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Heredity and Genetics

The human body is made of trillions of cells, and inside every cell is a set of coded instructions that the cell follows. These instructions are called DNA. They are like a blueprint, or a pattern, for the cell to follow. The DNA molecules provide all the information necessary for a living thing to grow and reproduce. If you could take a person's DNA from just one cell and lay it end to end, the DNA would be about 2 m (6 ft) long. The DNA from all the cells in a human body would reach from the earth to the sun and back more than 300 times! And, if you could fill every space on a piece of paper with a letter of the alphabet, the information in a person's DNA from just one cell would require a stack of pages about 91 m (300 ft) tall. Yet all of that information fits within the cell, in a tiny nucleus that is only about 0.005 millimeters wide. Scientists have learned much about DNA, but they still do not know how all of it works. Our loving and powerful God formed each one of us with our own unique set of DNA. Truly, we are fearfully and wonderfully made (Ps. 139:14).

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TEACHER HELPS

Chapter preview
Other preview and prereading activities may include using a K-W-L chart, a probe, or an anticipation guide.

Student Text diagrams
Diagrams from the Student Text are included on the Teacher's Toolkit CD.

Objectives

- Recognize that each human is uniquely planned and formed by God
- Preview the chapter content

Introduction

The DNA of each creature and person reflects the creativity of our powerful God. God's design for living organisms allows them to inherit exactly the traits they need to bring glory to Him. When man chooses not to believe God's record of Creation, he has difficulty explaining the variety among organisms.

Teach for Understanding

Provide time for the student to complete Looking Ahead, Activity Manual page 205. For part B, encourage the student to think of things he would like to learn about Punnett squares and genetic engineering. He should write his answers in question form, such as, "What is genetic engineering?"

Provide the answers for part A and allow the student to check his work. After the chapter is finished, you may choose to have him look back at this page and check his understanding of the items he missed.

As time allows, discuss student questions from part B about Punnett squares and genetic engineering. You may choose to provide trade books or other resources to help answer questions that are beyond the scope of this chapter.

Allow the student to leaf through the chapter, looking at the headings, pictures, captions, charts, etc., and discuss the things he thinks he will be learning about.

What is happening in the photo? The people are discussing the blueprints of the new building.

What are blueprints? technical drawings that show the architectural or engineering design

Why do you think that photo was used for this chapter? Answer should include the idea that a cell follows its DNA much like a builder follows a blueprint.

Activity Manual

Preview, page 205

The Looking Ahead page is intended to assess the student's prior knowledge before beginning the chapter.

Lesson 149

Student Text pages 310–12
Activity Manual pages 206–8

Objectives

- Describe the relationship among chromosomes, DNA, and genes
- Distinguish between learned and inherited traits
- Survey a sample group
- Graph survey results

Vocabulary

trait
gene
DNA
heredity

Introduction

Included with this two-page text lesson is the activity *It's All in the Genes*, which should be completed as part of the lesson.

In Chapter 4 we learned about the parts of a cell. Which part of the cell has the coded instructions that tell the cell what to do? DNA or chromosomes

Not only does DNA tell a cell what to do, it also determines characteristics that you as an individual will have, such as what you will look like and what abilities you will have.

Teach for Understanding

Purpose for reading

What is heredity?

How are learned traits different from inherited traits?

Discussion

Which verses tell us that God knew all about us before we were even born? Possible answer: Psalm 139:14–16

Read aloud Psalm 139:14–16.

Why should these verses give us great comfort? They tell us that God made us and knows all about us.

What are traits? characteristics

What controls inherited traits? genes

What are genes? small sections of the DNA strands found in the chromosomes in your cells

What is DNA? the chemical code that tells the cells what to do

What are some traits determined by genes? Possible answers: length of eyelashes, hair color, gender, shape of red blood cells, blood type, colorblindness

Which word describes the passing of traits from parents to offspring? heredity

How are your traits determined? Possible answers: heredity or genes, environment, and health habits

Heredity

Is your hair curly or straight? Do you have freckles? Can you roll your tongue? What color are your eyes? These are just some of the **traits**, or characteristics, that you have inherited from your parents. These traits are controlled by **genes**, small sections of the DNA strands found in the *chromosomes* in your cells.

