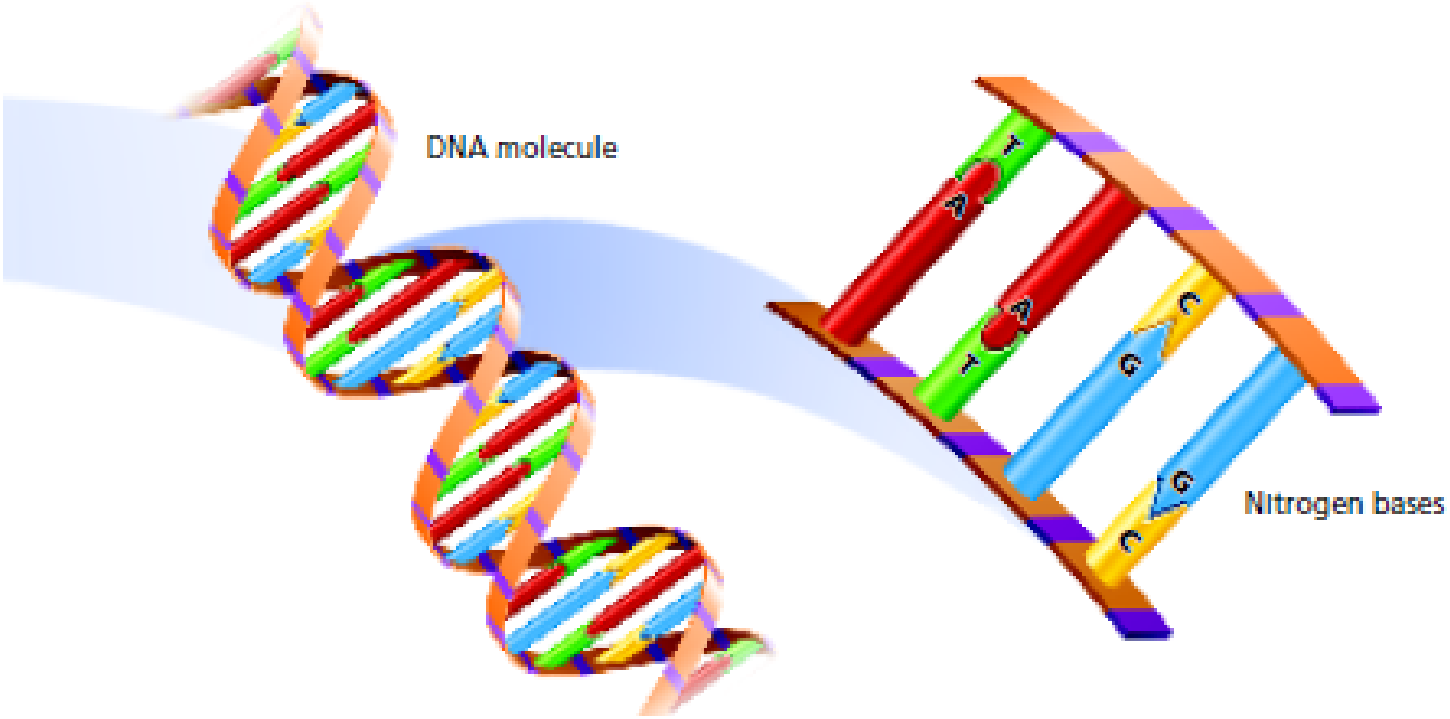
Lab zone **Skills Activity**

Drawing Conclusions

The following is a sequence of nitrogen bases on one strand of a nucleic acid molecule.



Does the strand come from DNA or RNA? Explain your answer.



Translating the Code The process of protein synthesis is shown in Figure 17. Look at the illustration as you read the following steps.

