TOPIC 3

Reproduction and Genetics

SC.7.L.16.1 Understand and explain that every organism requires a set of instructions that specifies its traits, that this hereditary information (DNA) contains genes located in the chromosomes of each cell, and that heredity is the passage of these instructions from one generation to another.

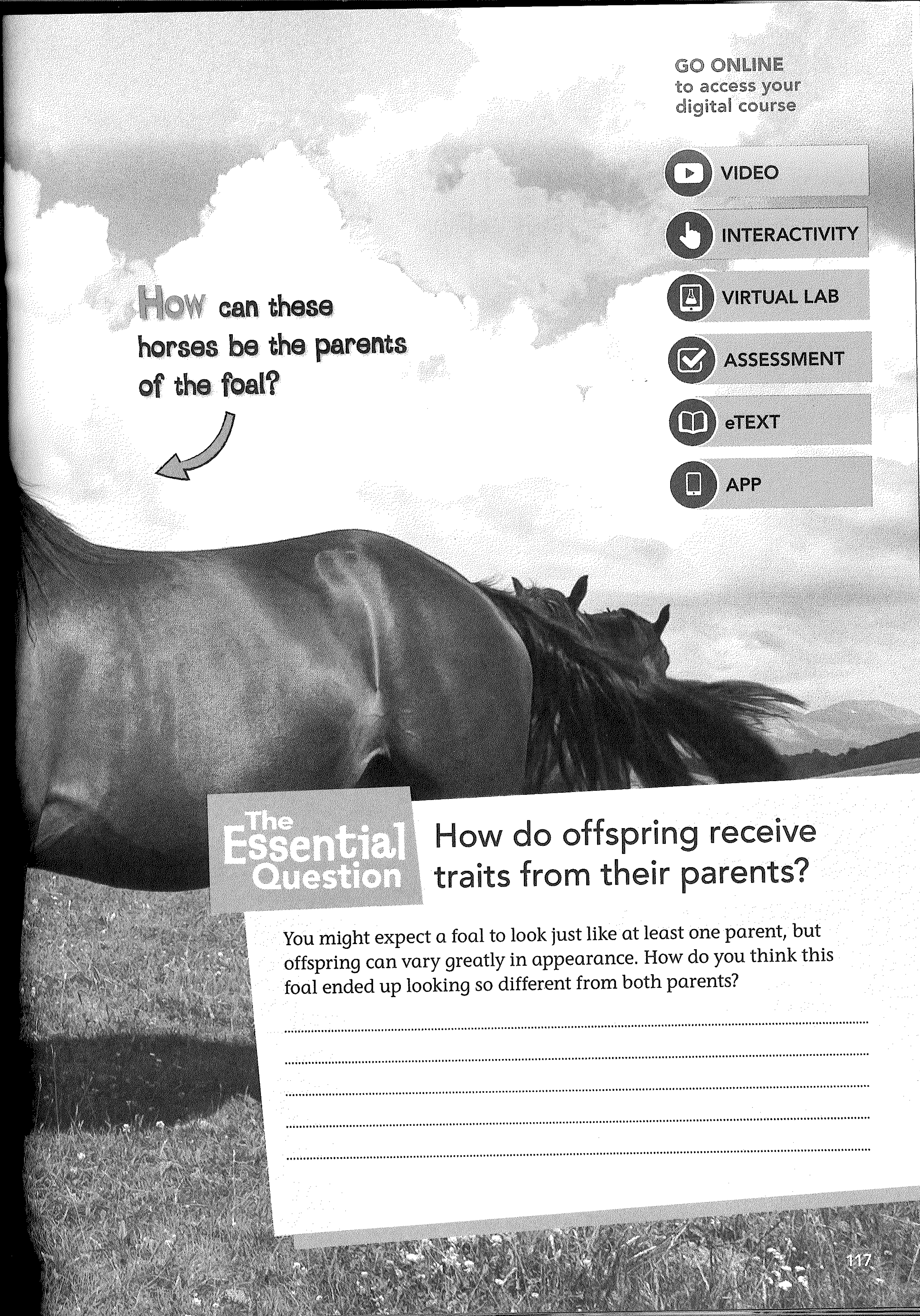
SC.7.L.16.2 Determine the probabilities for genotype and phenotype combinations using Punnett Squares and pedigrees.

SC.7.L.16.3 Compare and contrast the general processes of sexual reproduction requiring meiosis and asexual reproduction requiring mitosis.

SC.7.L.16.4 Recognize and explore the impact of biotechnology (cloning, genetic engineering, artificial selection) on the individual, society and the environment. (Also **SC.7.N.1.1, SC.7.N.1.3, SC.7.N.1.5, SC.7.N.1.6, SC.7.N.2.1,** and **SC.7.N.3.2**)

HANDS-ON LAB

uConnect Explore the effects of different methods of reproduction.



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How can these horses be the parents of the foal?

The Essential Question

How do offspring receive traits from their parents?

You might expect a foal to look just like at least one parent, but offspring can vary greatly in appearance. How do you think this foal ended up looking so different from both parents?

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Quest KICKOFF

How can you sell a new fruit?

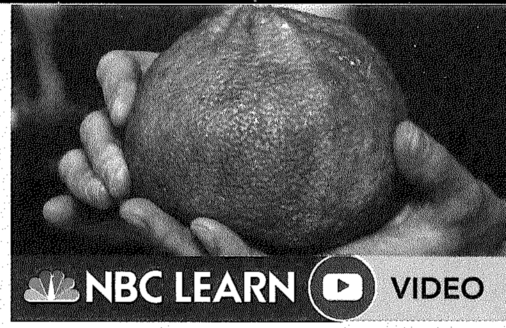
Consumers are often open to new ideas—especially tasty new ideas. But it may take some convincing. What new fruit sensation can you develop, and how will you get growers and consumers to buy in? In this Quest activity, you will explore reproduction, heredity, and genetics as you choose desirable traits and figure out how to ensure their consistent appearance in your product. Once your new fruit is characterized, you will create a brochure to help growers understand your product, why it is desirable, and how they can grow it successfully.

INTERACTIVITY

Funky Fruits

SC.7.L.16.1 Understand and explain that every organism requires a set of instructions that specifies its traits, that this hereditary information (DNA) contains genes located in the chromosomes of each cell, and that heredity is the passage of these instructions from one generation to another.

SC.7.L.16.4 Recognize and explore the impact of biotechnology (cloning, genetic engineering, artificial selection) on the individual, society and the environment. (Also **SC.7.N.1.3** and **SC.7.N.2.1**)



After watching the Quest Kickoff video about different kinds of fruit hybrids, think about the qualities you desire in your fruit. In the table below, identify the characteristics you want your new fruit to have.

Color	
Taste	
Size	
Shape	
Texture	

IN LESSON 1

What outcomes do sexual and asexual reproduction have? Consider how the two types of reproduction could affect how you develop your new fruit.

Quest CHECK-IN

IN LESSON 2

How can you use both sexual and asexual reproduction to develop your new fruit? Explore how farmers benefit from using both types of reproduction to establish and maintain a consistent product.

INTERACTIVITY

An Apple Lesson

Quest CHECK-IN

IN LESSON 3

What role do chromosomes and genes play in fruit reproduction? Make a chromosome map and locate genes that carry desirable traits.

INTERACTIVITY

About Those Chromosomes

These white strawberries, called pineberries, taste somewhat like pineapples.

Quest CHECK-IN

IN LESSON 4

How are dominant and recessive traits inherited? Examine data tables for trait inheritance and complete Punnett squares to determine the probable outcomes of crosses.

HANDS-ON LAB

All in the Numbers

IN LESSON 5

How do growers ensure consistency in their product? Consider how you might use genetic technologies to develop your new fruit.

Quest FINDINGS

Complete the Quest!

Create a brochure for prospective growers of your new fruit. Convince readers that your fruit will be a delicious success!

INTERACTIVITY

Reflect on Funky Fruits

LESSON 1

Patterns of Reproduction

Guiding Questions

- How do organisms reproduce and transfer genes to their offspring?
- How do offspring produced by asexual reproduction and sexual reproduction compare?
- Why do different offspring of the same parent usually look different?

Connections

Literacy Cite Textual Evidence

Math Summarize Distributions

SC.7.L.16.3 Compare and contrast the general processes of sexual reproduction requiring meiosis and asexual reproduction requiring mitosis. (Also **SC.7.N.1.6, SC.7.N.3.2**)

Vocabulary

asexual reproduction
sexual reproduction
fertilization
trait
gene
inheritance
allele

Academic Vocabulary

dominant

VOCABULARY APP

Practice vocabulary on a mobile device.

Quest CONNECTION

Think about how fruit-bearing plants reproduce to form offspring.

Connect It!

The pictures show offspring with their mothers. Circle the offspring you think might look like the father.

Construct Explanations Summarize what you already know about how the three kinds of animals in the picture produce offspring.

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Asexual and Sexual Reproduction

Living things reproduce. Giraffes make more giraffes, hermit crabs make more hermit crabs, and bald eagles make more bald eagles. Some animals produce offspring that look exactly like the parent. Others, such as humans and the animals in **Figure 1,** produce offspring that look different from the parents.

Animals use one of two main methods—asexual or sexual reproduction—to produce offspring. Reproduction guarantees that a species' genes are passed on to the next generation.

INTERACTIVITY

Consider the traits that make you unique.

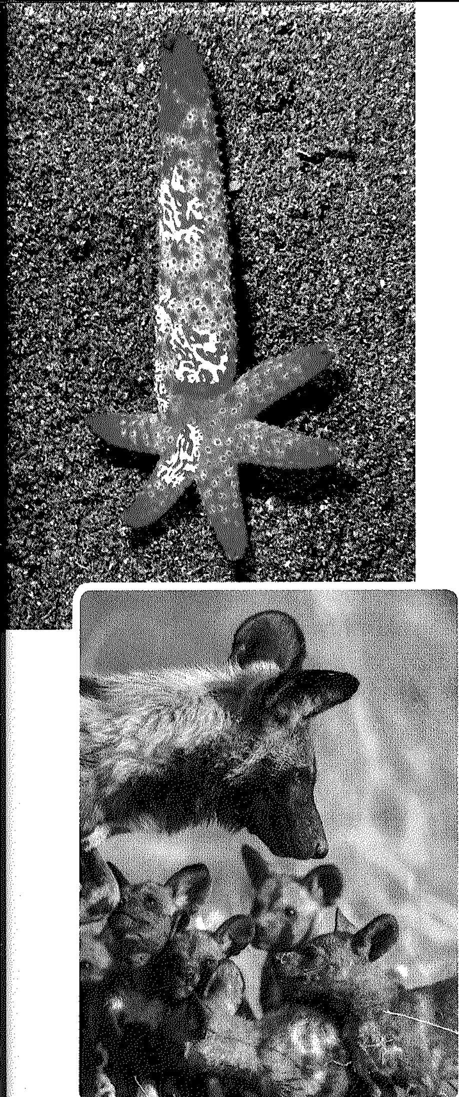
Asexual Reproduction A reproductive process that involves only one parent and produces offspring that are genetically identical to the parent is called **asexual reproduction**. It is the simplest form of reproduction. Animals such as sponges, corals, and certain jellyfish reproduce asexually.

Reflect What do you think is the benefit of reproducing asexually? In your science notebook, explain how asexual reproduction could give some animals an advantage.

One form of asexual reproduction is fragmentation. During fragmentation, a new organism forms from a piece of the original. For example, a whole new sea star can develop from a single arm that breaks off (see **Figure 2**). Another method of asexual reproduction is called budding. In this process, a new animal grows out from the parent until it fully matures and breaks off. Sponges and some sea anemones reproduce in this way.

Reproduction Results in Offspring

Figure 1 All living things have the ability to reproduce.



Sexual Reproduction Consider the variety of trees, birds, fish, and plants in the world around you. Clearly, many life forms are unique. When organisms reproduce sexually, their offspring display a variety of traits. Even members of the same species are not exact copies of each other. Sexual reproduction is responsible for the variety of life you see.

In **sexual reproduction**, two parents combine their genetic material to produce a new organism which differs from both parents. Sexual reproduction involves an egg cell and a sperm cell joining to form a new cell in a process called **fertilization**. Sperm cells are from the father and contain half of the father's chromosomes. Egg cells are from the mother and contain half the mother's chromosomes. When fertilization occurs, a full set of chromosomes is present in the new cell.

Because offspring receive roughly half their genetic information from each parent, they receive a combination of specific characteristics. A specific characteristic that an organism can pass to its offspring through its genes is called a **trait**. A **gene** is a sequence of DNA that determines a trait and is passed from parent to offspring. As a result, offspring may look very similar to their parents, or they may look very different, like the wild dogs in **Figure 2**. These differences are known as variations, and they are what make you different from your siblings. Individual variations depend on which genes were passed on from each parent.

Sexual vs. Asexual Reproduction

Figure 2 (top) A new sea star, identical to its parent, is developing from a single arm. (bottom) The fur patterns of the African wild-dog pups are different from their mother's.

Classify Which offspring resulted from sexual reproduction?

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Model It!

Develop Models Suppose two neighborhood dogs produce offspring. Draw a picture of the mother and the father. Draw one offspring that might result from the parents. Label the traits the father passed on to the offspring and the traits the mother passed on to the offspring.

Comparing Types of Reproduction Both methods of reproduction have advantages and disadvantages. Organisms that reproduce asexually do not have to find a mate. They can also produce many offspring fairly quickly. The downside is that all of the offspring have exactly the same genetic makeup as the parent. This can be a problem if the environment changes. If one individual organism is unable to tolerate the change, then chances are the rest of the identical offspring will not be able to handle it either.

Organisms that reproduce sexually pass on genes with greater genetic variation. This variation may increase their chances of surviving in a changing environment. It is possible that they received a gene from a parent that helps them adapt to the changing environment. One potential downside of sexual reproduction is that the organism needs to find a mate. This can sometimes be a problem for animals, such as polar bears, that live in remote areas.

VIDEO

Compare asexual reproduction and sexual reproduction.

READING CHECK **Cite Textual Evidence** What are some advantages of wild dogs reproducing sexually?

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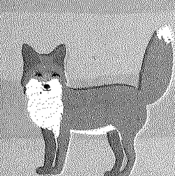
Math Toolbox

Sexual Reproduction

Gestation is the time period between fertilization and birth. The data in the table are based on recorded observations from hundreds of pregnant individuals in each species.

Animal	Gestation Range (days)	Median Gestation Time (days)	Bottom Quartile Median (days)	Top Quartile Median (days)
Hamster	16–23	20	17	22
Red Fox	49–55	52	50	53
Gerbil	22–26	24	23	25
Leopard	91–95	93	92	94



1. Make Generalizations What is the relationship between the size of the animal and how long it takes for its offspring to develop?

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2. Summarize Distributions Choose two species from the table and construct a box plot for each one.

Inheritance of Traits

Figure 3 Fur color, like human hair color, depends on which genes are inherited from the parents.

VIDEO

Explore the relationship between inheritance and alleles.

Inherited Traits

When sperm and egg cells come together, genetic information from the mother and father mix. **Inheritance** is the process by which an offspring receives genes from its parents. Genes are located on chromosomes and describe the factors that control a trait. Each trait is described by a pair of genes, with one gene from the mother and one from the father. Sometimes the pair of genes are the same. At other times, there are two different genes in the pair.

For example, imagine a mouse with white fur and a mouse with brown fur have offspring. The genes for fur color from each parent are different. As shown in **Figure 3,** some of the offspring produced may be brown, some may be white, and others may be combinations of more than one color. Each offspring's fur color depends on how its inherited genes combine.

An **allele** is a different form of the same gene. One allele is received from each parent, and the combination of alleles determines which traits the offspring will have. In the simplest case, alleles are either dominant or recessive. If an offspring inherits a **dominant** allele from either parent, that trait will always show up in the offspring. But, if the offspring inherits recessive alleles from each parent, a recessive trait will show. This relationship allows parents with two dominant alleles to pass on recessive alleles to their offspring. For example, two brown-eyed people may have a blue-eyed child. However, most genetic traits do not follow these simple patterns of dominant and recessive inheritance.

Academic Vocabulary

Describe a situation in which you have been dominant.

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Incomplete Dominance Sometimes intermediate forms of a dominant trait appear. This means that mixing of colors or sizes occurs. Incomplete dominance may occur when a dominant allele and recessive allele are inherited. The offspring will have a mixture of these two alleles. For example, in some species of sheep, gray fleece results from a dominant white-fleece allele and a recessive black allele. Incomplete dominance also occurs in petal color in some species of plants. **Figure 4** shows how petal color can result in the blending of two colors.

Incomplete Dominance
Figure 4 Circle the flowers that demonstrate incomplete dominance in petal color.

Codominance Unlike incomplete dominance, which shows blending of traits, codominance results in both alleles being expressed at the same time. In cattle, horses, and dogs, there is a color pattern called roan. This color pattern appears when a dominant white-hair allele and a dominant solid-color allele is inherited. The offspring has hairs of each color intermixed, giving the solid-color a more muted or mottled look.

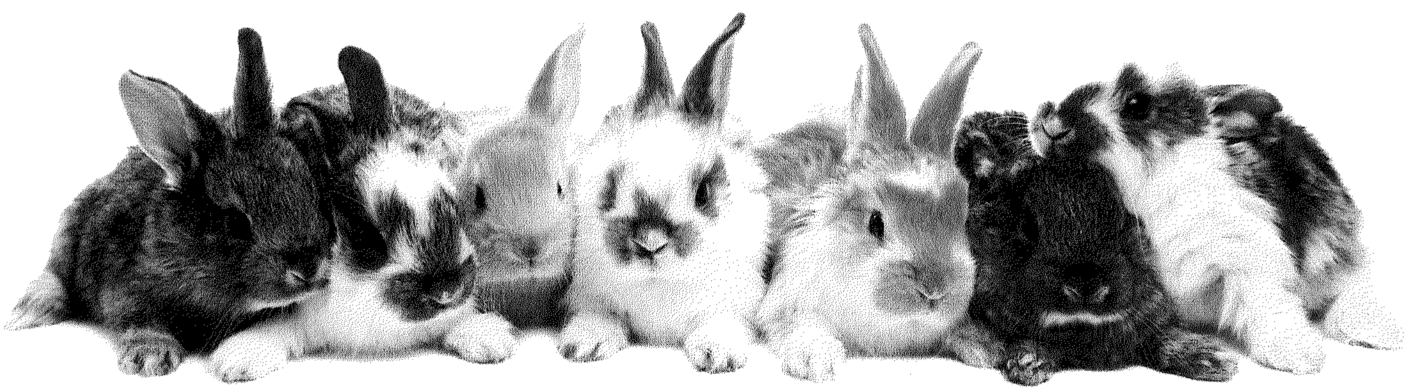
Model It!

Apply Concepts Draw the parents of this flower in the box. Assume that the flower's color is determined by codominance.

		Father's blood type				
		A	B	AB	O	
Mother's blood type	A	A or O	A, B, AB, or O	A, B, or AB	A or O	Child's blood type must be
	B	A, B, AB, or O	B or O	A, B, or AB	B or O	
	AB	A, B, or AB	A, B, or AB	A, B, or AB	A or B	
	O	A or O	B or O	A or B	O	

Human Blood Types
Figure 5 A gene with multiple alleles is expressed as one of four blood types: A, B, AB, and O.

Multiple Alleles Every offspring inherits one allele from each parent for a total of two alleles. However, sometimes one trait has more than two alleles. For example, there are three alleles for blood type—A, B, and O. The A and B blood types are codominant and O is recessive. As you see in **Figure 5**, you receive two of the multiple alleles from each parent, but each possible combination of alleles results in one of four different blood types. Multiple alleles are not found only in blood types. **Figure 6** shows how fur color in some rabbits is the result of multiple alleles.