You are a unique individual. God designed you and knew all about you even before you were born (Ps. 139:14, 16). Because of the process of meiosis, you inherited 23 chromosomes from your father and 23 from your mother. Unless you have an identical twin, no one else has the same combination of chromosomes and genes that you have. Your chromosomes contain **DNA** (deoxyribonucleic [dee ahk see rye boh noo KLAY ik] acid), the chemical code that tells your cells what to do. Your genes are small sections of DNA that determine your different traits.

Genes control many visible traits, such as the length of your eyelashes, the color of your hair, and whether you are a boy or a girl. However, genes also control traits that we cannot see. Your genes determine the shape of your red blood cells, your blood type, and whether or not you are colorblind.

Heredity is the passing of traits from parents to offspring. You have inherited, or received, traits from your parents. But not all of your traits are permanent and unchangeable. Your genes determine some of your traits, such as eye color and freckles. You have no control over these traits. However, other traits are determined by your genes but influenced by your environment and health habits. A person may have inherited the genes for tallness, but if he is malnourished, he will not grow to his full height. Your musical and academic abilities, height, weight, and blood pressure are just some

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TEACHER HELPS

Students not living with birth parents
Be sensitive to students who are adopted or who do not live with their birth parents. Assignments that include finding out about inherited family traits may be difficult for these students to do.

Review vocabulary
Review the following definitions from Chapters 4 and 12 as needed.

Chromosomes—tight bundles of DNA found in the nucleus of cells

Meiosis—the two-stage process of cell division in which the chromosomes duplicate once, but the cell divides twice; Each new cell has half of the chromosomes of the parent cell.

Mitosis—the process of cell division in which a cell makes an exact copy of itself; The chromosomes duplicate once, and the cell divides once.

LANGUAGE

Heredity root
The terms *heredity* and *inherit* come from the same root as *heir* and *heritage*.

attached earlobe unattached earlobe

bent thumb straight thumb

right thumb dominance left thumb dominance

straight hairline widow's peak

cannot roll tongue can roll tongue

of the traits that your environment and habits can influence.

Other traits are learned rather than inherited. For example, you did not inherit the ability to speak in a certain language. You learned the language of the people around you. Scientists are not sure how much of a trait is related to genetic inheritance and how much is influenced by environment, habits, and things that we learn.

Most traits are controlled by many genes, so it is difficult to determine which genes you may have. For example, eye color is controlled by multiple genes, so blue eyes come in many shades, not just one.

Other traits, however, you either have or you do not. Fold your hands together. Which thumb is on top? Unless you make a conscious effort to change, the same thumb will almost always be on top. Pictured above are some other traits that are easy to identify.

QUICK CHECK

1. How are genes, DNA, and chromosomes related?
2. What is heredity?

DIRECT A DEMONSTRATION

Demonstrate surveying sample groups

Materials: tally chart with three choices—hot breakfast, cold breakfast, and no breakfast

Choose five students as the sample group. Use tally marks to record the usual breakfast choice of each student on the chart.

Who was the sample group? the five students

Is this a large sample group or a small sample group? a small sample group

How many in the sample group usually have a hot breakfast? Answers will vary.

How many in the sample group usually have a cold breakfast? Answers will vary.

How many in the sample group usually do not eat breakfast? Answers will vary.

Repeat the activity using five different students and add their responses to the previous results.

How big is the sample group now? ten students

Which sample group probably gives a better representation of breakfast-eating habits—the five students or the ten students? Why? the ten students The greater the sample group is, the more accurate the representation of the whole is.

Discussion

Language is an example of a learned trait. How is a learned trait different from an inherited trait? People do not inherit the ability to speak in a certain language. Language is learned from other people.

Other than heredity, what can affect your musical or academic abilities? Possible answers: the instruction you receive; your study and practice habits; your overall health

Answers

1. Genes are small sections of DNA. DNA is the chemical code that tells the cells what to do. Chromosomes contain DNA.
2. Heredity is the passing of traits from parents to offspring.

Activity Manual

Bible Connection, page 206

On this page the student completes a word study of one of the characteristics Christians should demonstrate.

Purpose for reading

The student should read Student Text page 312 and Activity Manual pages 207–8 before beginning the activity.

This activity is included as part of Lesson 149. You may choose to do the Direct a Demonstration on TE page 339 before the student begins the activity.