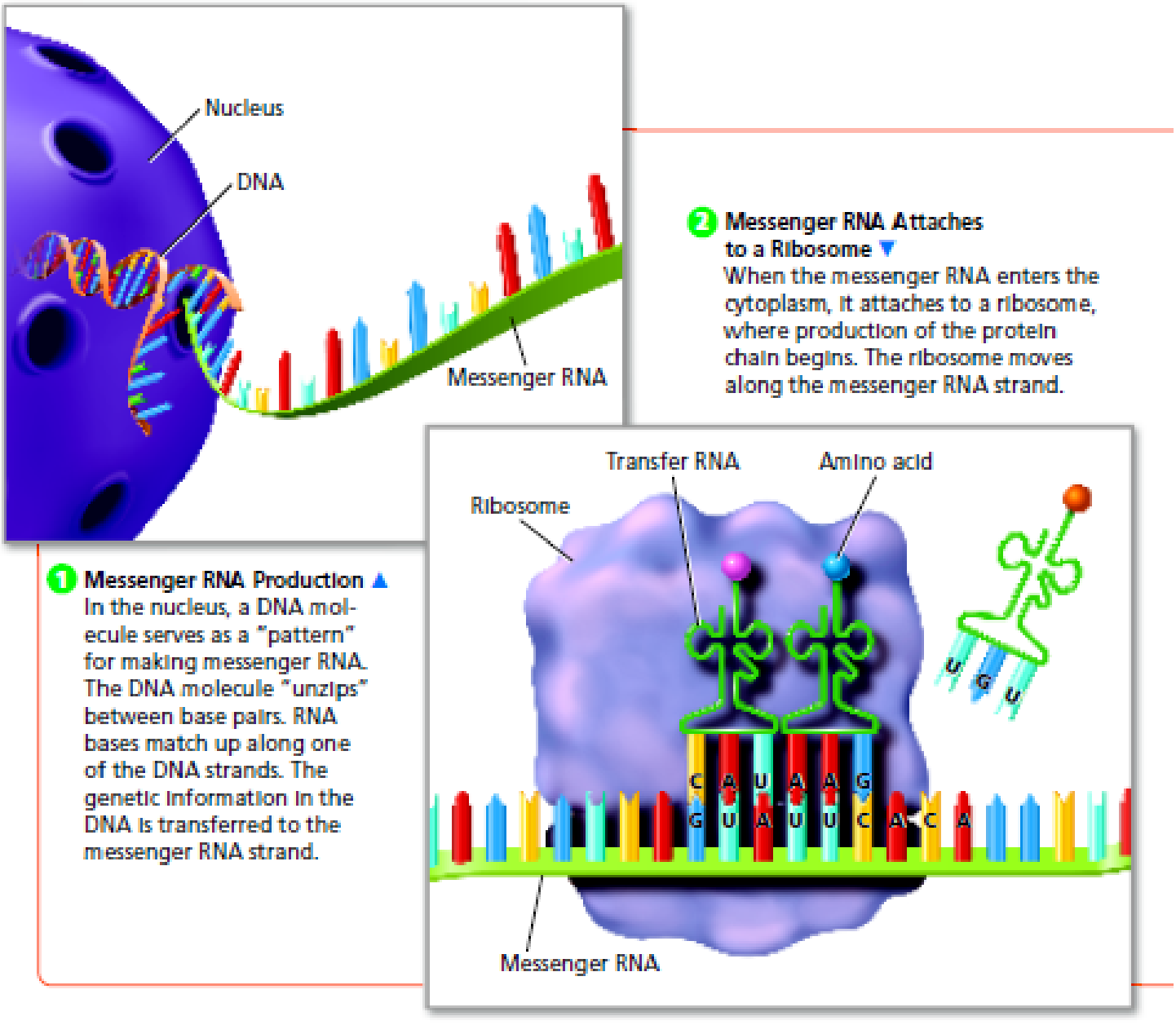
1 The first step is for a DNA molecule to "unzip" between its base pairs. Then one of the strands of DNA directs the production of a strand of messenger RNA. To form the RNA strand, RNA bases pair up with the DNA bases. The process is similar to the process in which DNA replicates. Cytosine always pairs with guanine. However, uracil—not thymine— pairs with adenine.

2 The messenger RNA then leaves the nucleus and enters the cytoplasm. In the cytoplasm, messenger RNA attaches to a ribosome. On the ribosome, the messenger RNA provides the code for the protein molecule that will form. During protein synthesis, the ribosome moves along the messenger RNA strand.

FIGURE 17

Protein Synthesis

To make proteins, messenger RNA copies information from DNA in the nucleus. Messenger RNA and transfer RNA then use this information to produce proteins.
Interpreting Diagrams *In which organelle of the cell are proteins manufactured?*



1 Messenger RNA Production ▲ In the nucleus, a DNA molecule serves as a "pattern" for making messenger RNA. The DNA molecule "unzips" between base pairs. RNA bases match up along one of the DNA strands. The genetic information in the DNA is transferred to the messenger RNA strand.