Multiple Alleles
Figure 6 These rabbits all came from the same litter.

Cite Evidence What evidence from the picture demonstrates that the fur color of these rabbits results from multiple alleles?

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Polygenic Inheritance Some traits are controlled by more than one gene. In polygenetic inheritance, these different genes are expressed together to produce the trait. Human height is an example of this. If the mother is 5 feet 2 inches tall and the father is 6 feet tall, then you might think that all of the offspring would be 5 feet 7 inches. However, there can be a large variation among the heights of the children. This fact is due to multiple genes working together to produce the trait.

READING CHECK **Distinguish Relationships** How do alleles influence inherited traits? Explain with an example of incomplete dominance.

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Genes and the Environment

What kinds of things have you learned in your life? Maybe you know how to paint. Maybe you can ride a unicycle. Or maybe you know how to solve very complicated math problems. Whatever your abilities, they are acquired traits that are the result of learned behaviors.

Acquired Traits The traits you inherited can be affected by your experience. For example, humans are born with teeth, vocal cords, and tongues—all of which enable us to speak. The language you learn to use depends on your environment. You were not born speaking a particular language, but you were born with the capacity to learn languages, whether a spoken language or sign language. The ability for language is an inherited trait. The language or languages you use, however, are acquired traits.

The combination of inherited traits and acquired traits helps many organisms to survive in their environment. The fox squirrel in **Figure 7** has inherited traits from its parents that help it survive in its environment. The squirrel also acquired traits that help it survive, by learning behaviors from its parents and by interacting with its environment.

INTERACTIVITY

Find out how we learn about genes and traits from studying twins.

HANDS-ON LAB

Investigate Explore traits in an imaginary organism.

1. Relate Text to Visuals List two inherited traits and two acquired traits of the fox squirrel.

2. Synthesize Information How does the fox squirrel use its traits to survive?

Acquired Traits

Figure 7 This fox squirrel has traits that were inherited as well as traits that were acquired through learning.

Environmental Interactions

Figure 8 Protection from the sun when you are outside all day is important.

Implement a Solution List three acquired behaviors that people have learned to protect themselves from ultraviolet light.

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Literacy Connection

Cite Textual Evidence Underline two sentences that tell how changes to genes in body cells differ from changes to genes in sex cells.

Environmental Factors Organisms interact with their environment on a regular basis. **Figure 8** shows some of the ways you interact with your environment. You may spend time with friends, breathe fresh air, exercise, and enjoy a sunny day. Unfortunately, some of these interactions may change the way a gene is expressed. Gene expression determines how inherited traits appear. The environment can lead to changes in gene expression in several ways.

Certain chemicals in tobacco smoke or exposure to the sun's harmful ultraviolet (UV) radiation may cause changes in the way certain genes behave. These changes alter the way an organism functions and may produce different traits than would normally have been expressed. Though not a guarantee, these changes may cause cancer and other diseases.

Not all changes in genes caused by environmental factors get passed on to offspring. For example, too much UV radiation can damage the DNA in skin cells to the point of causing cancer. These damaged genes, however, do not get passed to the next generation. In order to pass on genes that were changed by the environment, the change must occur in one of the sex cells—egg or sperm—that formed the offspring. Because the genes that were changed were most likely in the body cells, or cells other than sex cells, then the changed genes would not be passed on to you, and would instead affect only the individual with the changed genes.

LESSON 1 Check

SC.7.L.16.3

1. **Classify** Indicate whether each of the listed traits is acquired from the environment or has been inherited.

Trait	Acquired	Inherited
Brown fur in rabbits		
Length of an elephant's trunk		
Having a spiked haircut		
An overweight horse		
Feather patterns of a parrot		

2. **Construct Explanations** What is a possible benefit to an organism expressing codominant or incomplete dominant traits?

3. **Identify Patterns** Explain why sexual reproduction results in offspring with more genetic variation than asexual reproduction.

4. **Define** What does inheritance mean in terms of reproduction?

5. **Apply Concepts** A species of butterfly has alleles for wing color that are either blue or orange. When a blue butterfly and an orange butterfly mate, their offspring have wings that are both blue and orange. Explain the process through which wing color is expressed.

6. **Evaluate Evidence** A father has blond hair. A mother has black hair. Their three offspring have brown hair, blond hair, and red hair, respectively. Which pattern of inheritance could account for human hair color? Explain your answer.

7. **Synthesize** Identical twins are born with black hair. They grow up together as children, but as adults they live far apart and lead very different lives. How do you explain why one of the twin's black hair turns gray over time?

LESSON 2

Patterns of Inheritance

Guiding Questions

- How did Gregor Mendel advance the fields of genetics and inheritance?
- How are inherited alleles related to an organism's traits?
- How is probability related to inheritance?

Connections

Literacy Determine Conclusions

Math Use a Probability Model

SC.7.L.16.1 Understand and explain that every organism requires a set of instructions that specifies its traits, that this hereditary information (DNA) contains genes located in the chromosomes of each cell, and that heredity is the passage of these instructions from one generation to another.

SC.7.L.16.2 Determine the probabilities for genotype and phenotype combinations using Punnett Squares and pedigrees.

SC.7.L.16.3 Compare and contrast the general processes of sexual reproduction requiring meiosis and asexual reproduction requiring mitosis. (Also **SC.7.N.1.5** and **SC.7.N.2.1**)

Vocabulary

heredity
dominant allele
recessive allele
probability
genotype
phenotype

Academic Vocabulary

quantify
factor

VOCABULARY APP

Practice vocabulary on a mobile device.

Quest CONNECTION

Think about how favorable traits can be used to develop the most desirable fruit.

Connect It!

Male northern cardinals express the trait for bright red feather color. Circle the male cardinal.

Predict List four more visible characteristics that these birds will pass on to their offspring. Then list the inherited trait that their offspring will possess.

Visible Characteristics	Inherited Traits
reddish bill color	bill color

Apply Concepts Will their offspring look exactly like the parents? Explain.

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Mendel's Observations

Like all other organisms, the cardinals in **Figure 1** pass their traits to their offspring. To better understand **heredity**, the passing of traits from parents to offspring, it is important to learn about the history behind the science. In the 1800s, a European monk named Gregor Mendel studied heredity. Mendel's job at the monastery was to tend the garden. After several years of growing pea plants, he became very familiar with seven possible traits the plants could have. Some plants grew tall, while others were short. Some produced green seeds, while others produced yellow.

INTERACTIVITY

Examine different methods of passing on genes to offspring.

Mendel's Experiments

Mendel's studies became some of the most important in biology because he was one of the first to **quantify** his results. He collected, recorded, and analyzed data from the thousands of tests that he ran.

Academic Vocabulary

In Latin, *quantus* means "how much." Have you heard the word quantify used before? Does it remind you of any other words?

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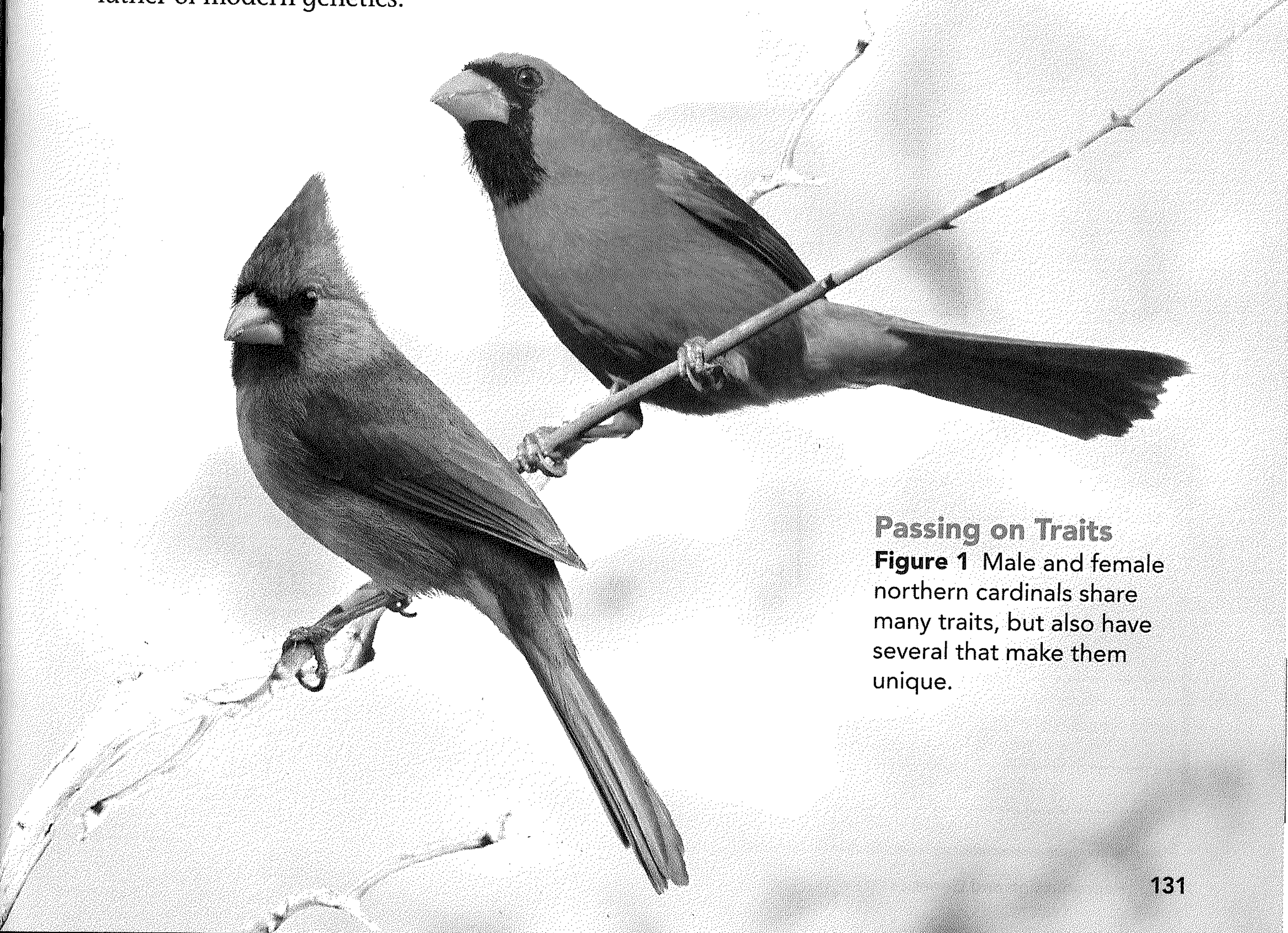
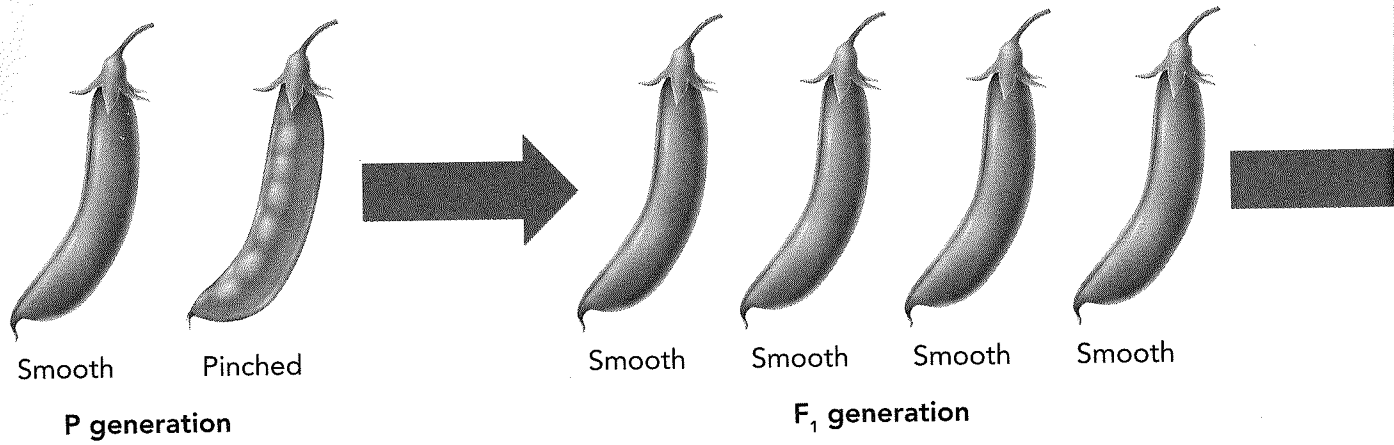
The experiments Mendel performed involved transferring the male flower part of a pea plant to the female flower part to get a desired trait. Mendel wanted to see what would happen with pea plants when he crossed different traits: short and tall, yellow seeds and green seeds, and so on. Because of his detailed work with heredity, Mendel is often referred to as the "father of modern genetics."



Passing on Traits

Figure 1 Male and female northern cardinals share many traits, but also have several that make them unique.



Pea Pod Shape

Figure 2 ✎ Circle the pod shape in the P generation that has the dominant trait.

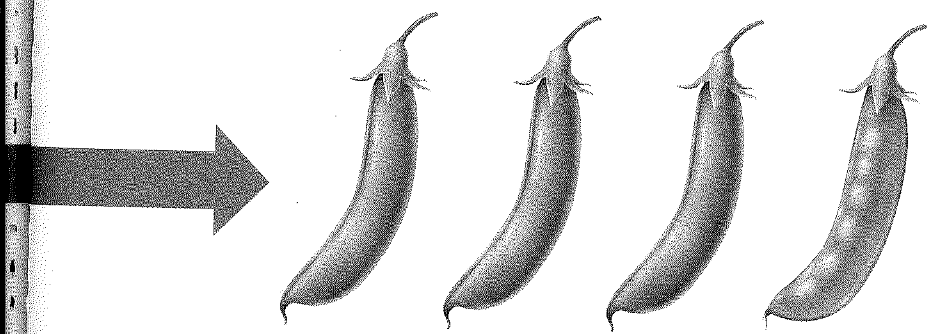
Parents and Offspring When Mendel cross-pollinated, or crossed, a tall plant with a short one, all of the offspring were tall. The tall plant and short plant that were crossed are called the parent plants, or P generation. The offspring are called the F_1, or first filial generation. The term *filial* originates from the Latin terms *filius* and *filia*, which mean "son" and "daughter," respectively.

Mendel examined several traits of pea plants. Through his experimentation, he realized that certain patterns formed. When a plant with green peas was crossed with one with yellow peas, all of the F_1 offspring were yellow. However, when he crossed these offspring, creating what is called the second filial generation, or F_2, the resulting offspring were not all yellow. For every four offspring, three were yellow and one was green. This pattern of inheritance appeared repeatedly when Mendel tested other traits, such as pea pod shape shown in **Figure 2**. Mendel concluded that while only one form of the trait is visible in F_1, in F_2 the missing trait sometimes shows itself.

Plan It!

Develop a Procedure Consider five other traits that Mendel investigated. Explain how you could repeat Mendel's procedure for one of these traits and what the likely results would be.

Trait	Dominant	Recessive
seed shape	round	wrinkled
seed color	yellow	green
pod color	green	yellow
flower color	purple	white
pod position on stem	side of stem	top of stem



F_2 generation

HANDS-ON LAB

Explore cross-pollination by examining the parts of a flower.

Alleles Affect Inheritance

In Mendel's time, people had no knowledge of genetic material or its ability to carry the code for an organism's traits. However, Mendel was still able to formulate several ideas about heredity from his experiments. He called the information that carried the traits **factors**, because they determined what was expressed. He also determined that for every trait, organisms receive one factor from their mother and one factor from their father. He concluded that one factor can mask the expression of the other even if both are present at the same time.

Academic Vocabulary

How is factor used differently in math and science?

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Genes and Alleles Today, the term *factor* has been replaced with *gene* or *allele*. Alleles are the different forms of a gene. Pea plants have one gene that controls the color of the seeds. This gene may express itself as being either yellow or green through a combination of yellow alleles and green alleles. When crossed, each parent donates one of its alleles for seed color to the offspring. The allele that each parent donates is random. An offspring's seed color is determined by the combination of both alleles.

An organism's traits are controlled by the alleles it inherits. A **dominant allele** is one whose trait always shows up in the organism when the allele is present. A **recessive allele**, on the other hand, is hidden whenever the dominant allele is present. If one parent donates a dominant allele and the other donates a recessive allele, only the dominant trait will be expressed.

READING CHECK **Determine Conclusions** What conditions would have to occur for an offspring to express the recessive trait?

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Dominating Color

Figure 3 Mendel discovered that yellow is the dominant pea seed color, while recessive pea seed color is green. Complete the statements. Use the letters *G* and *g* as needed.

Apply Concepts What are the alleles for the green pea seed? Would it be a purebred or a hybrid?

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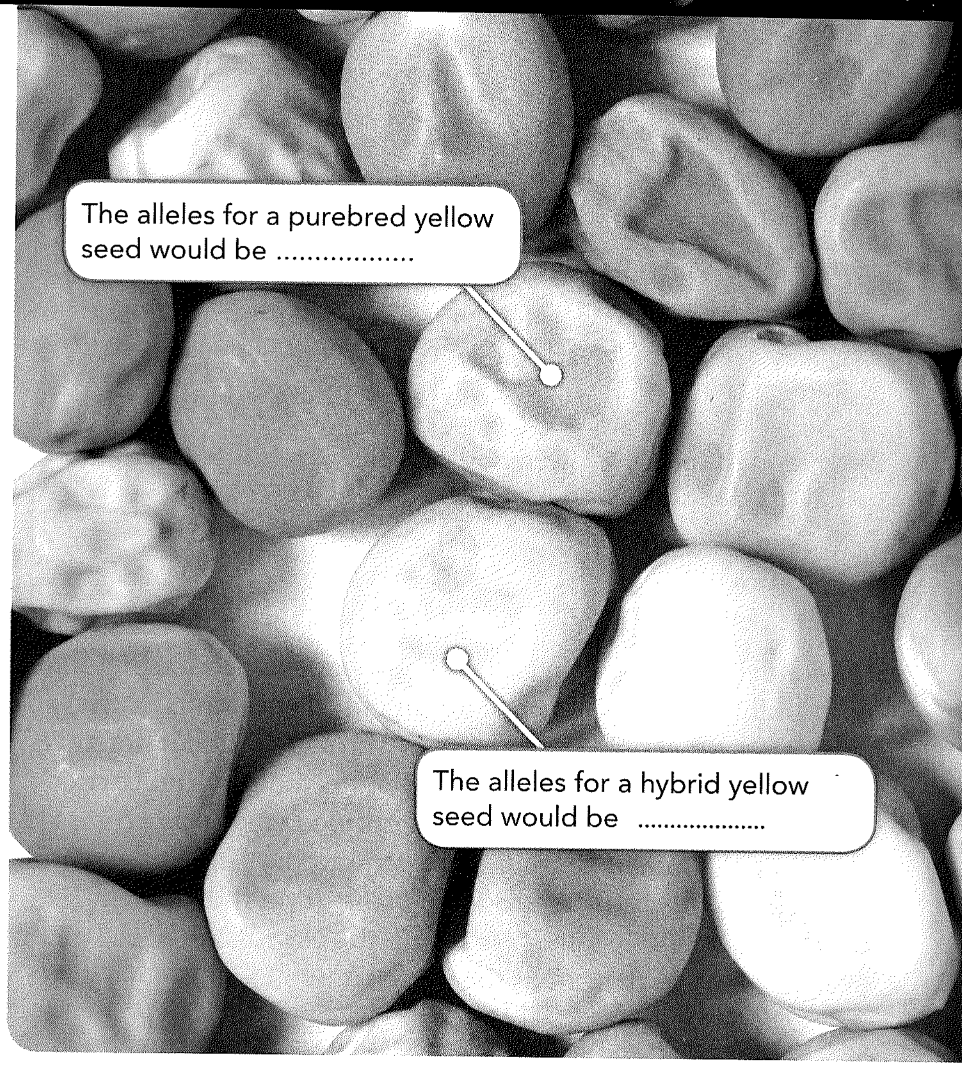


Literacy Connection

Determine Conclusions How did Mendel come to the conclusion that an organism's traits were carried on different alleles? Underline the sentence that answers this question.