Materials

- See Student Text page

Introduction

You will conduct a survey using a sample group to determine the occurrence of certain traits. A sample group is the group that is surveyed.

Teach for Understanding

Procedure

If you have a class of fifteen or more students, then the activity could be completed during class. Otherwise, assign the survey to be completed at a later date to allow the student to survey the required number outside of class. Possible larger groups to survey may include the students and teachers in the school's lunch room, a homeschool co-op group, a sports team, or a church group.

Refer the student to Student Text page 311 for pictures of the traits. Remind each student to record tally marks while conducting the survey.

After the survey is completed, guide the student in labeling and completing the bar graphs.

Conclusions

Did one of the traits in each pair occur more often than the others? If so, which one?

Use the Science Process Skills information to discuss recording data.

Activity Manual

Activity, pages 207–8

Assessment

Rubrics

Select the prepared rubric, or design a rubric to include your chosen criteria.

ACTIVITY

It's All in the Genes

Process Skills
- Collecting data
- Interpreting data
- Communicating

Kayla was frustrated. She could not roll her tongue. All of her friends could do it, and Kayla really did try. Even though she practiced and practiced, she couldn't get her tongue to roll. It just flopped in her mouth and refused to stand up in a nice, neat roll. Surely something was wrong with her!

Perhaps you have felt like Kayla. Although you try, you cannot get your tongue to roll. But now you know that being able to roll your tongue is not a matter of practice. It is a matter of genes.

For this activity you will conduct a survey to find out how many people have specific genetic traits. The people that you survey will represent a sample group. When conducting a survey, the larger your sample group is the more accurate your data, or gathered information, is likely to be.

Materials
Activity Manual

Procedure

1. Look at the traits that your teacher gives you. Survey a minimum of fifteen people to determine which of the traits they have. If you are unsure of what to look for, you may refer to page 311 of your text.
2. Record your findings in your Activity Manual.
3. Prepare a bar graph to show your data.

Conclusions

- Compare your findings with those of others. In each pair of traits, did one trait show up more frequently than the other?

Follow-up

- Figure out the ratio between the two corresponding traits shown on your bar graph.
- Survey another 15 people. See if the ratio changes as your sample group increases.

Example

Ears

Attached earlobes	𝍸 |
Unattached earlobes	𝍸 ||||

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TEACHER HELPS

Activity goal
In this activity, help the student realize that one trait tends to occur more often than the corresponding trait. Lesson 152 discusses dominant and recessive traits.

Validity of a small sample
Because of the relatively small sample group, representation of the dominant trait may be inaccurate. If that occurs, emphasize to the students that small samplings sometimes give faulty information.

SCIENCE PROCESS SKILLS

Recording data
Recording data allows others to determine what information you found, as well as the size of the sample group used. The sample group size may have a large impact on the validity of the collected information.

SCIENCE BACKGROUND

Common dominant traits
The following are considered common dominant traits.

bent pinky
curly hair
dimples (many variations possible)
freckles (many variations possible)
hair on fingers
left thumb dominance when hands are folded
right-handedness
straight thumb (cannot bend backwards)
unattached earlobes
widow's peak

Genetics

DNA: The Double Helix

How can your genes determine your hairline and the shape of your ears? Each of your genes contains a section of the DNA found in your chromosomes. This DNA contains all the instructions for your cells. Each time a cell divides through mitosis, the DNA duplicates itself so that each new cell will have a copy of your DNA pattern.

Structure of DNA

For many years scientists studied DNA, trying to determine its shape and structure. Then in 1953, after seeing an x-ray photograph of DNA, James Watson and Francis Crick announced that they had discovered "the secret of life." Their model of DNA was shaped like a twisted spiral ladder. Because of its shape, they called it a *double helix*.

Sugar and phosphate molecules form the sides of this ladder. The rungs are formed with the four basic molecules of DNA, called *bases*. These four bases are similar to a four-letter alphabet for DNA. Even before Watson and Crick discovered the shape of the DNA molecule, scientists learned that only certain bases would fit together. Base A fits only with base T, and base G fits only with base C. The order in which the bases are arranged creates the code, or pattern, for each gene.