2 Messenger RNA Attaches to a Ribosome ▼ When the messenger RNA enters the cytoplasm, it attaches to a ribosome, where production of the protein chain begins. The ribosome moves along the messenger RNA strand.

3 Molecules of transfer RNA attach to the messenger RNA. The bases on the transfer RNA "read" the message by pairing up three-letter codes to bases on the messenger RNA. For example, you can see that a molecule of transfer RNA with the bases AAG pairs with the bases UUC on the messenger RNA. The molecules of transfer RNA carry specific amino acids. The amino acids link in a chain. The order of the amino acids in the chain is determined by the order of the three-letter codes on the messenger RNA.

4 The protein molecule grows longer as each transfer RNA molecule puts the amino acid it is carrying along the growing protein chain. Once an amino acid is added to the protein chain, the transfer RNA is released into the cytoplasm and can pick up another amino acid. Each transfer RNA molecule always picks up the same kind of amino acid.

Reading Checkpoint **What is the function of transfer RNA?**

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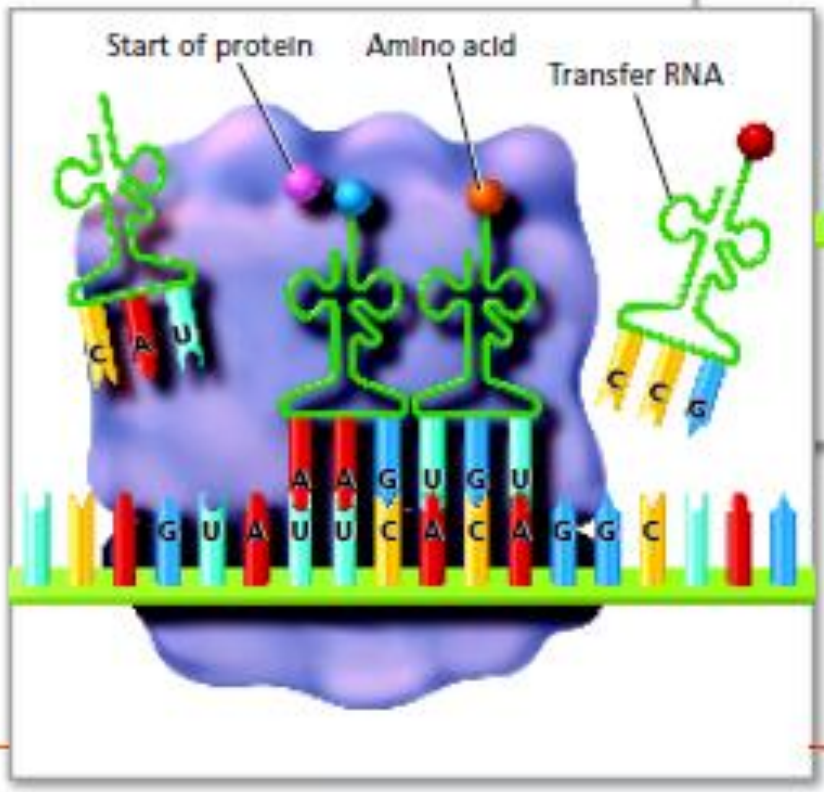
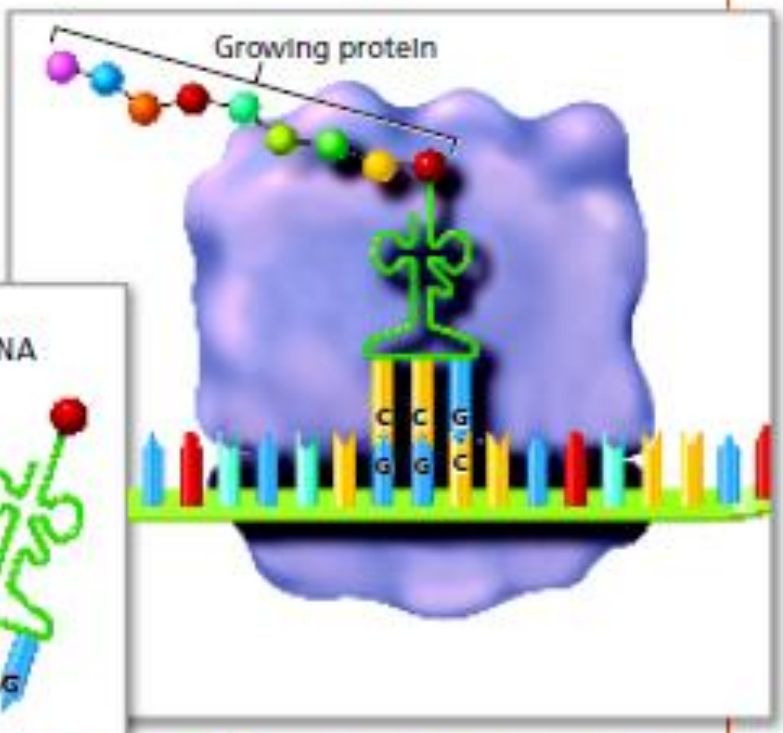
3 **Transfer RNA Attaches to Messenger RNA** ▼
Transfer RNA molecules carry specific amino acids to the ribosome. There they "read" the message in messenger RNA by matching up with three-letter codes of bases. The protein chain grows as each amino acid is attached.