Writing Alleles The traits we see are present because of the combination of alleles. For example, the peas in **Figure 3** show two different colors. Pea color is the gene, while the combinations of alleles determines how the gene will be expressed. To represent this, scientists who study patterns of inheritance, called geneticists, use letters to represent the alleles. A dominant allele is represented with a capital letter (G) and a recessive allele with a lowercase letter (g).

When an organism has two of the same alleles for a trait, it is called a purebred. This would be represented as GG or gg. When the organism has one dominant allele and one recessive allele, it is called a hybrid. This would be represented as Gg. Remember that each trait is represented by two alleles, one from the mother and one from the father. Depending upon which alleles are inherited, the offspring may be a purebred or a hybrid.

Mendel's work was quite revolutionary. Prior to his work, many people assumed that all traits in offspring were a mixture of each parent's traits. Mendel's experiments, where traits appeared in the F_2 generation that were not in the F_1 generation, disproved this idea.

Probability and Heredity

When you flip a coin, what are the chances it will come up heads? Because there are two options (heads or tails), the probability of getting heads is 1 out of 2. The coin has an equal chance of coming up heads or tails. Each toss has no effect on the outcome of the next toss. **Probability** is a number that describes how likely it is that an event will occur. The laws of probability predict what is likely to happen and what is not likely to happen.

INTERACTIVITY

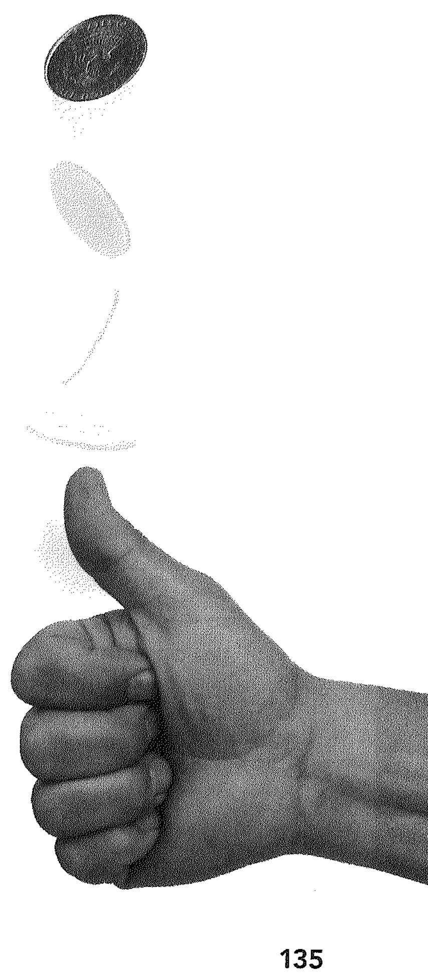
Collect data to determine whether a trait is genetic or acquired.

Probability and Genetics When dealing with genetics and inheritance, it is important to know the laws of probability. Every time two parents produce offspring, the probability of certain traits getting passed on is the same. For example, do you know any families that have multiple children, but all of them are the same sex? Picture a family where all the children are girls. According to the laws of probability, a boy should have been born already, but there is no guarantee of that happening. Every time these parents have a child, the probability of having a boy remains the same as the probability of having a girl.

Math Toolbox

Determining Probability

Probability is an important part of the science of genetics. Answer the questions on probability below.



1. **Predict** The probability of a specific allele from one parent being passed on to an offspring is 1 in 2, or ½. This is the same probability as predicting a coin toss correctly. How often would you expect a coin to show tails if you flip it 100 times?

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2. **Identify Patterns** A die is a six-sided cube with dots representing the numbers 1 through 6. What is the probability of rolling a 3?

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3. **Use a Probability Model** You and a friend both roll a die at the same time. On the first roll, the dots on the two dice add up to 7. On the second roll, they add up to 2. Which do you think was more likely, rolling a total of 2 or a total of 7? Explain your answer.

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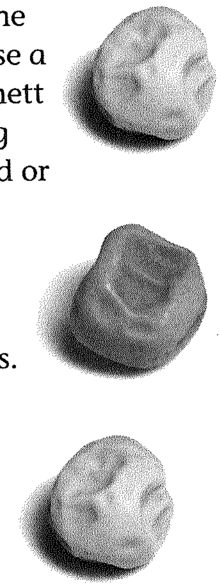
VIDEO

Further examine the process of making a Punnett square.

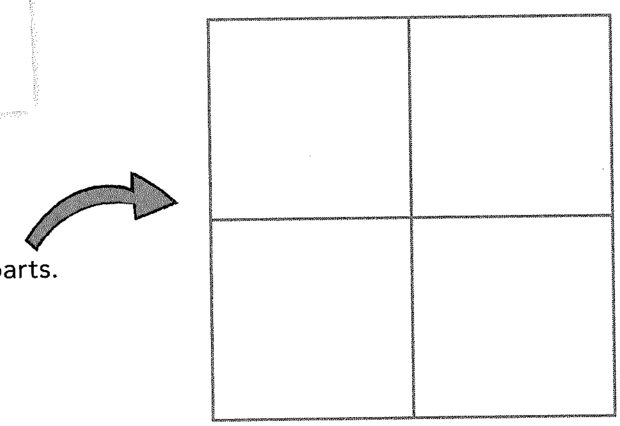
Making a Punnett Square To determine the probability of inheriting alleles, geneticists use a tool called a Punnett square. To construct a Punnett square, it is important to know what trait is being considered and whether the parents are purebred or hybrid.

The following steps demonstrate how to use a Punnett square to calculate the probability of offspring having different combinations of alleles. The example describes the procedure for a cross between two hybrid parents; however, this procedure will work for any cross.



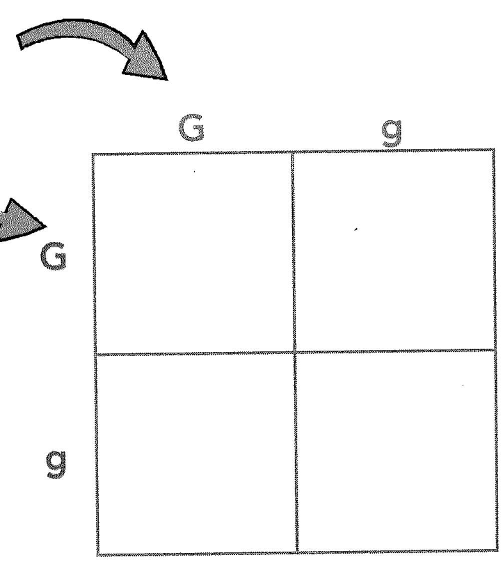
Using a Punnett Square

Mendel's experiments involved crossing two hybrid pea plants in the F_1 generation. Most plants in the F_2 generation showed the dominant trait, but some showed the recessive trait. A Punnett square uses the laws of probability to demonstrate why those results occurred. Consider the question of what the offspring of two hybrid pea plants with yellow seed color will be.



1 **Draw a square box** divided into four square parts.

One parent's alleles go on top and the other parent's alleles go on the left.



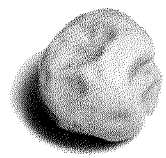
2 **Determine the alleles** of each of the parents. You know that they are both hybrids, so they have one dominant allele (represented as a capital letter) and one recessive allele (represented as a lowercase letter). Place one set of alleles on top of the columns of the box, and one set of alleles next to the rows of the box, as shown.

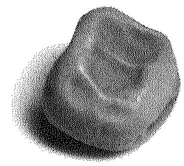
3 Do the cross! Inside each box, combine the letter at the top of the column with the letter to the left of the row the box is in. Always write a dominant allele before a recessive allele.

	G	g
G	GG	Gg
g	Gg	gg

4 Determine the likelihood of different combinations of alleles. As you can see from the Punnett square, the combination GG occurs ¼ of the time, the combination Gg occurs ²⁄₄, or ½ of the time, and the combination gg occurs ¼ of the time.

5 Determine which trait is expressed for each combination of alleles. In this example, the combination GG and Gg result in the dominant yellow seed color, while the combination gg results in the green seed color. Therefore, the dominant allele will be expressed ¾ of the time. This matches the results of Mendel's experiments.





Use a Probability Model You cross a pea plant that is hybrid for yellow seed color (Gg) with a purebred green seed color (gg) plant. Draw a Punnett square to show the results of the cross. What is the probability that the offspring will have green seed color?

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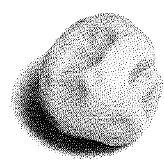
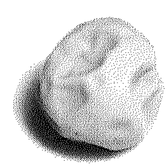




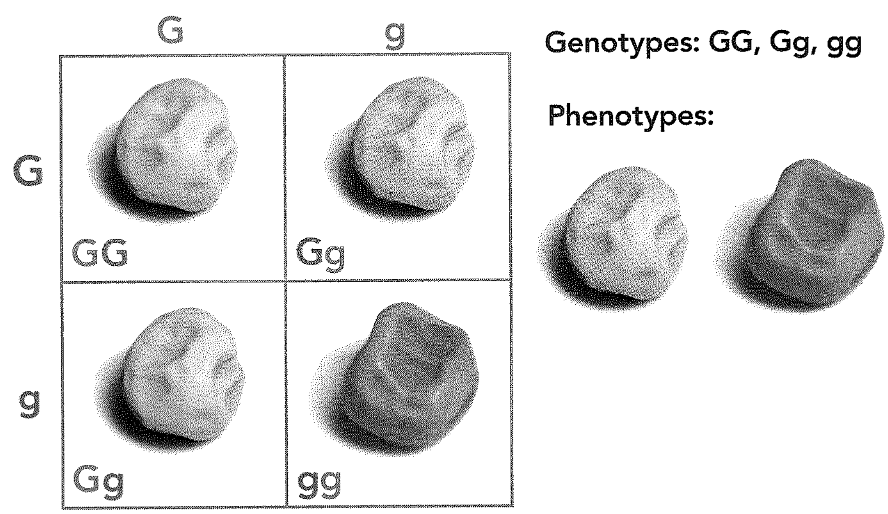
INTERACTIVITY

Use models to describe how sexual reproduction leads to genetic variation.

Genotype

You are already familiar with the terms *purebred* and *hybrid*. These terms refer to **genotype**, an organism's genetic makeup or combination of alleles. As shown in **Figure 4**, the genotype of a purebred green seed pea plant would be gg. Both alleles are the same (purebred) and they are recessive because green is the recessive trait in terms of seed color. The hybrid genotype for this trait would be Gg.

The expression of an organism's genes is called its **phenotype**, the organism's physical appearance or visible traits. The height, the shape, the color, the size, the texture—whatever trait is being expressed, is referred to as the phenotype. So, a pea plant with the phenotype of yellow seed color could have two possible genotypes, GG or Gg.



Genotypes and Phenotypes for Seed Color

Figure 4 The phenotype of an organism is explained as physical characteristics we see, while the genotype describes the combination of alleles that are inherited.

There are two other terms geneticists use to describe genotypes. Instead of saying purebred, they refer to an organism with two identical alleles as homozygous (*homo-* means "the same"). When the alleles are both dominant, as in the yellow seed plant (GG), the genotype is called homozygous dominant. However, when the alleles are both recessive, as in the green seed color (gg), the genotype is called homozygous recessive. When an organism is a hybrid, as in yellow seed color (Gg), the genotype is called the heterozygous condition (*hetero-* means "different").

READING CHECK **Determine Differences**
Explain how genotypes and phenotypes are different.

LESSON 2 Check

SC.7.L.16.1, SC.7.L.16.2

Use the information you calculated in the Punnett square activity to answer Question 1.

1. Cause and Effect What would happen to the probabilities of yellow and green seeds if one parent were homozygous recessive and the other were homozygous dominant?

2. Infer The dominant allele for dimples is *D*. What genetic condition does an individual with the alleles *dd* have?

3. Evaluate Claims A student claims that for an organism to be called purebred the two alleles for a trait must be the same and that both alleles must be also dominant. Do you agree? Explain.

4. Predict For plant stem length, the dominant allele for height is *T* and the recessive allele is *t*. What would be the genotypes, phenotypes, and offspring probabilities of a cross between two heterozygous parents for tall stem length?

5. Apply Concepts How would you evaluate the contribution of Mendel's experiments with pea plants to the study of biology? Explain.

6. Identify What controls the traits an organism has?

Quest CHECK-IN

In this lesson, you learned how inherited alleles determine traits and how probability is related to inheritance. You also explored the factors that determine an organism's genotype and phenotype.

Apply Concepts How can you increase the likelihood that the desired trait will be inherited in your fruit?

INTERACTIVITY

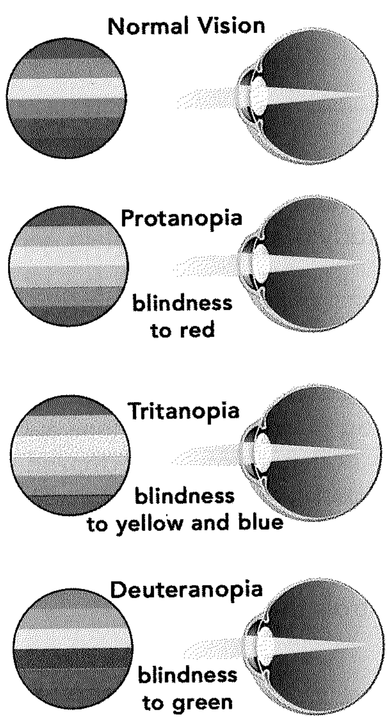
An Apple Lesson

Go online to explore how you can utilize both sexual and asexual reproduction to develop your new fruit.

Case Study

SC.7.L.16.1, SC.7.L.16.2, SC.7.N.3.2

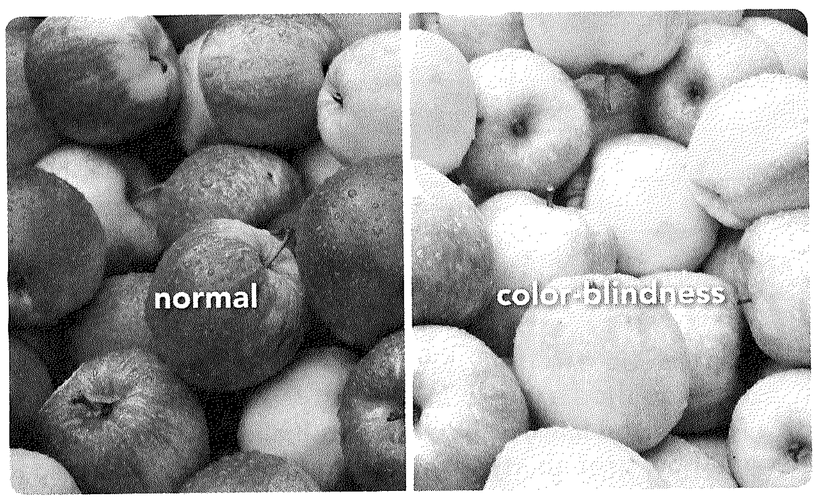
Can You Predict Color-Blindness?



The human eye can detect about a million colors. People with color-blindness are more limited in the colors they can see.

We all know that an apple is red, but do we all see exactly the same shade of red? Probably not. And some people may not see red at all because they are color-blind.

Millions of people in the United States have some form of color-blindness, sometimes without even realizing it. Normally, cone-shaped cells inside the retina detect red, blue, and green light. People with color-blindness have damaged cones, so their perception of these colors is limited or altered. To them, a red apple might look green.

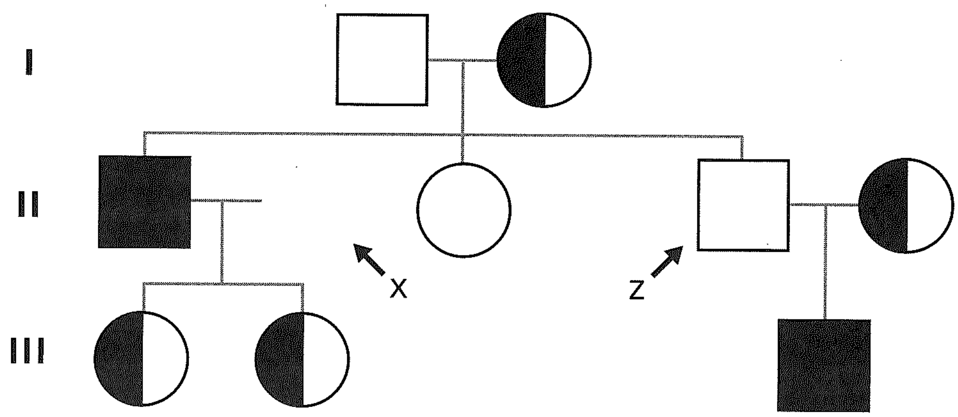


Because color-blindness is an inherited trait, it can be traced through the generations of a family using a pedigree chart. Protanopia, the most common form of color-blindness, is carried on the X chromosome. Because men have only one X chromosome, whatever allele they receive from their mother will be expressed. Women have two X chromosomes, however, so even if one X carries the color-blindness gene, the other X may not. A female who has color-blindness must have the gene on both X chromosomes, so she inherited the gene from both of her parents.

A pedigree chart shows the following:

- Circles represent females and squares represent males.
- Roman numerals show the generation in the family.
- A black circle or square is an individual with color-blindness.
- A half-black circle carries the gene for color-blindness.
- Horizontal lines connect male and female couples.
- Vertical lines connect parents to their children.

Use the pedigree chart to answer the following questions.



1. Use Models Fill in the missing individual labeled *X* in generation II. Explain your answer.

2. Explain Why can only females be carriers of the color-blindness gene without actually being color-blind?

3. Develop Models If the individual labeled Z had married a female who was color-blind, could their daughter be color-blind? Could their son?

4. Identify Limitations Can you predict how severe the color-blindness is for the boy in generation III? Why or why not?

LESSON 3

Chromosomes and Inheritance

Guiding Questions

- What is the relationship among genes, chromosomes, and inheritance?
- How is a pedigree used to track inheritance?
- How does the formation of sex cells during meiosis differ from the process of cell division?

Connections

Literacy Read and Comprehend

Math Model With Mathematics

SC.7.L.16.1 Understand and explain that every organism requires a set of instructions that specifies its traits, that this hereditary information (DNA) contains genes located in the chromosomes of each cell, and that heredity is the passage of these instructions from one generation to another.

SC.7.L.16.2 Determine the probabilities for genotype and phenotype combinations using Punnett Squares and pedigrees.

SC.7.L.16.3 Compare and contrast the general processes of sexual reproduction requiring meiosis and asexual reproduction requiring mitosis. (Also **SC.7.N.1.3** and **SC.7.N.2.1**)

Vocabulary

chromosome
cell cycle
pedigree
meiosis
chromatids
mitosis

Academic Vocabulary

structure
function

VOCABULARY APP

Practice vocabulary on a mobile device.

Quest CONNECTION

Think about how chromosomes are passed down from parents to offspring.

Connect It!

Circle the traits that are similar between the parents and the offspring.

Apply Concepts How were the traits transferred from the parents to the ducklings during reproduction? Where were those traits found?

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Apply Scientific Reasoning Each duckling came from these parents. They look similar, but they are not exactly the same. Why are they not identical? Explain.