Rosalind Franklin

Rosalind Franklin

Rosalind Franklin (1920–1958), a British scientist working at King's College in London, was the first person to photograph a DNA molecule. Her colleague Maurice Wilkins showed the photograph and some of her work to James Watson and Francis Crick. Franklin's research enabled them to conclusively identify the twisted spiral structure of DNA. She supported their model of DNA with other research that she had done. Franklin continued to study DNA, but she also researched plant viruses and the structure of the live polio virus. She died from cancer in 1958, four years before Wilkins, Crick, and Watson received the Nobel Prize for their DNA discoveries.

James Watson

Francis Crick

Objectives

- Describe the structure of a DNA molecule
- Recognize James Watson and Francis Crick as those who identified DNA structure
- Identify uses of DNA testing
- Create a model of a DNA molecule

Materials

- *Coded Instructions* (IA), for display

Introduction

Display *Coded Instructions*.

What is the name of this code? the Morse code

How is it useful? Possible answer: to send telegraph messages

Direct the student to decode the message.

What is the message from the code? DNA is the chemical code that tells cells what to do.

Teach for Understanding

Purpose for reading

What does a molecule of DNA look like?

What are ways that DNA testing is used?

Discussion

How do new cells have the same pattern of DNA as old cells? Each time a cell divides, the DNA replicates itself so that each new cell has a copy of the organism's complete DNA.

Which two scientists received credit for being the first to discover the structure of DNA? James Watson and Francis Crick

The word *helix* means "a coil, or something that is twisted." Why do you think a DNA molecule is described as a *double helix*? Answers may vary but should include that DNA looks like a twisted ladder or two coils twisted together.

What kinds of molecules make up the structure of DNA? The sides of the "ladder" are made up of sugar and phosphate molecules. The "rungs" are the four molecules called bases—A, T, G, and C.

Which base fits with base T? base A with base C? base G

Discuss the Rosalind Franklin box.

Whose research and photograph helped Watson and Crick with their discovery? Rosalind Franklin's

SCIENCE BACKGROUND

Names of bases
The base molecules for DNA are adenine (A), thymine (T), guanine (G), and cytosine (C).

DNA replication
When DNA replicates itself, it "unzips" the ladder. New bases floating in the nucleus pair up with the bases on each side of the ladder, creating two copies of the same DNA.

HISTORY

The Nobel Prizes
Nobel Prizes are awarded yearly to living men and women who make outstanding advances in chemistry, economics, literature, medicine, physics, and creating peace. They are named for the Swedish scientist Alfred Bernard Nobel (1833–96), who is known for inventing dynamite. Nobel's will stated that much of his fortune should be used to award the Nobel Prizes. The first Nobel Prizes were awarded in 1901.

SCIENTIST

Rosalind Franklin
Rosalind Franklin and Maurice Wilkins both studied DNA at King's College in London, but they did not get along with each other. It is believed that Maurice Wilkins showed Franklin's DNA photograph and research to James Watson and Francis Crick without her permission. At that time, women scientists did not get the same respect and benefits as their male colleagues. Her photograph, often referred to as Photograph 51, and her research enabled Watson and Crick to realize the shape and structure of the DNA molecule.

Discussion

Why can DNA patterns be used to identify organisms? Every organism has a different DNA pattern.

Is the DNA in your hair cells the same as the DNA in the cells inside of your mouth? yes **Why?** Your DNA is the same in all the cells of your body.

Why would the United States government say that it might never have another unknown soldier? Technology has improved so much that DNA can be used to identify people who have died.

What is another use of DNA testing? to help solve crimes

Compare the DNA samples on page 314. Which suspect committed the crime? suspect B **How do you know?** His DNA sample matches the sample produced as evidence.

Why might a scientist or an investigator have difficulty using DNA testing to identify which person of a pair of twins matched a blood or hair sample? Identical twins have the same DNA patterns.

Answers

1. the four basic molecules of DNA
2. Possible answers: to identify servicemen killed in action; to aid police in identifying a criminal

Activity Manual

Reinforcement, pages 209–10

Reinforce the student's knowledge about the structure of DNA by making a model from chenille wires. Compare models and discuss the variety of color sequences. Relate the variety seen in the students' models to the innumerable combinations of real DNA. This activity uses inch rather than centimeter measurements.

Review, pages 211–12

These pages review Lessons 149 and 150.

Assessment

Quiz 13-A

The quiz may be given any time after completion of this lesson.