4 **Protein Production Continues** ▲
The protein chain continues to grow until the ribosome reaches a three-letter code that acts as a stop sign. The ribosome then releases the completed protein.

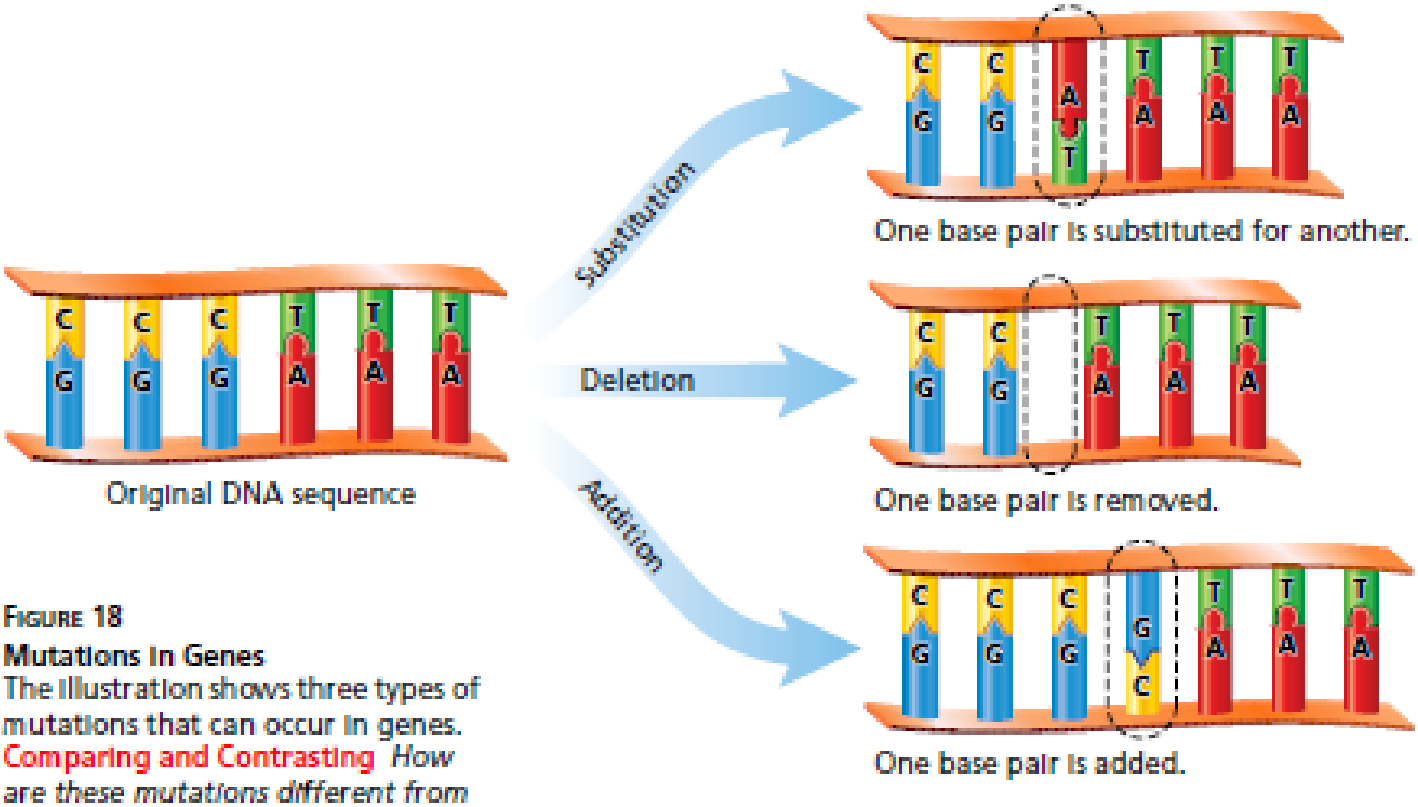


FIGURE 18
Mutations in Genes
The illustration shows three types of mutations that can occur in genes. Comparing and Contrasting *How are these mutations different from the mutations that occur when chromosomes do not separate during meiosis?*

Mutations

Suppose that a mistake occurred in one gene of a chromosome. Instead of the base A, for example, the DNA molecule might have the base G. Such a mistake is one type of mutation that can occur in a cell's hereditary material. Recall that a mutation is any change in a gene or chromosome. **Mutations can cause a cell to produce an incorrect protein during protein synthesis. As a result, the organism's trait, or phenotype, may be different from what it normally would have been.** In fact, the term *mutation* comes from a Latin word that means "change."

If a mutation occurs in a body cell, such as a skin cell, the mutation will not be passed on to the organism's offspring. If, however, a mutation occurs in a sex cell, the mutation can be passed on to an offspring and affect the offspring's phenotype.

Types of Mutations Some mutations are the result of small changes in an organism's hereditary material. For example, a single base may be substituted for another, or one or more bases may be removed from a section of DNA. This type of mutation can occur during the DNA replication process. Other mutations may occur when chromosomes don't separate correctly during meiosis. When this type of mutation occurs, a cell can end up with too many or too few chromosomes. The cell could also end up with extra segments of chromosomes.

Effects of Mutations Because mutations can introduce changes in an organism, they can be a source of genetic variety. Some mutations are harmful to an organism. A few mutations, however, are helpful, and others are neither harmful nor helpful. A mutation is harmful to an organism if it reduces the organism's chance for survival and reproduction.