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Chromosomes and Genes

Gregor Mendel's ideas about inheritance and probability can be applied to all living things. Mendel determined that traits are inherited using pieces of information that he called factors and we call genes. He observed and experimented with genes in pea plants. He discovered how genes, such as those in ducks (**Figure 1**), were transferred from parents to offspring and how they made certain traits appear. However, Mendel did not know what genes actually look like.

Today, scientists know that genes are segments of code that appear on structures called **chromosomes**. These threadlike **structures** within a cell's nucleus contain DNA that is passed from one generation to the next. These threadlike strands of genetic material have condensed and wrapped themselves around special proteins. This provides support for the chromosome structure.

Chromosomes are made in the beginning of the **cell cycle**, the series of events in which a cell grows, prepares for division, and divides to form daughter cells. During this time, the chromosome gets its characteristic *X* shape.

HANDS-ON LAB

Investigate genetic crosses in imaginary creatures.

Academic Vocabulary

Identify and describe something that has a particular structure.

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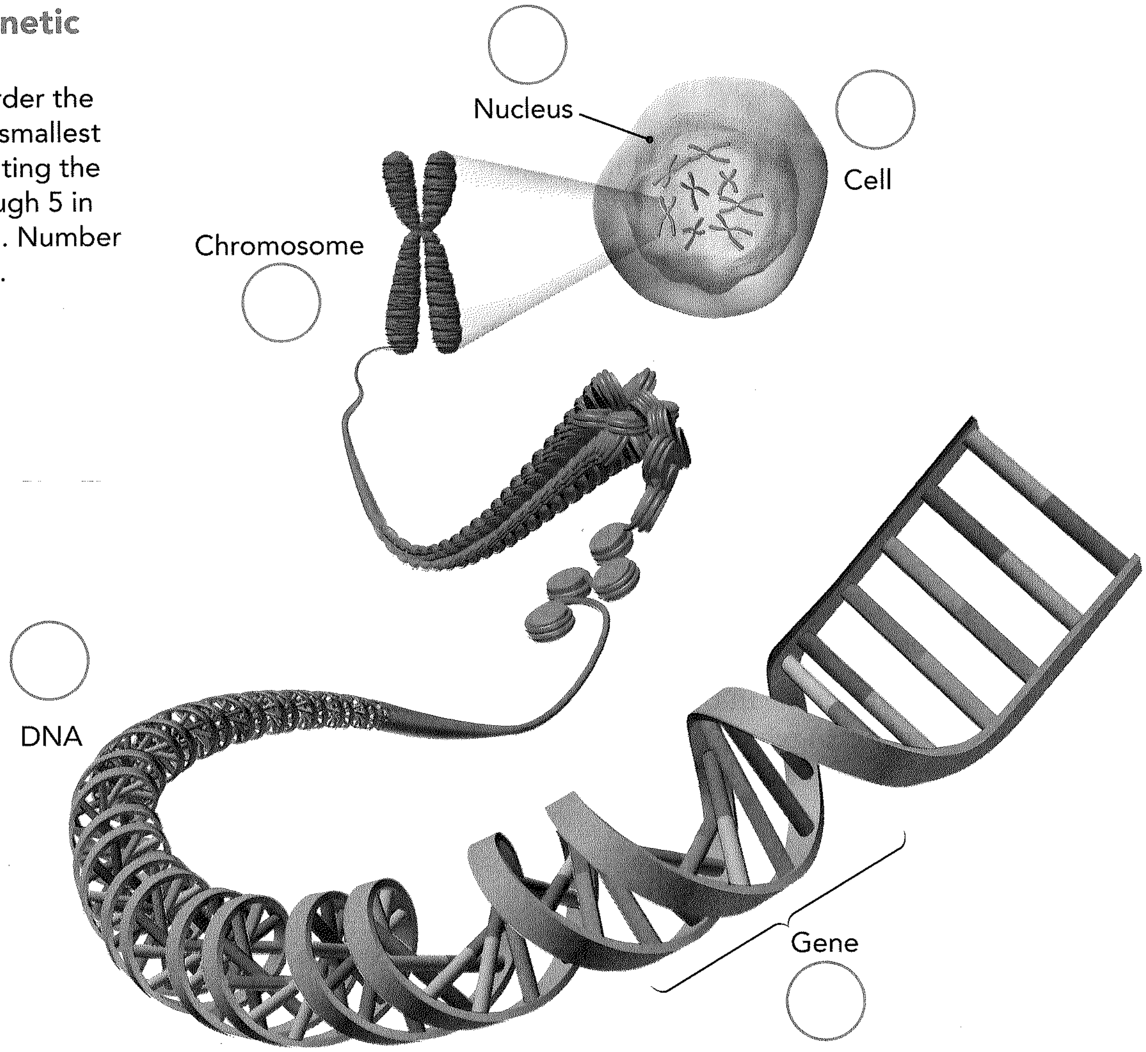
Parents Pass Traits to Their Offspring

Figure 1 Each baby mallard duck receives some traits from the mother and some from the father.

Scales of Genetic Material

Figure 2 ✏ Order the structures from smallest to largest by writing the numbers 1 through 5 in the blank circles. Number 1 is the smallest.



📓 **Make Meaning** Why do sex cells contain only half the number of chromosomes needed for offspring? In your science notebook, explain what would happen if sex cells contained the same number of chromosomes as body cells.

Number of Chromosomes Every cell in your body other than the sex cells has the same number of chromosomes. In humans, this number is 46. Other organisms have different numbers of chromosomes, and there is a great variety. For example, mallard ducks have 80 chromosomes. All sexually-reproducing organisms form sex cells, which have half the number of chromosomes that body cells have.

Genes on Chromosomes Every living thing needs instructions to live. Without these instructions, living things would not be able to grow and **function**. These instructions are located on genes. As you can see in **Figure 2,** genes are located on chromosomes.

In humans, between 20,000 and 25,000 genes are found on the 46 chromosomes. Chromosomes are different sizes. Larger chromosomes contain more genes than smaller chromosomes. Each gene contains instructions for coding a particular trait. There are hundreds to thousands of genes coding traits on any given chromosome. For many organisms, these chromosomes come in sets.

Academic Vocabulary

What is the difference between an object's structure and its function?

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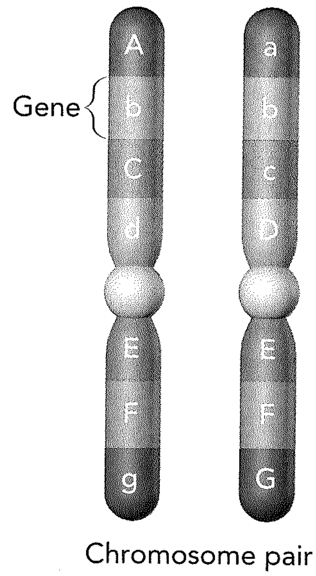
Chromosome Pairs During fertilization, you receive 23 chromosomes from your father and 23 chromosomes from your mother. These chromosomes come in pairs, called homologous chromosomes, that contain the same genes. Two alleles—one from the mother and one from the father—represent each trait. However, the alleles for these genes may or may not be the same. Some of the alleles for how the gene is expressed may be dominant or recessive. In **Figure 3**, the offspring that received these chromosomes inherited two different forms of a gene—allele *A* from one parent and allele *a* from the other. The individual will be heterozygous for that gene trait. Because more than one gene is present on the 23 pairs of chromosomes, there is a wide variety of allele combinations.



A Pair of Chromosomes

Figure 3 Circle all the pairs of alleles that would be homozygous for a trait.

READING CHECK **Read and Comprehend** How would geneticists—people who study genes—know whether an organism is homozygous or heterozygous for a certain trait by examining its chromosomes?

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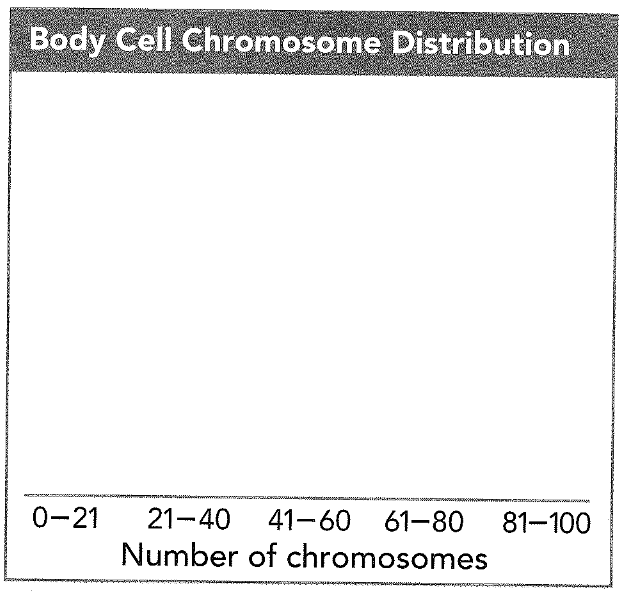
Math Toolbox

Counting on Chromosomes

1. Model with Mathematics Fill in the table with the appropriate chromosome number for the missing body cell or sex cell.

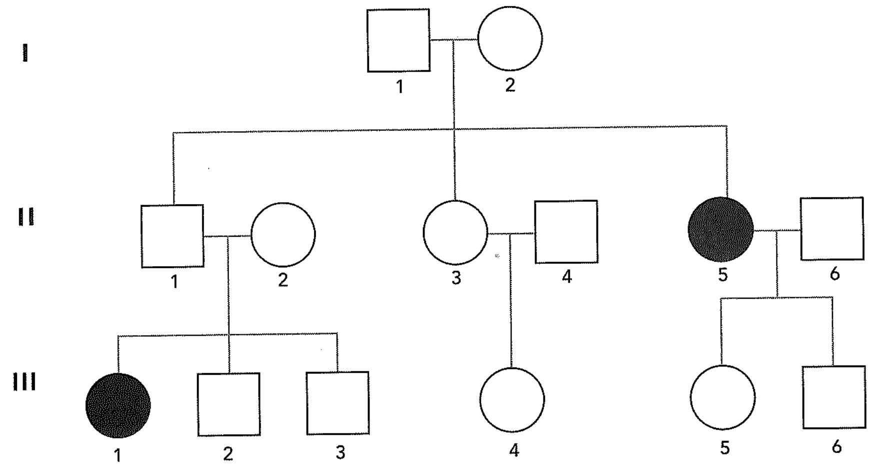
Organisms	Number of Chromosomes	
	Body Cells	Sex Cells
House cat	38	
Mallard duck		40
Corn	20	
Peanut	40	
Horse		32
Oak tree		12
Sweet potato	90	
Camel		35
Chicken	78	

2. Construct Graphs Complete the line plot below. Place an *X* for each organism whose body cell chromosome number falls within the given range.



Tracking Traits

Figure 4 Sickle cell anemia is a genetic disease that changes the structure of red blood cells. In the pedigree, affected members are shaded. Circle any individuals on the pedigree who are definitely carriers for the trait.



INTERACTIVITY

Take a look inside the formation of sex cells through meiosis.

Using a Pedigree

Alelles can sometimes recombine to produce traits that are not favorable, such as a genetic disease. Geneticists study how traits are inherited in order to trace their genetic origin and predict how they may be passed on to future generations.

A **pedigree** is a tool that geneticists use to map out the inheritance of traits. You saw one example of a pedigree in the Case Study. The diagram shows the presence or absence of a trait according to the relationships within a family across several generations. It is like a family tree. **Figure 4** shows multiple generations represented by Roman numerals I, II, and III. Most pedigrees show which family members express a particular trait (shaded figures) as well as the individuals who carry the trait but do not express it (half-shaded figures). In a pedigree, males are represented with squares and females with circles. One horizontal line connects the parent couple and another line leads down from the parents to their children.

Model It!

Develop Models Think of a trait that you admire. How can that trait get passed through a family? Create a pedigree that outlines the transmission of this trait through a family. Consider who has the trait, who is a carrier for it, and who does not have it.

Forming Sex Cells

In an organism that is reproduced sexually, a body cell has twice as many chromosomes a sex cell. Why is this important? Well, it is through the sex cells that parents pass their genes on to their offspring. When the sperm and egg fuse, they form a zygote, or fertilized egg. The zygote gets two sets of chromosomes—one set from the sperm and one set from the egg. Human eggs, for example, contain 23 total chromosomes in a set and sperm contain 23 total chromosomes in a set. So, each of your body cells contains one set of chromosomes from your mother and another set from your father for a total of 46 chromosomes.

Sex cells (sperm and egg) are formed through a very specialized process called **meiosis**, during which the number of chromosomes is reduced by half. It is through meiosis that homologous chromosomes separate into two different cells. This creates new cells with half as many chromosomes as the parent cell.

Homologous chromosomes have one chromosome from each parent. While the two chromosomes share the same sequence of genes, they may have different alleles. Before the chromosomes separate and move into separate cells, they undergo a process called crossing over. Notice in **Figure 5** that a small segment of one chromosome exchanges places with the corresponding segment on the other chromosome. By exchanging this genetic information, the new cells that form will have a slightly different combination of genes. This allows for minor variations in traits to form, which means there is a higher likelihood that offspring with desirable traits will form within the larger population.

Literacy Connection

Read and Comprehend Underline statements that explain why body cells have two times as many chromosomes as sex cells.

Swapping Genetic Material

Figure 5 During crossing over, a segment of the gene from the mother changes places with a segment of the same gene from the father. Circle the gene segments that exchanged places.

Cause and Effect What would happen to offspring if crossing over did not occur during the first part of meiosis?

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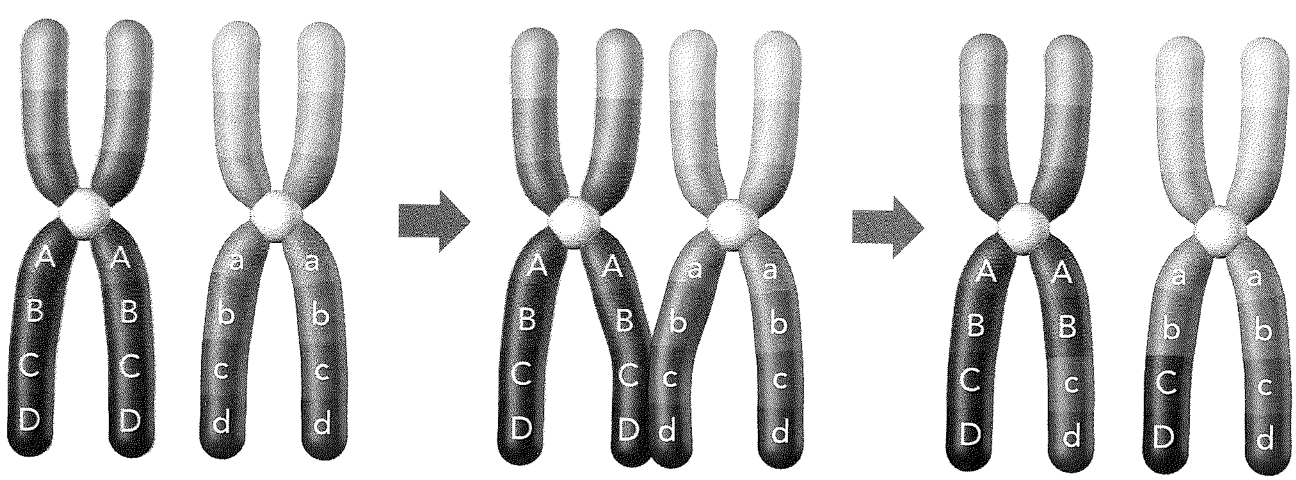


Homologous Chromosomes — Crossing Over — Segments Exchange

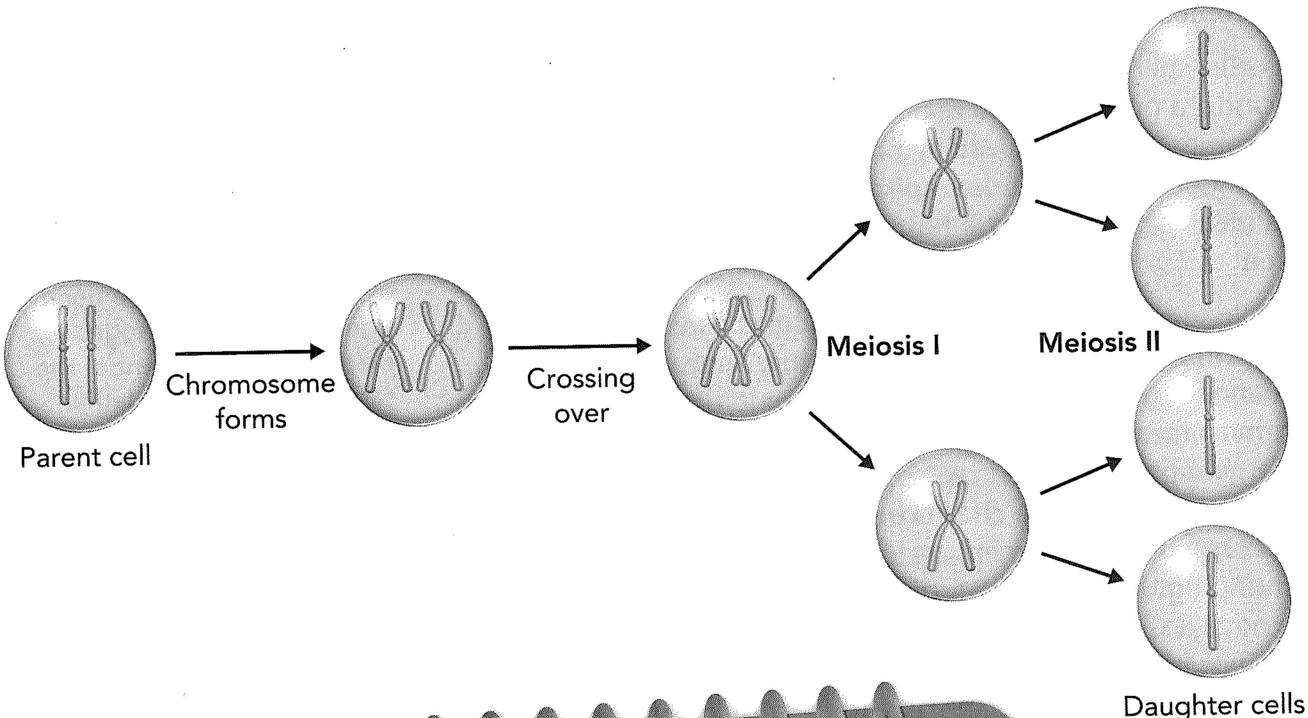
VIDEO

Observe the process of meiosis in action.

INTERACTIVITY

Trace the path of a particular trait through meiosis.

Meiosis Before a cell can divide, the genetic material condenses into chromosomes. **Figure 6** shows how meiosis starts with the genetic material being copied and condensing into chromosomes. After crossing over, the chromosomes separate and the cell divides into two cells. Each new cell, now containing half the number of chromosomes, then divides again, making a total of four daughter cells. Meiosis II in **Figure 6** shows how this second division occurs. Each chromosome splits into two rod-like structures called **chromatids**. Each chromatid contains a double helix of DNA. Note that each of the four daughter cells has one distinct chromatid.



Meiosis

Figure 6 The process of meiosis forms sex cells.