Patterns of DNA

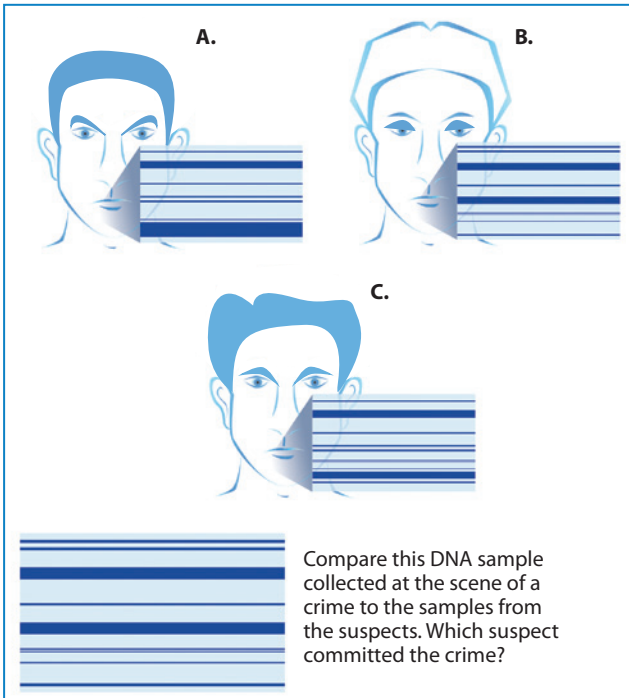
Even with only four "letters," many different patterns of DNA are possible. Every organism has a different DNA pattern, even within the same species. However, within the organism, every cell has the same DNA pattern, no matter what the job of the cell is. The DNA pattern of your blood is the same as the DNA pattern of your skin. However, no one, except an identical twin, has the same DNA pattern as another person.

Have you ever heard of DNA testing? It is a process where scientists and investigators take samples of DNA and compare them. They can use these DNA samples to help identify soldiers who were killed in action. In every war there have been servicemen killed who could not be identified. The Tomb of the Unknown Soldier is a memorial in the United States that honors American servicemen whose remains could not be identified. But with the increased use of DNA testing, government officials have remarked that America may never have another unknown soldier.

DNA testing is also used to help solve many crimes. Crime scene investigators can use samples of hair, skin, and blood cells from the scene of a crime to help identify the criminal. Machines analyze the DNA and show the DNA as a pattern of bands somewhat similar to a bar code on a product. Detectives can then compare the DNA pattern with DNA from suspects in the case.

QUICK CHECK

1. What are DNA bases?
2. What is one way that DNA testing is used?



Compare this DNA sample collected at the scene of a crime to the samples from the suspects. Which suspect committed the crime?

TEACHER HELPS

Working in pairs
When doing Activity Manual pages 213–14, you may choose to assign the students to work in pairs.

Encourage variety
Encourage each student to design a DNA molecule that is different from the other DNA molecules.

SCIENCE BACKGROUND

DNA of the "Unknown Soldier"
In 1998, DNA testing was done on the Vietnam War soldier buried at the Tomb of the Unknown Soldier in Washington, D.C. He was later identified as 1st Lt. Michael J. Blassie. This DNA testing was actually mitochondrial DNA testing.

Two types of DNA
Genetic DNA is found in the chromosomes, located in the cell's nucleus. This DNA is different for each individual, since it is a mixture received from both parents. Mitochondrial DNA is found in the mitochondria, located in the cell's cytoplasm. Mitochondrial DNA is inherited from the mother only, so offspring from the same mother will have similar mitochondrial DNA. This DNA is passed to other generations through the female side of the family only.

Other uses for DNA testing
DNA testing has also been used on animals to indicate parentage, breed, genetic information about color, and the possibility of certain genetic diseases or health conditions.