Whether a mutation is harmful or not depends partly on the organism's environment. The mutation that led to the production of a white lemur would probably be harmful to an organism in the wild. The lemur's white color would make it more visible, and thus easier for predators to find. However, a white lemur in a zoo has the same chance for survival as a brown lemur. In a zoo, the mutation neither helps nor harms the lemur.

Helpful mutations, on the other hand, improve an organism's chances for survival and reproduction. Antibiotic resistance in bacteria is an example. Antibiotics are chemicals that kill bacteria. Gene mutations have enabled some kinds of bacteria to become resistant to certain antibiotics—that is, the antibiotics do not kill the bacteria that have the mutations. The mutations have improved the bacteria's ability to survive and reproduce.

Reading Checkpoint **What are two types of mutations?**

FIGURE 19
Six-Toed Cat
Because of a mutation in one of its ancestors, this cat has six toes on each front paw.

Section 4 Assessment

Target Reading Skill Sequencing Refer to your flowchart as you answer Question 2.

Reviewing Key Concepts

1. a. Explaining What is the relationship between a gene, a DNA molecule, and a protein?
   b. Relating Cause and Effect How does a DNA molecule determine the structure of a specific protein?
   c. Inferring The DNA base sequence GGG codes for the amino acid proline. Could this same base sequence code for a different amino acid? Why or why not?
2. a. Listing List the sequence of events that happens during protein synthesis.
   b. Describing What is messenger RNA? Describe how it performs its function.
   c. Inferring Does transfer RNA perform its function in the nucleus or cytoplasm? Explain your answer.
3. a. Reviewing How does a mutation in a gene affect the order of DNA bases?
   b. Relating Cause and Effect How can a mutation in a gene cause a change in an organism's phenotype?

Writing in Science

Compare/Contrast Paragraph Write a paragraph comparing and contrasting gene mutations and chromosome mutations. In your paragraph, explain what the two types of mutations are, and how they are similar and different.