1. Use Models How is the genetic material of the parent cell different from the four cells that are formed?

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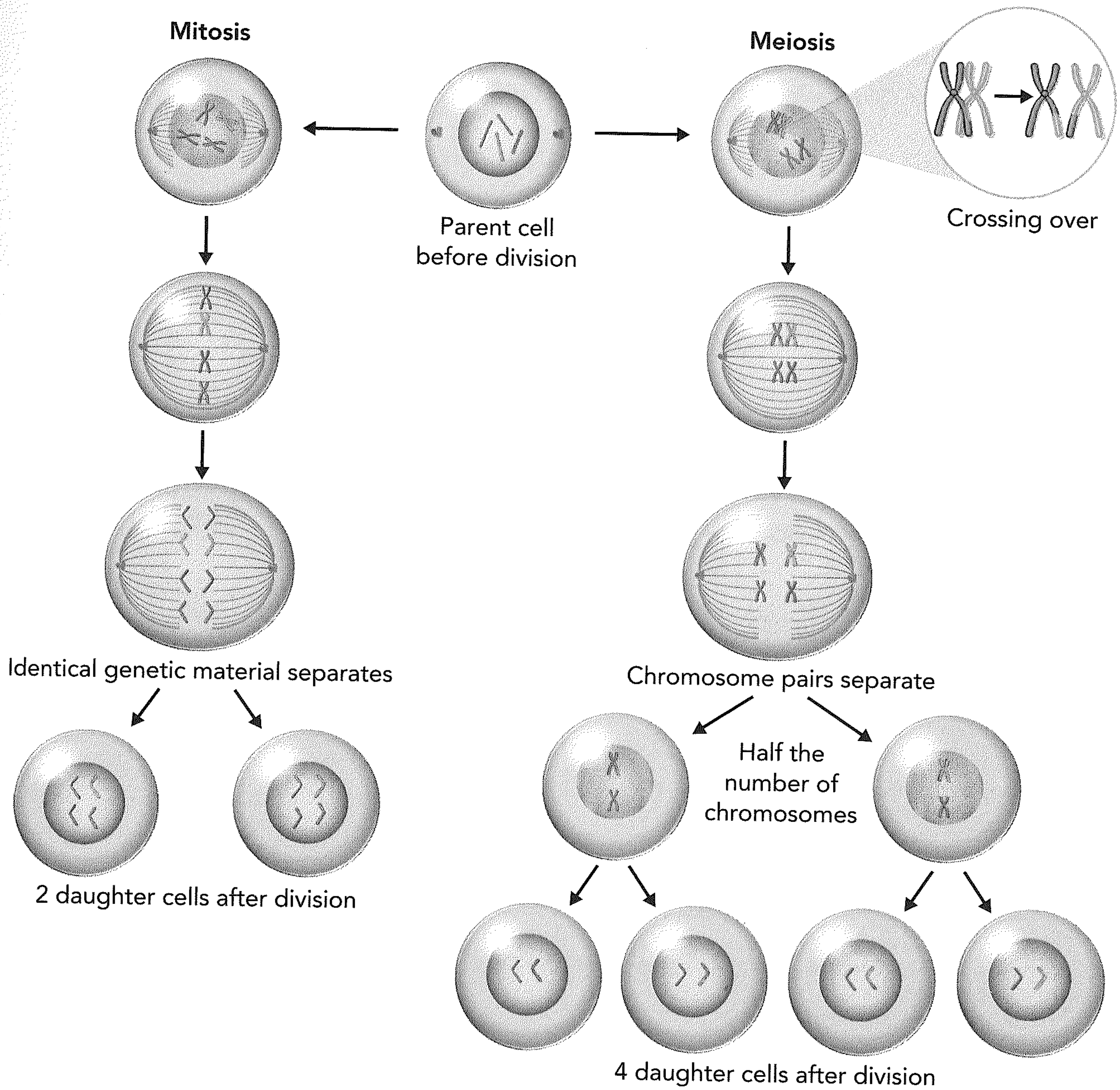
2. Sequence Order the events of meiosis correctly.

_________ Four daughter cells are formed.

_________ Chromosome splits into two chromatids.

_________ Chromosome pairs come together and cross over.

_________ Cell divides into two daughter cells.



Comparing Meiosis and Mitosis The two main types of cell division are meiosis and mitosis. The majority of our body cells divide to make two genetically identical new cells in a process called **mitosis**: The cell's nucleus divides into two new nuclei, and identical copies of the parent cell's genetic material are distributed into each daughter cell.

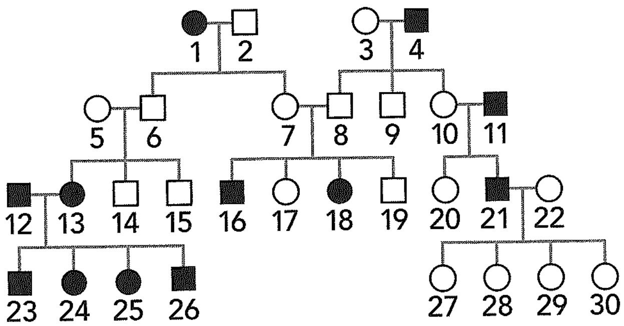
Compare the processes of meiosis and mitosis shown in **Figure 7**. Mitosis produces two identical daughter cells with the same DNA as the parent cell. The sex cells produced by meiosis, however, are not genetically identical. There are two reasons for this difference. First, crossing over exchanges genetic material between homologous chromosomes. Secondly, the two cell divisions that occur in meiosis produce four daughter cells and each cell has half its parent cell's DNA. As a result, each sex cell has different genetic information.

Meiosis versus Mitosis
Figure 7 While meiosis forms sex cells, mitosis forms new body cells.

LESSON 3 Check

SC.7.L.16.1, SC.7.L.16.2, SC.7.L.16.3

1. **Draw Conclusions** In humans, free earlobes are dominant and attached earlobes are recessive. The pedigree shows the transmission of attached earlobes through four generations of a family. Note the four offspring in the fourth generation, individuals 27, 28 29, and 30. What conclusions can you draw about their mother, individual 22? Explain.



2. **Analyze Data** Is the number of chromosomes in a body cell a good predictor of an organism's complexity? How do you know?

3. **Calculate** A male king crab has 104 chromosomes in a sperm cell. How many chromosomes does it have in each of its body cells?

4. **Cite Evidence** Which type of cell division increases the likelihood of variation within a species? Explain how it happens.

Quest CHECK-IN

In this lesson you learned how chromosomes carry genes. You also learned you receive one set of chromosomes from each parent. You explored how combinations of alleles are passed down in families. You also learned how cells divide to produce genetically similar cells or to produce sex cells.

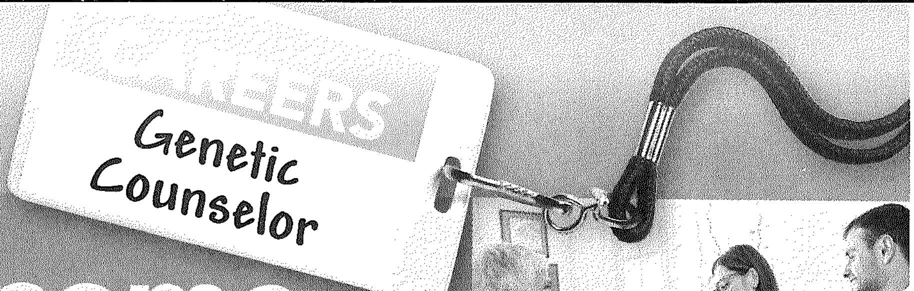
Apply Concepts A domestic cat has 38 chromosomes in its skin cells, while a dog has 78 chromosomes. How does this fact help to explain why dogs and cats cannot interbreed?

INTERACTIVITY

About Those Chromosomes

Go online to begin your chromosome map.

SC.7.L.16.1, SC.7.N.1.5



Chromosome COUNSELORS

Sometimes it runs in the family, as they say. We get traits such as eye color from genes passed on to us by our parents, but we can inherit diseases, too.

Genetic counselors help people who are at risk for a disease or a genetic disorder. They are experts in genetics, so they know better than anyone how genes work. And they are trained counselors, too. They give emotional support and help families make health decisions.

For example, a genetic counselor might help new parents of a baby with Down syndrome. Or the counselor might meet with a patient whose family has a history of Alzheimer's.

Genetic counselors study a family's health history, order genetic tests, and help people to live with a genetic disease. They even advise doctors. They're the genetic experts, and they share their knowledge to help people.

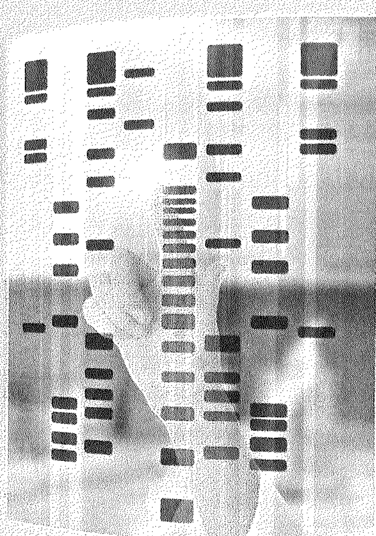
Genetic counselors complete a four-year bachelor's degree in biology or a healthcare field. After graduating, they work on completing a master's degree. This degree will focus on human genetics and counseling. They also complete extensive research. In addition, excellent communication and decision-making skills are required.

VIDEO

Watch what's involved with being a genetic counselor.

MY CAREER

Want to help people understand their genes? Do an online search for "genetic counselor" to learn more about this career.



Genetic counselors help others understand the complex world of DNA, genes, and chromosomes.

LESSON 4

Genetic Coding and Protein Synthesis

Guiding Questions

- Why do cells undergo DNA replication?
- How do cells make proteins?
- Why do cells undergo protein synthesis?

Connection

Literacy Draw Comparative Inferences

SC.7.L.16.1 Understand and explain that every organism requires a set of instructions that specifies its traits, that this hereditary information (DNA) contains genes located in the chromosomes of each cell, and that heredity is the passage of these instructions from one generation to another. (Also **SC.7.N.1.5** and **SC.7.N.3.2**)

Vocabulary

DNA
protein synthesis
messenger RNA
transfer RNA

Academic Vocabulary

sequence

VOCABULARY APP

Practice vocabulary on a mobile device.

Quest CONNECTION

Think about how you might change a fruit's DNA to alter its traits.

Connect It!

A blueprint is a plan to build something. Circle the blueprint.

Make Connections When have you used instructions to build something?

....

....

Construct Explanations How did the instructions help you with building the structure?

....

....

The Genetic Code

Just as the couple in **Figure 1** need a blueprint to renovate a house, your body needs a plan to carry out daily functions. Your "blueprint" is found in the nucleus of each cell in the form of **DNA**. DNA (deoxyribonucleic acid) is the genetic material that carries information about an organism and is passed from parent to offspring.

In 1953, almost 100 years after DNA was discovered, scientists realized that DNA was shaped like a double helix—a twisted ladder. The structure of DNA consists of sugars, phosphates, and nitrogen bases. The sides of the ladder are made of sugar molecules, called deoxyribose, alternating with phosphate molecules. The rungs of the ladder are made of nitrogen bases. DNA has four nitrogen bases: adenine (A), thymine (T), guanine (G), and cytosine (C).

Genes are sections of DNA found on chromosomes. Each gene consists of hundreds or thousands of nitrogen bases arranged in a **sequence**. And it's this order that forms the instructions for building proteins — long chains of amino acids. Genes direct the construction of proteins, which in turn affect the traits that individuals receive from their parent(s). In other words, proteins trigger cellular processes that determine how inherited traits get expressed.

INTERACTIVITY

Explore the role of DNA in cellular processes and reproduction.

Academic Vocabulary

List some other contexts in which you have seen the word sequence.

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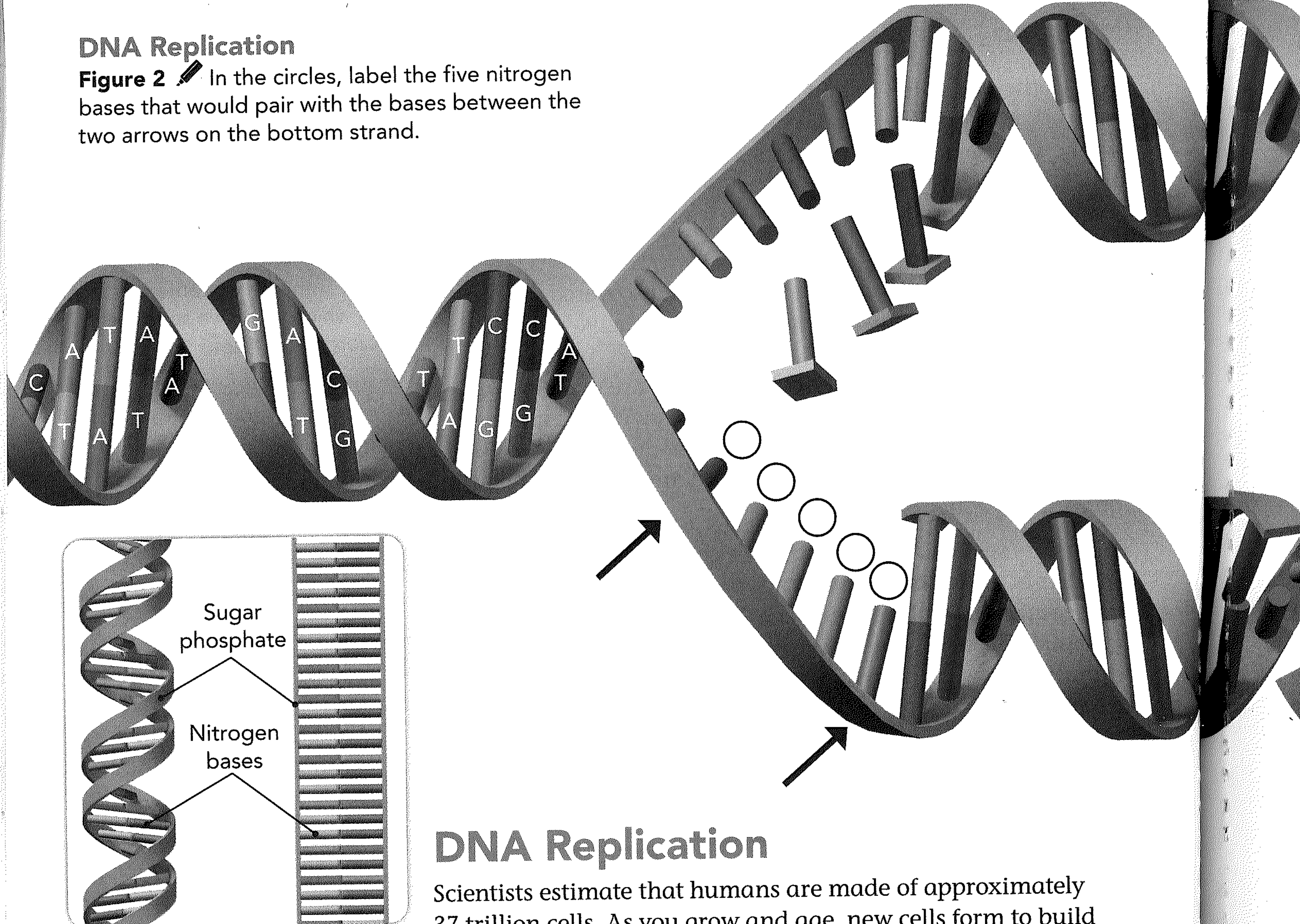
Using a Blueprint

Figure 1 A blueprint is a plan for a building. DNA is the blueprint for constructing an organism.

DNA Replication

Figure 2 ✎ In the circles, label the five nitrogen bases that would pair with the bases between the two arrows on the bottom strand.



DNA Replication

Scientists estimate that humans are made of approximately 37 trillion cells. As you grow and age, new cells form to build and repair structures or to replace cells that have died. For this to happen, cells need to replicate, and this requires making copies of DNA.

As shown in **Figure 2**, DNA replication begins when the double helix untwists. Then, a protein breaks the DNA strand in half—at the structure's weakest point—between the nitrogen bases. This separation actually looks like a zipper (**Figure 3**), and is often referred to as "unzipping the DNA." Next, nitrogen bases with a sugar and phosphate attached pair up with the bases on each half of the DNA. Because nitrogen bases always pair in the same way, adenine with thymine and guanine with cytosine, the order of the bases on both strands are identical. At the end of replication, a chromosome with two identical DNA strands is formed.

VIDEO

Learn how the simplicity of DNA's four-letter code leads to the complexity of life.

✓ READING CHECK **Draw Comparative Inferences** How is the separation of DNA like a zipper?

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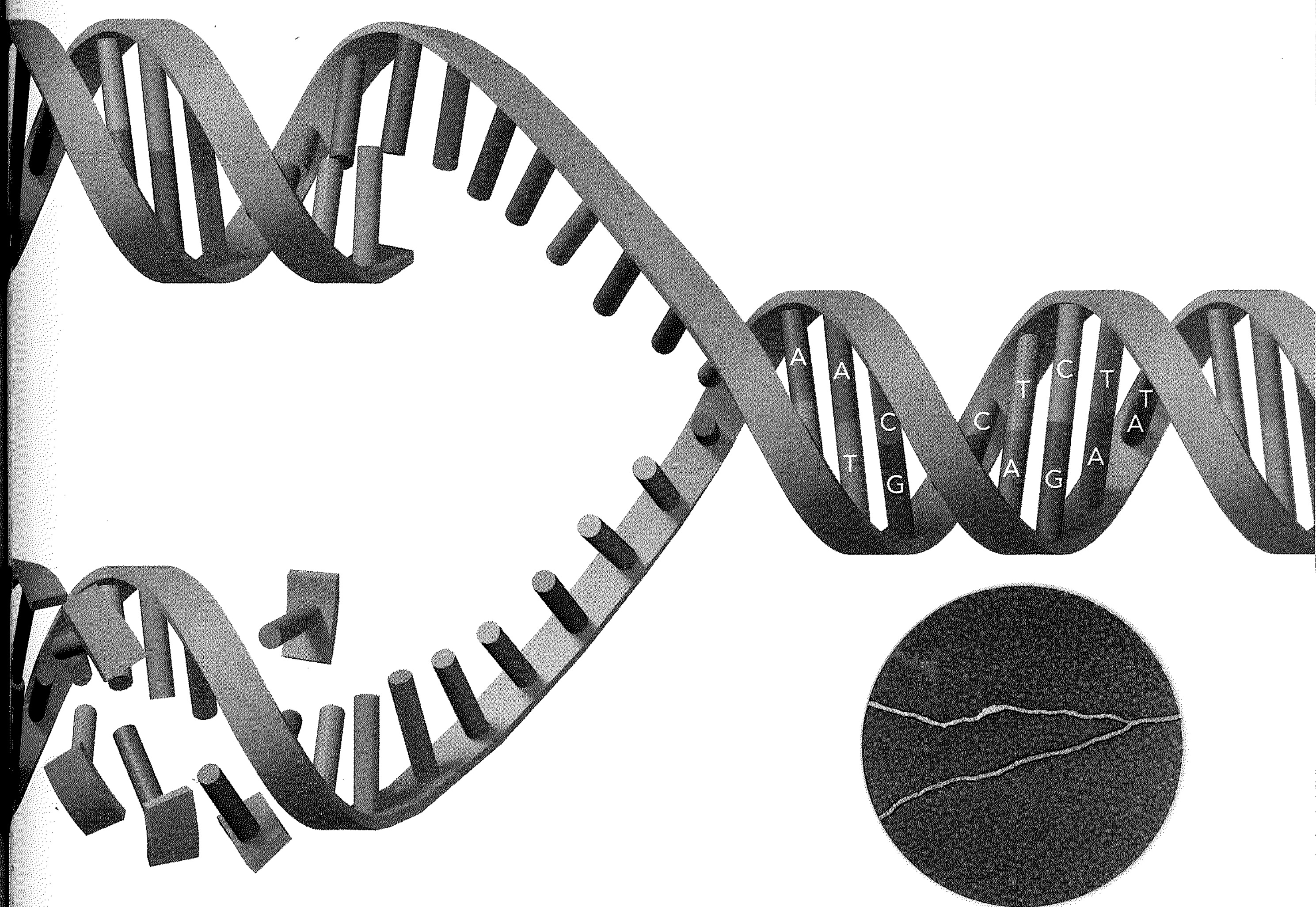

The process of DNA replication, or copying, ensures that each chromatid of a chromosome has identical DNA. During cell division, chromosomes split. During mitosis, the identical chromatids separate, resulting in identical DNA in each daughter cell. During meiosis, crossing over occurs before the chromatids split. No matter the type of cell division, DNA replication ensures that each cell contains the correct amount of DNA to carry out life processes.