DNA Extraction

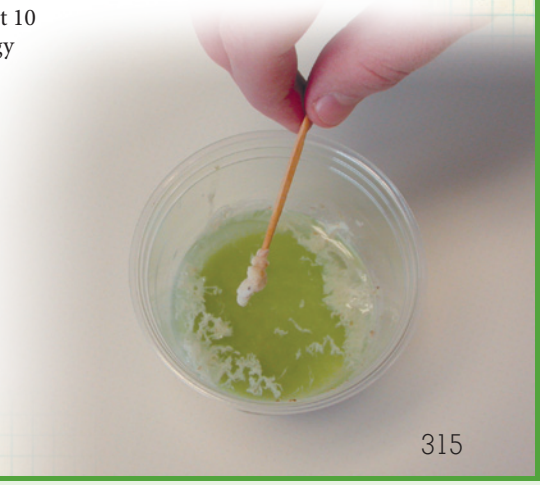
DNA molecules are the chemical blueprints of all living organisms. DNA is the mysterious substance that makes a plant a rose instead of a daisy or makes an animal a cat instead of a dog. It is also responsible for giving you the skin color, hair color, and eye color that you have.

Most DNA molecules are part of a cell's nucleus. Though the molecules are very small, you can perform an activity that will allow you to see the strands of DNA molecules.

Materials
- 15 mL raw wheat germ
- 45 mL water
- 8 mL liquid detergent
- 4 mL meat tenderizer
- 45 mL rubbing alcohol
- toothpicks, wooden skewers, or craft sticks
- metric measuring spoons
- clear plastic containers
- Activity Manual

What to do

1. Measure 15 mL of the wheat germ into a clear container.
2. Pour 45 mL of water into the same container.
3. Stir thoroughly. Add 8 mL of detergent and stir occasionally for 5 minutes.
4. Add 4 mL of meat tenderizer and stir occasionally for 5 minutes.
5. Tip the container slightly and gently pour 45 mL of alcohol along the side of the container. The alcohol on top should form a separate layer.
6. Carefully set the container upright. Allow the solution to sit for at least 10 minutes. Observe the white, stringy substance that moves into the alcohol layer. Use a toothpick to lift one of the strings up. This is a DNA molecule.
7. Refer to your Activity Manual for additional information about extracting DNA molecules.



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TEACHER HELPS

Sources for wheat germ
Raw wheat germ is available in health food stores and in other stores that carry organic flours in bulk.

Alternative substances
You may choose to use other organic substances as described in FAQ #1 on Activity Manual page 213. Another substance that works well is strawberries.

Test detergents
Some liquid dish and laundry detergents work better than others. Test your brand to make sure that it gives the desired result.

Objectives
- Extract DNA from organic matter

Materials
- See Student Text page

Introduction

Are DNA molecules large or small? small

How do you know? Possible answer: DNA molecules are parts of cells, which are very small.

The amount of DNA found in one cell is microscopic. But since DNA molecules stick together easily, we can do an activity that will allow us to actually see strands of DNA molecules.

We will be observing the chromosome material of hundreds of thousands of cells that have stuck together.

Teach for Understanding

Purpose for reading
The student should read page 315 before beginning the exploration.

What to do
Guide the student in following the procedure to extract strands of DNA. Remind him to stir gently. Try to avoid causing foam when stirring in the detergent. The foam will make it difficult to see the DNA molecule. If a lot of foam is made, use a paper towel to absorb it before adding the rubbing alcohol.

After completing the extraction, discuss the questions and answers on Activity Manual pages 213–14.

Activity Manual

Explorations, pages 213–14
Read and discuss these pages after completing the activity.

Assessment

Rubrics
Select the prepared rubric, or design a rubric to include your chosen criteria.

Objectives

- Describe Mendel's experimental procedures
- Explain Mendel's conclusions
- Interpret diagrams and charts
- Differentiate between dominant genes and recessive genes

Vocabulary

purebred plant
hybrid
dominant trait
recessive trait
phenotype
genotype
codominant
incomplete dominance

Introduction

Suppose you are a scientist who has been researching and studying a topic for several years. You have spent much time and effort on your experiments and have carefully recorded your results. You are almost ready to publish your results when you discover that an unknown scientist did similar experiments years earlier and made the same discovery that you made. Would you acknowledge the other scientist's work or ignore it?

Allow the student to discuss what he would do. Acknowledge that the choice to do right is not always easy even though we know that the Bible tells us not to lie. [BAT: 4c Honesty]

Today's lesson includes a very similar situation.

Teach for Understanding

Purpose for reading

Who is known as the Father of Genetics?

How are dominant and recessive genes different?

Discussion

Why did Gregor Mendel begin studying peas? He wanted to find out how traits were passed from generation to generation.