Magnified Strand of DNA

Figure 3 This photograph taken by an electron microscope shows DNA replication in action.

Design It!

Develop Models Sketch how you would model DNA replication using household materials such as beads and pipe cleaners. How do the pipe cleaners and beads relate to the structure and function of DNA?

Structure of DNA and RNA

Figure 4 Differences between DNA and RNA are apparent when comparing their structure. Use the diagram to identify two differences between a DNA molecule and an RNA molecule.

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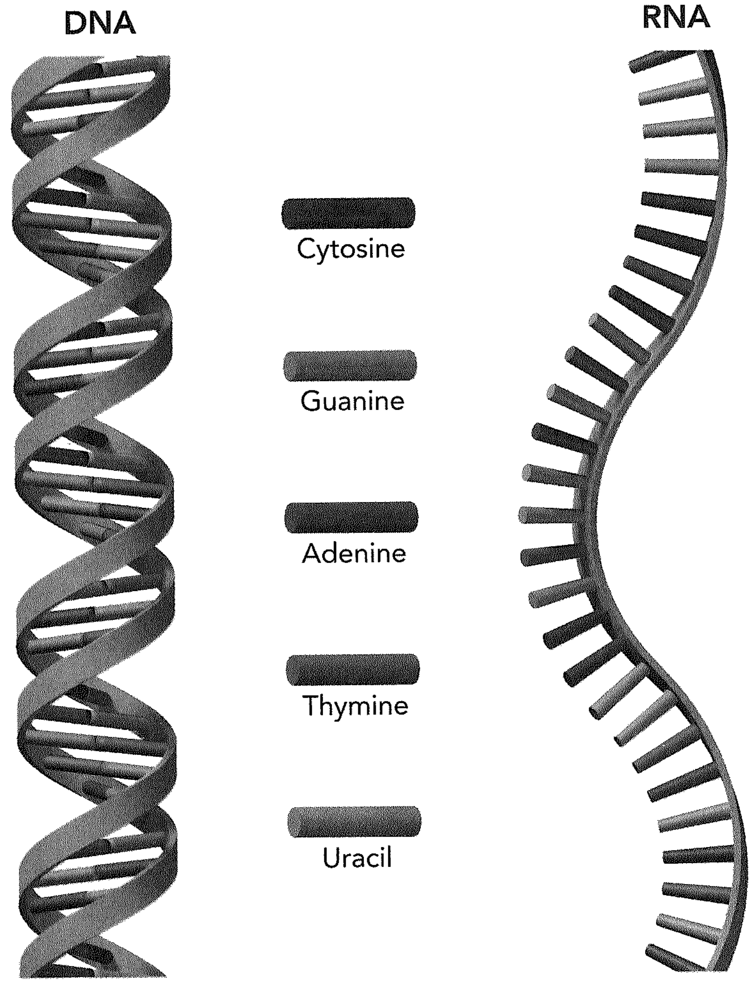


HANDS-ON LAB

Make a model of the process of protein synthesis.

Making Proteins

Proteins are made from building blocks called amino acids. There are only 20 amino acids in the human body, but your body can combine them in thousands of ways to make many different types of proteins needed to carry out cell processes. Inside the cell, amino acids link to form proteins through a process called **protein synthesis**. Once the protein is made, the cell will express the trait or perform a function.

RNA The process of protein synthesis starts in the nucleus, where the DNA contains the code for the protein. However, the actual assembly of the protein occurs at an organelle called the ribosome. Before a ribosome can assemble a protein, it needs to receive the blueprint to assemble the right protein from the nucleus.

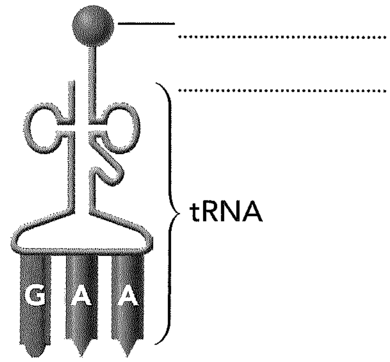
The blueprint is transferred from the nucleus to the ribosome by a different nucleic acid called RNA (ribonucleic acid). Even though both RNA and DNA are nucleic acids, they have some differences. One difference is that RNA contains the sugar ribose instead of deoxyribose. **Figure 4** shows two other differences.

Literacy Connection

Draw Comparative Inferences Identify locations in both the diagram and the text that describe the similarities and differences between DNA and RNA.

How RNA Is Used There are two main types of RNA involved in protein synthesis: messenger RNA and transfer RNA. **Messenger RNA** (mRNA) carries copies of instructions for the assembly of amino acids into proteins from DNA to ribosomes in the cytoplasm. **Transfer RNA** (tRNA), shown in **Figure 5**, carries amino acids to the ribosome during protein synthesis.

The order of the nitrogen bases on a gene determines the structure of the protein it makes. In the genetic code, a group of three nitrogen bases codes for one specific amino acid. For example, the three-base DNA sequence C-G-T (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 6**). See **Figure 7** for a summary of the entire process of protein synthesis.



tRNA Molecule

Figure 5 Fill in the label to identify what tRNA molecules carry.

Knowing the Code

Figure 6 A codon is a sequence of three bases that codes for one amino acid. For the DNA sequence C-T-A, the complementary mRNA codon would be G-A-U. Since RNA does not have thymine, the RNA complement to adenine will always be uracil. Scientists use an mRNA codon table to determine which codons will code for each amino acid. The highlighted parts of the table show you how the codon G-A-U codes for aspartic acid, also known as aspartate.

mRNA Codon Table

Second position

First position	U	C	A	G	Third position
U	phenyl-alanine	serine	tyrosine	cysteine	U
					C
	leucine		stop	stop	A
			stop	tryptophan	G
C	leucine	proline	histidine	arginine	U
					C
			glutamine		A
					G
A	isoleucine	threonine	asparagine	serine	U
					C
			lysine	arginine	A
	methionine/start				G
G	valine	alanine	aspartic acid	glycine	U
					C
			glutamic acid		A
					G

1. Synthesize What is the mRNA sequence for the DNA sequence A-C-C?

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2. Use Tables What amino acid is that mRNA sequence coding for?

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3. Construct an Explanation Why would it be incorrect to say that the DNA sequence A-C-G codes for the amino acid threonine?

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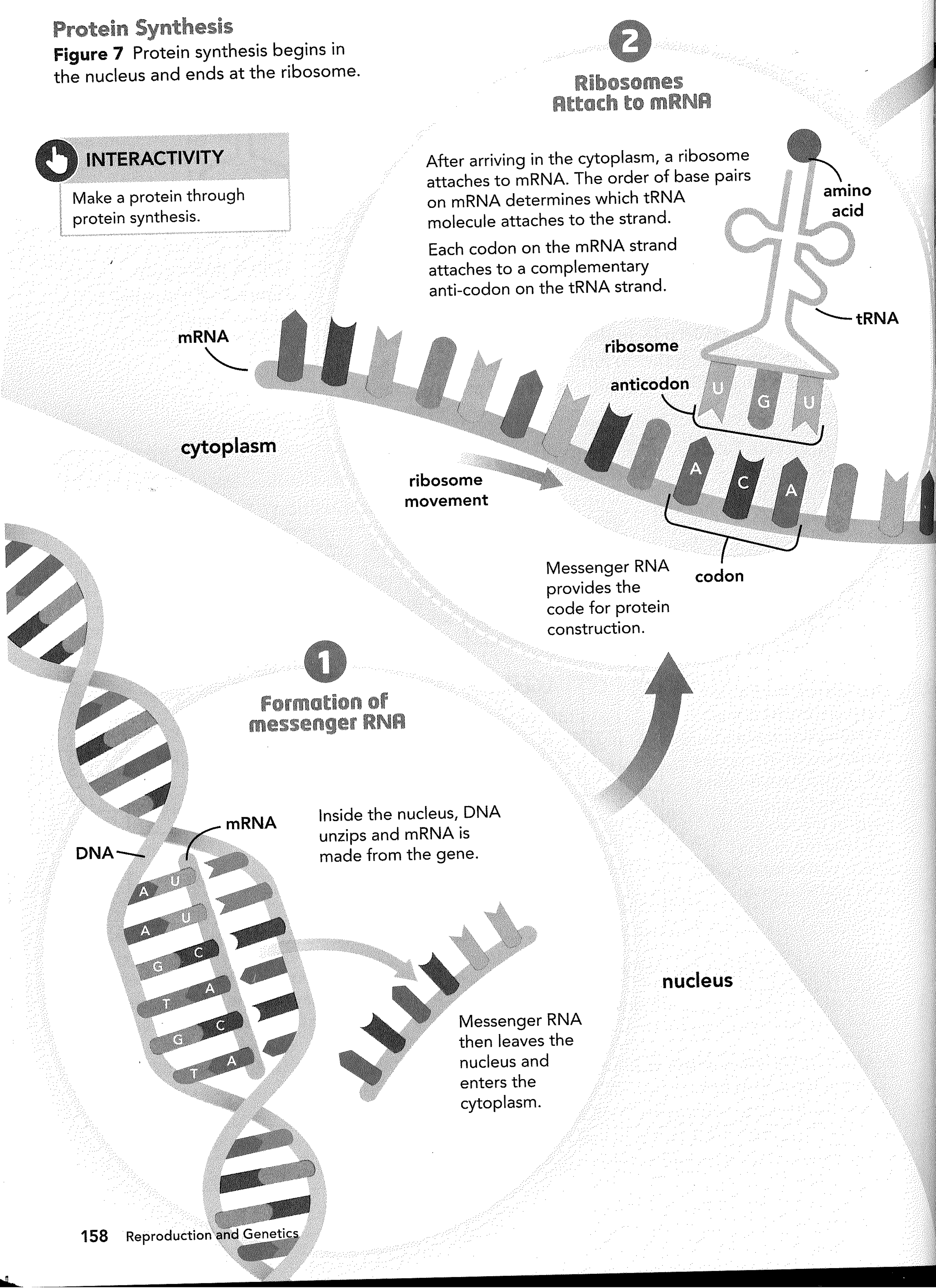
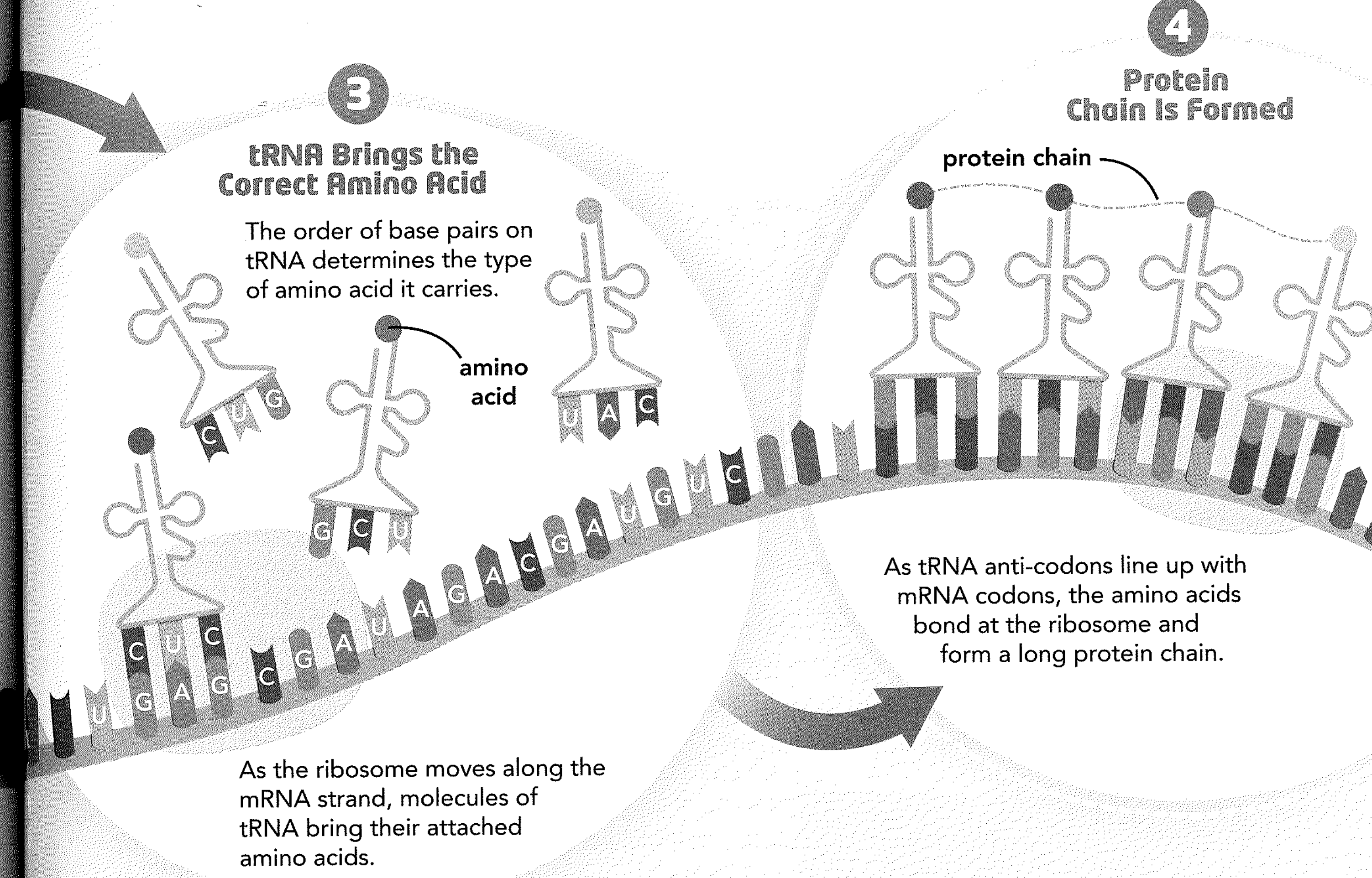
Protein Synthesis

Figure 7 Protein synthesis begins in the nucleus and ends at the ribosome.

INTERACTIVITY

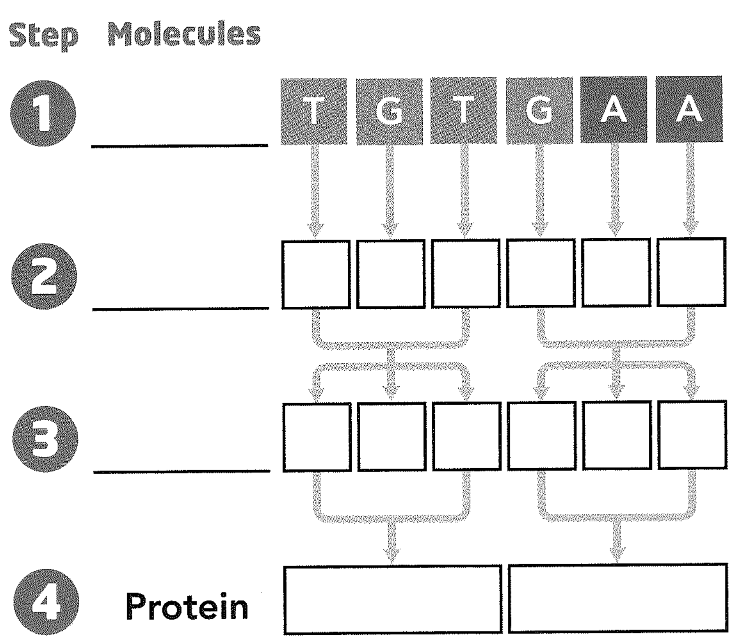
Make a protein through protein synthesis.





Model It!

Use Models Use the steps in **Figure 7** as a guide to fill in the missing molecules that drive each step of the process. Then complete the flowchart with the complementary nitrogen bases or amino acids (refer to codon table in **Figure 6**).



LESSON 4 Check

SC.7.L.16.1, SC.7.L.16.3

1. **Identify Patterns** List the six nitrogen bases that would pair with the following sequence of bases in a strand of DNA: T C G A C A

2. **Explain** What is the relationship between making proteins and the inheritance of traits?

3. **Explain Phenomena** What would happen if a sex cell could not complete DNA replication?

4. **Analyze Structure and Function** DNA replication begins when the double helix untwists and breaks in half between the nitro- gen bases. What are the next two steps in the process of DNA replication?

5. **Apply Concepts** What is the role of DNA in protein synthesis?

Quest CHECK-IN

In this lesson you learned how DNA holds the genetic blue-print for organisms and how it replicates the code when necessary for cell division or meiosis. You also examined the process by which DNA is used to build proteins to carry out cellular processes.

Apply Concepts In order to change the traits of an organism, what must happen to its DNA?

HANDS-ON LAB

All in the Numbers

Go online to complete Punnett squares and examine the probabilities that desired traits will be passed on to the DNA of offspring.

uEngineer It! Impact on Society STEM

SC.7.L.16.4, SC.7.N.1.5

REINVENTING DNA AS Data Storage

VIDEO

See how scientists use DNA to store digital information.

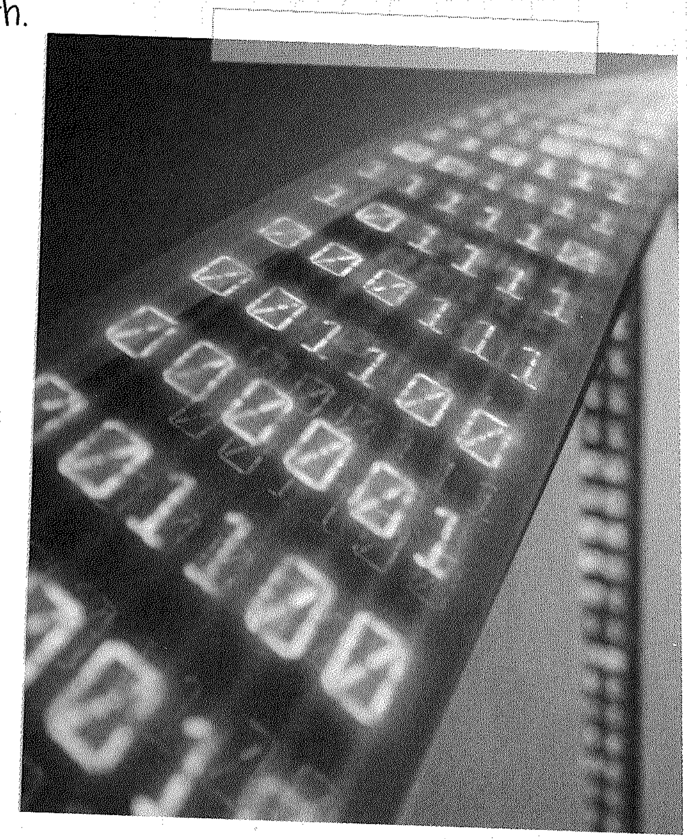
How much digital space do you need for all your texts, emails, photos, and music? Digital information can take up lots of space.

Code	P	l	a	y
Binary data	01010000	01101100	01100001	01111001
DNA nucleotides	GCGAG	ATCGA	AGAGC	TGCTCT

The Challenge: To provide storage solutions for the data storage needs of everyone on Earth.

Some estimates state that the world has 40 trillion gigabytes (GB) of data. Forty trillion GB equals about 40 million petabytes (PB). Ten billion photos on social media sites use about 1.5 PB. So, if every star in our Milky Way galaxy were one byte of data, then we would need 5,000 Milky Ways, each with 200 billion stars, to amass one PB of data. How can we possibly store all of our data?

Nature may offer an answer: DNA. Our entire genetic code fits within the nucleus of a single cell. Scientists have figured out how to convert digital data (in 1s and 0s) into DNA's A-C-T-G code. Then they constructed synthetic DNA in a lab. So far, scientists have been able to encode and store images and videos within a single strand of DNA. If current cost constraints are overcome, DNA could be the next microchip. Someday, the data currently stored on computers in enormous buildings may fit in the palm of your hand!



Scientists can store documents and photos by converting digital code to DNA code and then making synthetic DNA. To retrieve a file, the DNA code gets converted back to digital code.

DESIGN CHALLENGE Can you design your own code to store information? Go to the Engineering Design Notebook to find out!

LESSON 5

Genetic Technologies

Guiding Questions

- How do humans use artificial selection to produce organisms with desired traits?
- How do scientists engineer new genes?
- How can genetic information be used?

Connection

Literacy Corroborate

SC.7.L.16.4 Recognize and explore the impact of biotechnology (cloning, genetic engineering, artificial selection) on the individual, society and the environment. (Also **SC.7.N.1.1** and **SC.7.N.1.5**)

Vocabulary

artificial selection
genetic engineering
gene therapy
clone
genome

Academic Vocabulary

manipulation

VOCABULARY APP

Practice vocabulary on a mobile device.

Quest CONNECTION

Consider how genetic technologies can help you design your new fruit.

Connect It!

Dogs come in many different shapes, sizes, and colors. Which of the ones shown here would you prefer as a pet? Circle your choice.

Apply Concepts Many purebred dogs have problems later in life, such as joint or eye diseases. Why are purebred dogs more likely to develop problems later in life?

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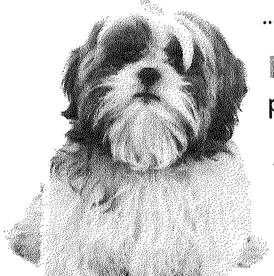

Make Inferences What can be done to decrease the likelihood of these problems appearing?

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Artificial Selection

When consumers make choices, they are often attracted to products with the highest quality. We want the healthiest and best-tasting fruits and vegetables. We want the right amount of fat and flavor in our meats. We even want the best traits in our pets, such as the dogs you see in **Figure 1**. These high-quality products do not appear only in nature. Scientists and breeders have influenced the traits that other organisms inherit through the process of selective breeding.

INTERACTIVITY

Consider how artificial selection affects the traits of dogs.

Selective Breeding In the natural world, individuals with beneficial traits are more likely to survive and successfully reproduce than individuals without those traits. This is called natural selection. **Artificial selection** is also known as selective breeding. It occurs when humans breed only those organisms with desired traits to produce the next generation. It's important to note that desired traits are not necessarily the traits that benefit the organism's chances for survival. Instead, they are traits that humans desire.

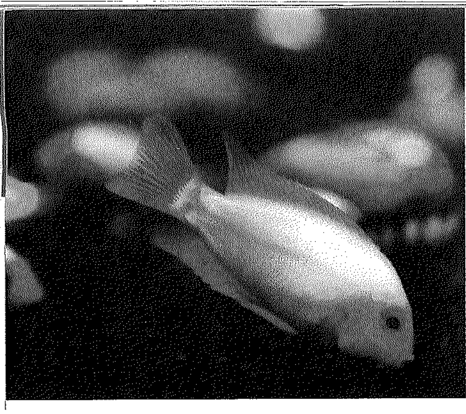
Literacy Connection

Corroborate Find statements in the text that support the claim that artificial selection is not a natural process and does not necessarily help the organism's survival.

Dogs, cats, and livestock animals have all been selectively bred. Cows, chickens, and pigs have been bred to be larger so that they produce more milk or meat. Breeding and caring for farm animals that have certain genetic traits that humans desire is called animal husbandry. The many different breeds of dogs shown in **Figure 1** have also been bred over time for very specific functions.

Purebred Dogs

Figure 1 Each type of purebred dog shown here is the result of selective breeding over the course of many generations.



Glowing Fish

Figure 2 Genetic engineering made glowing fish possible.

Genetic Engineering

With the discovery of DNA and its relationship to genes, scientists have developed more methods to produce desired traits. Through a process called **genetic engineering**, modern geneticists can transfer a gene from the DNA of one organism into another. Genetic engineering is used to give organisms genes they could not acquire through breeding.

Scientists use genetic engineering techniques to insert specific desired genes into animals. By **manipulating** a gene, scientists have created a fish that glows when under a black light **(Figure 2)**. A jellyfish gene for fluorescence was inserted into a fertilized fish egg to produce the glowing fish. Scientists are hoping that further research on this gene will lead to a method that helps track toxic chemicals in the body.

Genetic engineering is also used to synthesize materials. A protein called insulin helps control blood-sugar levels after eating. People who have diabetes cannot effectively control their blood-sugar levels, and many must take insulin injections. Prior to 1980, some diabetics were injecting themselves with insulin from other animals without getting the desired results. To help diabetics, scientists genetically engineered bacteria to produce the first human protein — insulin. The process they used, and still use today, is shown in **Figure 3**. Furthermore, bacteria can reproduce quickly, so large amounts of human insulin are produced in a short time.

Academic Vocabulary

Explain the difference between manipulating a tool and manipulating another person.

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Plan It!

Synthesize a New Trait

Create a trait that has never been seen before in an animal. Identify a trait you would like an animal to have. Then, sketch the animal and describe a process by which you could achieve your desired result.

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Bacteria Make Human Insulin

Figure 3 Bacteria can be used to produce insulin in humans. Complete the diagram by showing the process for Step 5.

HANDS-ON LAB

Investigate Extract DNA from a strawberry.

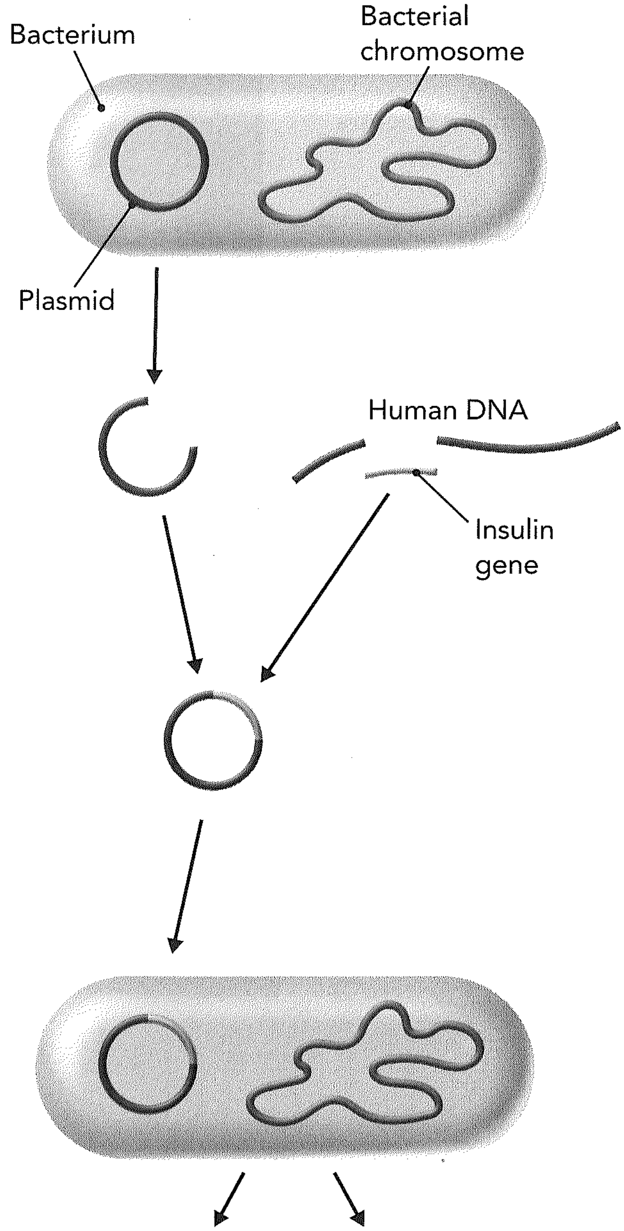
1 Small rings of DNA, or plasmids, are found in some bacteria cells.

2 Scientists remove the plasmid and cut it open with an enzyme. They then insert an insulin gene that has been removed from human DNA.

3 The human insulin gene attaches to the open ends of the plasmid to form a closed ring.

4 Some bacteria cells take up the plasmids that have the insulin gene.

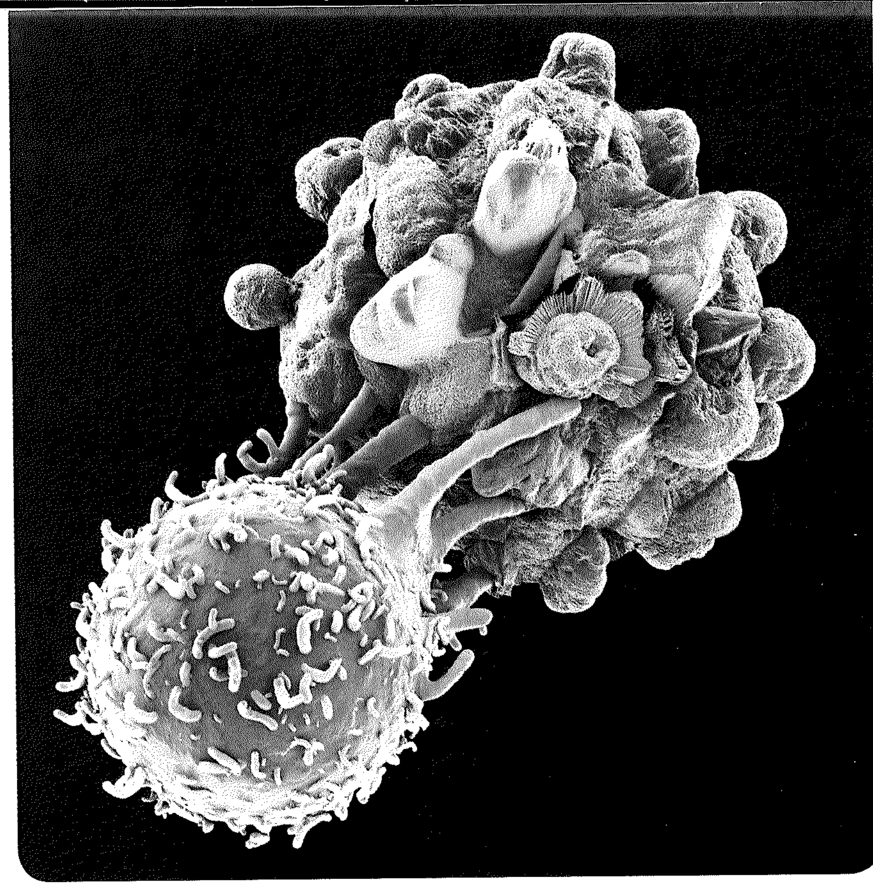
5 When the cells reproduce, the new cells contain copies of the "engineered" plasmid. The foreign gene directs the cells to produce human insulin.



T-cell Destroys Cancer Cell

Figure 4 T-cells are a type of white blood cell that help to fight disease in your body. Scientists have genetically engineered a T-cell that can attack and destroy up to 1,000 cancer cells.

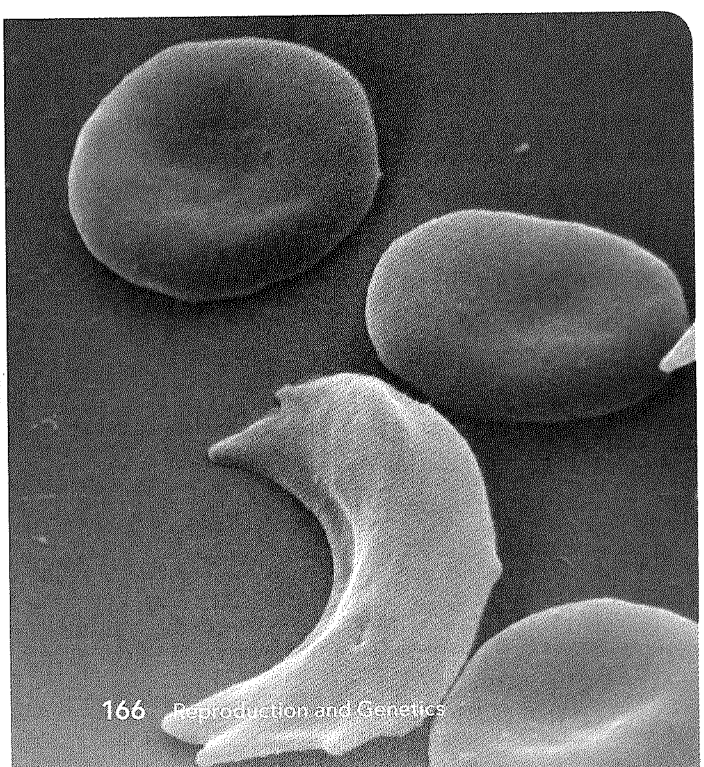
Predict How might doctors use this new T-cell?



Gene Therapy in Humans Genetic diseases are caused by mutations, or changes in the DNA code. Some mutated genes pass from parent to child; others occur spontaneously. Soon, it may be possible to use genetic engineering to correct some genetic disorders in humans. This process, called **gene therapy**, involves changing a gene to treat a medical disease or disorder. A normal working gene replaces an absent or faulty gene. One promising therapy involves genetically engineering immune-system cells and injecting them into a person's body.

Sickle-cell Disease

Figure 5 Sickle-shaped red blood cells cannot carry as much oxygen as normal cells and can also clog blood vessels.



Millions of people worldwide suffer from sickle cell disease. This painful genetic disorder is caused by a singe mutation that affects hemoglobin, a protein in red blood cells. Hemoglobin carries oxygen. The mutation causes the blood cells to be shaped like a sickle, or crescent, as shown in **Figure 5.**

CRISPR is a gene-editing tool that can help people with sickle cell disease. CRISPR uses a "guide RNA" and an enzyme to cut out the DNA sequence causing the dangerous mutation. The "guide RNA" takes the enzyme to the DNA sequence with the sickle cell mutation, and the enzyme then removes that sequence. Then another tool pastes a copy of the normal sequence into the DNA.

Cloning Organisms A **clone** is an organism that has the same genes as the organism from which it was produced. The process of cloning involves removing an unfertilized egg and replacing its nucleus with the nucleus of a body cell from the same species. Because this body cell has a full set of chromosomes, the offspring will have the same DNA as the individual that donated the body cell. The egg is then implanted into a female so it can develop. If the process is successful, the clone is born.

Cloning is used to develop many of the foods we eat. Many plants are cloned simply by taking a small piece of the original and putting it in suitable conditions to grow. For example, the Cavendish banana (see **Figure 6**) is the most common banana for eating. All these bananas are clones of the original plant. Cloning helps to produce crops of consistent quality. But a population with little genetic diversity has drawbacks.

READING CHECK **List** List the steps to creating a clone.

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VIDEO

Learn how selective breeding and cloning can lead to populations with desired traits.

Cloned Bananas

Figure 6 A fungus that causes bananas to rot is spreading across the globe. The Cavendish banana is particularly vulnerable.

Construct Explanations Why is a disease more damaging to cloned crops?

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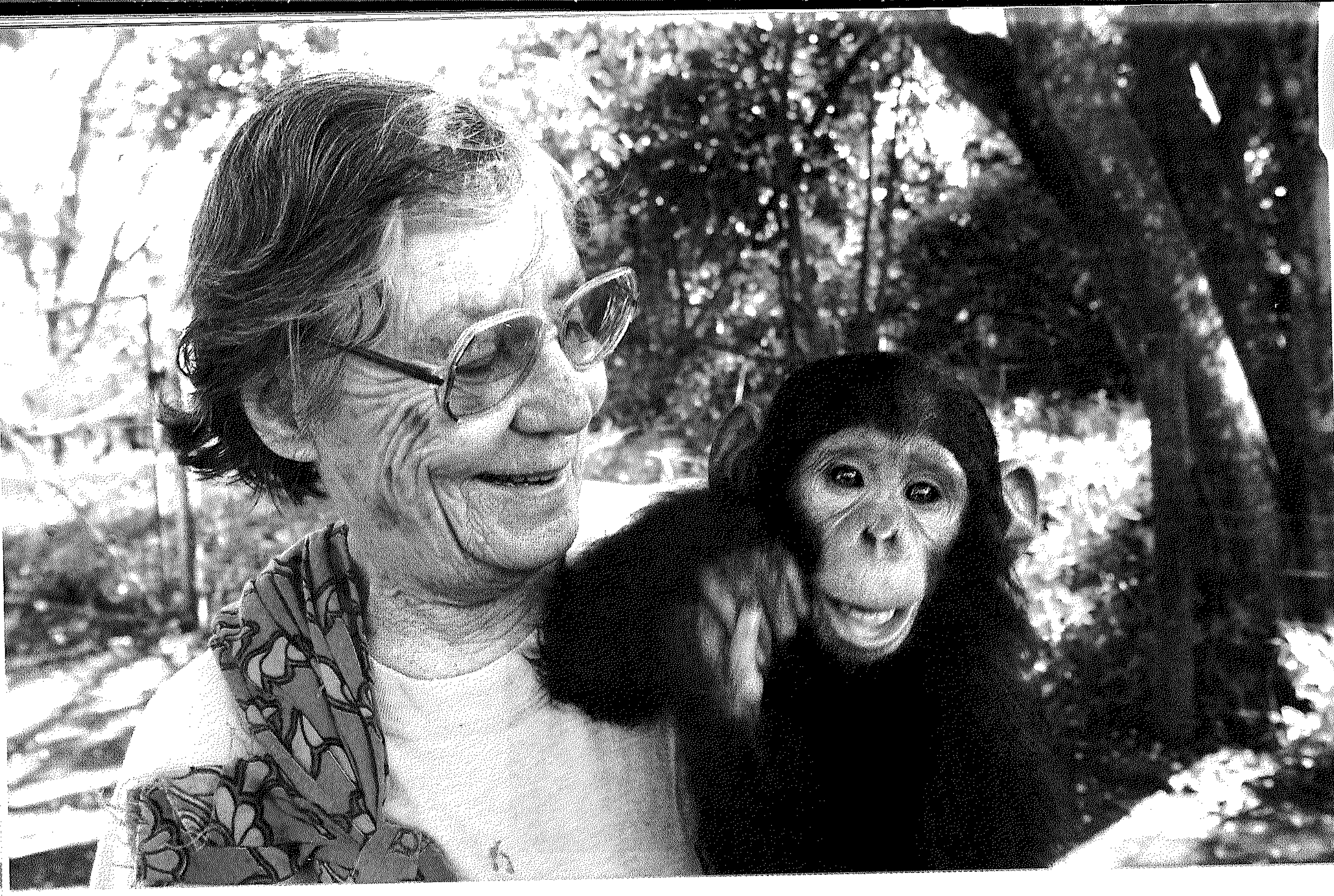

Genetic Cousins

Figure 7 Humans and modern-day chimpanzees share about 99 percent of their DNA.

Infer How does knowing we are close genetically to chimpanzees help humans?

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Practical Uses for DNA

Due to new technologies, geneticists now study and use genes in ways that weren't possible before. Modern geneticists can now determine the exact sequence of nitrogen bases in an organism's DNA. This process is called DNA sequencing.

Sequencing the Human Genome Breaking a code with six billion letters may seem like an impossible task to undertake. But scientists working on the Human Genome Project did just that. The complete set of genetic information that an organism carries in its DNA is called a **genome**. The main goal of the Human Genome Project was to identify the DNA sequence of the entire human genome. Since sequencing the human genome, scientists now research the functions of tens of thousands of human genes. Some of these genes also allow scientists to better understand certain diseases.

Our genome can also help us understand how humans evolved on Earth. All life on Earth evolved from simple, single-celled organisms that lived billions of years ago, and we still have evidence of this in our DNA. For example, there are some genes that exist in the cells of almost every organism on Earth, which suggests we all evolved from a common ancestor. Some organisms share a closer relationship than others. By comparing genomes of organisms, scientists continue to piece together a history of how life on Earth evolved.

INTERACTIVITY

Gather fingerprints and identify who committed a crime.

DNA Technologies Before the Human Genome Project, scientists such as Gregor Mendel used experimentation to understand heredity. Since the project's completion in 2003, the use of technologies to understand heredity and how DNA guides life processes has increased greatly. For example, DNA technologies help diagnose genetic diseases.

Genetic disorders typically result from one or more changed genes, called mutations. Medical specialists can carry out a DNA screening to detect the presence of a mutation. To complete a DNA screen, samples of DNA are analyzed for the presence of one or more mutated genes. This information is then used to help those individuals whose DNA includes mutated genes.

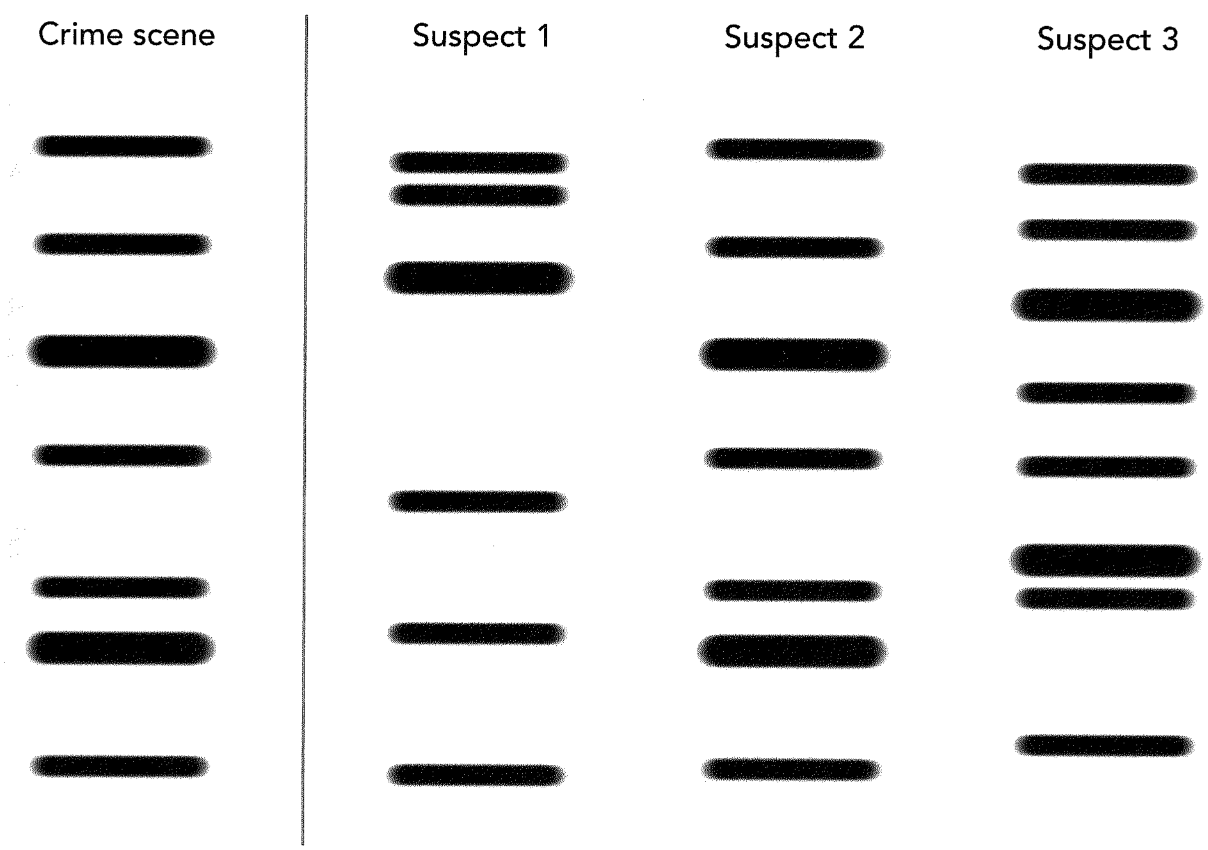
DNA comparisons determine how closely related you are to another person. To do this, DNA from a person's cell is broken down into small pieces, or fragments. These fragments are put into a machine that separates them by size. When this happens, a pattern is produced creating a DNA fingerprint, like the one shown in **Figure 8**. Similarities between patterns determine who contributed the DNA. Genetic fingerprints can be used to tie a person to a crime scene, prevent the wrong person from going to jail, identify remains, or identify the father of a child.

INTERACTIVITY

Consider using technology to solve the world's food problem.

DNA Fingerprint

Figure 8 Circle the suspect that left his or her DNA at the crime scene.



Using Genetic Information

Figure 9 Some people fear that medical insurance companies will not cover their medical expenses if they have been genetically tested and results show a genetic disorder.

Evaluate Reasoning Why is this a fear of many people? What can we do to protect our privacy?

Controversies of DNA Use As genetic research advances, some people are concerned about how genetic information will be used or altered. Some people are concerned about the use of genetically modified organisms (GMOs) in our food supply. Others worry about who can access their DNA information, and how this information will be used.

Your genetic information is a big part of your identity, and many people want to keep it as private as possible. The Genetic Information Nondiscrimination Act (GINA) was signed into law in 2008. This act makes it illegal for health insurance companies and employers to discriminate against individuals based on genetic information. Health insurance companies cannot deny you care and a company cannot refuse to hire you simply because of the results of a genetic test (**Figure 9**). Genetic information cannot be used without consent, and must be used in a way that is fair and just.

GMOs are made by changing the original DNA so desired traits are expressed. Growing our food from seeds that have been genetically modified is highly controversial. Many people fear the impact it could have on human health and the environment in the future. Yet farmers are able to yield more product with GMO crops that are not eaten by pests or over-come by weeds. Scientists must balance sustaining a growing human population with safeguarding the environment.

Write About It Organ transplants save lives. Scientists have learned how to genetically modify pigs in order to grow human organs for transplant. Do you think it's a good idea to transplant organs from pigs into humans? Explain.

READING CHECK **Corroborate** What are the pros and cons of GMO foods?

LESSON 5 Check

SC.7.L.16.4

1. Mutations cause
   A. DNA screenings.
   B. genetic fingerprints.
   C. genetic disorders.
   D. protein synthesis.

2. **Infer** Compared to chickens today, the chickens raised before World War II grew much more slowly and produced much less meat. What must have happened to chickens since the war?

3. **Explain Phenomena** Some genetically engineered fish can mate with wild members of their species. Farm-raised fish are often genetically modified. What can happen to the wild species of fish if they mate with GMOs?

4. **Apply Concepts** What could be done, in terms of genetic engineering, to minimize the chance of farmed-raised fish from breeding with wild fish?

5. **Evaluate Information** What type of evidence could you use to support the claim that all life on Earth evolved from a simple, single-celled organism? Explain.

6. **Construct Explanations** What sort of evidence could geneticists have used to determine that gorillas and humans were more closely related than previously thought?

7. **Relate Structure and Function** How can changes to the structure of DNA lead to the development of new traits in a species?

8. **Design Solutions** The procedure used to make insulin in bacteria can also be used to synthesize other biological materials. Think of a chemical or material inside the human body that could be synthesized within bacteria. What would be the potential benefits of this process? What would be the potential drawbacks?

TOPIC 3 Review and Assess

1 Patterns of Reproduction

SC.7.L.16.1

1. Incomplete dominance results in a phenotype that
   - **A.** shows both traits of an allele pair.
   - **B.** has a complex genotype.
   - **C.** results from three different alleles
   - **D.** is a blend of two traits in an allele pair.

2. Asexual reproduction is different from sexual reproduction in that the offspring of asexual reproduction
   - **A.** are identical to the parent.
   - **B.** contain half the chromosomes of the parent.
   - **C.** have no genetic material.
   - **D.** have more variety in their traits.

3. **Distinguish** How is codominance different from incomplete dominance? Provide examples.

4. **Synthesize** The shells on some nuts are too hard for crows to crack open. Researchers have observed crows dropping such nuts onto roadways and waiting for cars to smash them open. Is this behavior inherited or acquired? Explain.

2 Patterns of Inheritance

SC.7.L.16.1, SC.7.L.16.2

5. Which **best** defines phenotype?
   - **A.** how alleles are arranged
   - **B.** how the genotype is expressed
   - **C.** half the parent's chromosomes
   - **D.** the probability of traits

6. **Use a Model** Show a cross between two guinea pigs who are heterozygous for coat color. *B* is black coat and *b* is white coat.

7. **Interpret Tables** What is the probability that an offspring from the cross in Question 6 has a white coat?

8. Two guinea pigs mate. At least one offspring has a white coat. Which of the following crosses could **NOT** have produced such an offspring?
   - **A.** *Bb, Bb*
   - **B.** *Bb, BB*
   - **C.** *Bb, bb*
   - **D.** *bb, bb*

9. **Apply Concepts** What conclusions can you draw about the genotypes and phenotypes of offspring if one parent is homozygous dominant for a trait?

ASSESSMENT

Evaluate your understanding by taking a Topic Test.

3 Chromosomes and Inheritance

SC.7.L.16.1, SC.7.L.16.2, SC.7.L.16.3

10. When a sperm and egg fuse, they form a zygote, also known as
    - A. homologous chromosomes.
    - B. a fertilized egg.
    - C. crossing over.
    - D. recombined alleles.

11. **Identify Patterns** Each body cell in a manatee has 48 chromosomes. How many chromosomes are in a manatee's sex cells? Explain your answer.

12. **Construct Explanations** In sexual reproduction, if the homologous chromosomes have the same genes, then how is genetic variety possible?

13. **Analyze** What evidence do you have that every cell in your body has DNA located in the nucleus?

4 Genetic Coding and Protein Synthesis

SC.7.L.16.1, SC.7.L.16.3

14. **Support Your Explanation** How it is possible that the wrong protein could be formed during protein synthesis?

15. **Relate Structure and Function** Explain the importance of the sequence of nitrogen bases on a gene to heredity.

5 Genetic Technologies

SC.7.L.16.4

16. **Design a Solution** Rot could wipe out all Cavendish bananas. What do you propose for a solution?

17. **Engage in Argument** What do you think could be done to minimizes people's fears about genetic engineering?

Science Assessment Practice

Circle the letter of the best answer.

1 Scientists determined that manatees are closely related to elephants but not to other marine mammals. Which of the following could provide the proof?

- **A** comparing phenotypes
- **B** comparing genome sequences
- **C** comparing chromosome numbers
- **D** comparing pedigrees

A brown male rabbit mates with a black female rabbit. They produce offspring with a range of colors. **Answer questions 2 and 3 about the offspring of the rabbits.**

2 Which statement **most accurately** reflects how the color of each offspring is determined?

- **F** The color of each rabbit depends on randomly donated alleles.
- **G** The color of each rabbit depends on multiple alleles.
- **H** The color of each rabbit depends on environmental changes.
- **I** The color of each rabbit depends on its sex.

3 Which of the following cellular processes will be involved in the growth, development, and reproduction of the offspring?

- **A** meiosis only
- **B** mitosis only
- **C** both meiosis and mitosis
- **D** neither meiosis nor mitosis

4 Why was Mendel's work especially important in the field of biology?

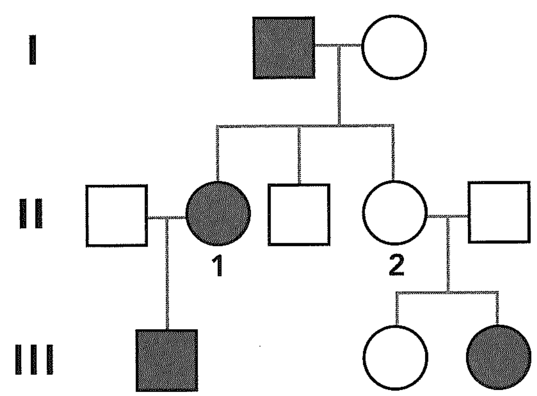
- **F** It was used to create new hybrid plants.
- **G** It explained different types of peas.
- **H** It described the experimental process.
- **I** It was the first to quantify results of breeding experiments.

5 In dogs, the gene for wire hair (W) is dominant over the gene for smooth hair (w). Suppose a dog with wire hair (Ww) mates with a smooth-hair dog (ww). One of the offspring mates with an unknown dog. The resulting offspring are all smooth hair. What **must** be true about the unknown dog?

- **A** The dog is heterozygous.
- **B** The dog is homozygous for smooth hair.
- **C** The dog is homozygous for wire hair.
- **D** The dog is missing a trait.

Use this information to answer questions 6–8.

This pedigree traces sickle cell disease. Shaded symbols indicate sickle cell disease. Circles indicate females and squares indicate males. People with sickle cell disease are homozygous for the sickle cell allele and have the *SS* genotype. People with normal blood cells have genotype *AA*. Carriers of the disease have genotype *AS*.



6 Which statement about the offspring of daughter 2 in generation II **best** explains their genotypes?

- **F** Their father is AS.
- **G** Their mother is AA.
- **H** Both parents are AS.
- **I** Neither parent is AS.

7. The son in generation II is a carrier for sickle cell disease. He marries a woman who is also a carrier. They have four children who are free of sickle cell disease. How do you explain that outcome?

   A The woman's genotype is AS, but her phenotype is normal.
   B The woman's genotype must be normal, AA.
   C As Mendel proved, F1 traits often skip a generation.
   D They beat the odds. Real life is not like a Punnett Square.

8. The protein Cas9 is an enzyme that acts like a pair of molecular scissors, capable of cutting strands of DNA. How could a geneticist use Cas9 to treat sickle cell disease?

   F to replace all S alleles in human red blood cells
   G to destroy all S alleles in fertilized eggs
   H as a genetically engineered virus that can destroy sickle-shaped blood cells
   I with a guide RNA to cut out the DNA sequence causing the mutation

9. Scientists modified a common strain of rice by inserting the carotene gene from carrots. The result was a rice enriched with vitamin-A, a crucial vitamin for humans. What process enabled this new variety of rice?

   A artificial selection
   B crossing over
   C genetic engineering
   D genome sequencing

Quest FINDINGS

SC.6.L.16.3

Complete the Quest!

Determine the best way to design your sales brochure for the new fruit.

Describe What are some important facts and features about your new fruit that will get people to buy it?

INTERACTIVITY

Reflect on Funky Fruit

uDemonstrate Lab

SC.7.L.16.2, SC.7.N.1.5, SC.7.N.3.2

Make the Right Call!

How can you design and use a **model** to make **predictions** about the possible results of **genetic crosses**?

Materials

(per pair)

- 4 small paper bags
- 12 red marbles
- 12 blue marbles
- 12 green marbles
- 12 yellow marbles
- marking pen

Background

Suppose your neighbors tell you that their cat is going to have kittens. They can't stop talking about what color they think the kittens will be and whether their hair will be long or short. Using the suggested materials and your knowledge of genetic crosses, how can you make a model to show your neighbors the probabilities of the possible color and hair length combinations for the kittens?

Your neighbors got both the mother and father cat from a respected breeder. The index card shows background information about the two cats.

Max, male cat, short hair, homozygous black hair.

Willa, female cat, heterozygous short hair, heterozygous black hair.

Design Your Investigation

☐ **1.** In the space below, use Punnett squares to determine the possible outcomes from a cross between the male and female cats. **TIP: First identify each parent's alleles, noting that all of them are known.**

HANDS-ON LAB

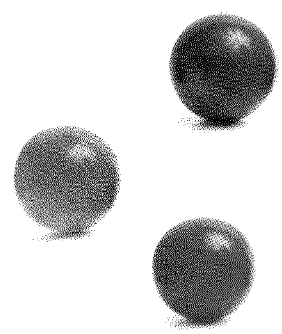
Demonstrate Go online for a downloadable worksheet of this lab.

Homozygous — parent or offspring has either two dominant or two recessive alleles.

Heterozygous — parent or offspring has one of each allele (one dominant and one recessive)

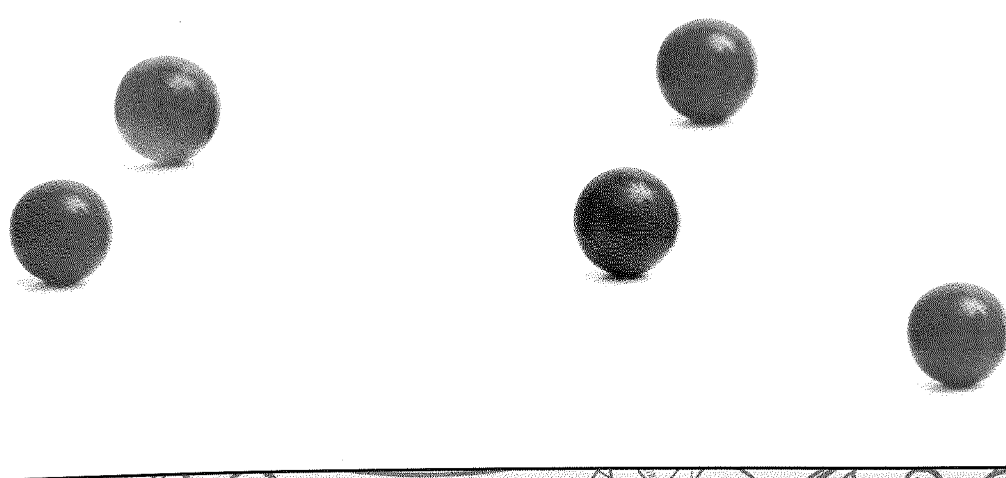
Dominant Trait	Recessive Trait
Short Hair	Long Hair
Black Hair	Brown Hair

☐ **2.** Design a way to model these crosses using the marbles and bags. The bags should contain the alleles of the male and female parent cats—two bags for each parent (one bag for hair color, the other bag for hair length). **TIP: Use four marbles for each allele in each cat.**



☐ **3.** In the space provided in the Procedure section, describe or sketch a procedure for modeling the crosses. Have your teacher review and approve the procedure before you carry it out. If necessary, make adjustments based on your teacher's feedback.

☐ **4.** Use your model. Record your observations in the data tables.



Procedure

Observations

Data Table 1 Hair Length

Trial Cross	Allele from Bag 1 (Max)	Allele from Bag 2 (Willa)	Offspring's Alleles
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

Data Table 2 Hair Color

Trial Cross	Allele from Bag 3 (Max)	Allele from Bag 4 (Willa)	Offspring's Alleles
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

Analyze and Interpret Data

1. Develop a Model How did you use the materials? What did the different parts of the model represent?

2. Characterize Data Refer to your Punnett squares. What percentages of brown kittens (Bb) and black kittens (BB or Bb) did you predict? What percentages of shorthair kittens (SS or Ss) and longhair (ss) kittens did you predict?

3. Use a Model to Evaluate Refer to your data table. Did the percentages of offspring with a given genotype match the percentages that you obtained by completing the Punnett squares? Explain.

4. Compare Data How did using a Punnett square differ from using your model? Which did you prefer?

5. Form an Opinion Was your model effective at showing the neighbors all of the possible combinations of hair color and length to expect in their kittens? Explain.