Why are peas a good type of plant to study? Possible answers: Peas grow quickly and produce many seeds, making it possible to study many generations. Peas also have traits that can be traced easily.

Father of Genetics

Genetics (juh NET iks) is the study of how traits are inherited. The idea that genes determine many physical traits began with Gregor Johann Mendel, an Austrian monk and scientist. The son of a farmer, Mendel became a monk in order to continue his education. He was in charge of the monastery gardens and was also a substitute teacher at a school nearby.

Mendel studied peas for eight years, seeking to discover how traits are passed on from generation to generation. Since pea plants grow quickly and produce many seeds, Mendel was able to study many generations of plants. Pea plants also have traits that are easy to trace because they appear in only one of two forms. For example, a pea plant has either yellow seeds or green seeds. It is either a tall plant or a short plant and has either white flowers or purple flowers.

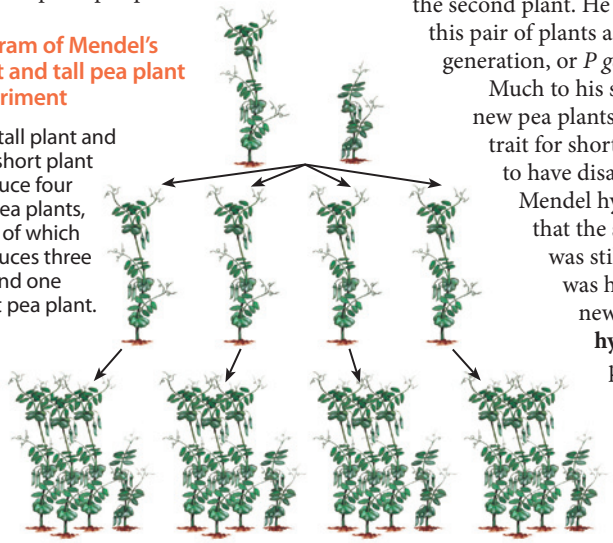
Mendel

Mendel began his experiments with purebred plants. **Purebred plants** are plants that show the same trait for many generations when pollinated naturally. Pea plants usually self-pollinate, so Mendel cross-pollinated tall pea plants with short pea plants. He took pollen from the stamens of one plant and added it to the pistil of another plant. He then removed the stamens from the second plant. He referred to this pair of plants as the parent generation, or *P generation*.

Much to his surprise, all the new pea plants were tall. The trait for shortness seemed to have disappeared. Mendel hypothesized that the shortness trait was still there but was hidden. These new plants were **hybrids**, plants produced by crossing purebred parent

Diagram of Mendel's short and tall pea plant experiment

One tall plant and one short plant produce four tall pea plants, each of which produces three tall and one short pea plant.



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SCIENCE MISCONCEPTIONS

The fact that a trait is dominant does not mean that the majority of people possess that trait. A dominant trait simply means that this trait will be expressed if it is present in a person's genes. It is possible that a majority of people may actually have a recessive trait, especially when surveying only a small sample, such as in Lesson 149.

SCIENTIST

Gregor Mendel

Mendel (1822–84) loved studying and learning, but he had great test anxiety. He could not become a full-time teacher because he failed his teacher's examinations twice.

Mendel's younger sister gave him her dowry so that he could continue studying and preparing for university work. Her money was not enough to cover expenses, so Mendel eventually joined an Augustinian monastery that emphasized teaching and research. In gratitude for his sister's unselfish gift to him, Mendel later helped to raise and support her three sons.

plants that each have a different form of the same trait. These plants are also called the first filial (fill ee ul) generation, or *F1 generation*, because they are the offspring of the parent generation.

To test his hypothesis, Mendel allowed the tall hybrid plants to self-pollinate. The next generation, *F2*, included both tall and short plants. For every three tall plants, there was one short plant—a ratio of three to one.

Mendel continued testing his plants while keeping detailed records of the results. In another experiment, he crossed plants with round seeds with plants that had wrinkled seeds. Only the round seeds appeared in the hybrid generation. The trait for wrinkled seeds was hidden. He also experimented with the flower color, seed color, and pod shape.

Mendel concluded that offspring inherit traits in pairs of factors, receiving one factor from each parent. He also realized that some traits were hidden in some generations but reappeared in following generations. This led to the idea of dominant and recessive traits. A **dominant trait** is the characteristic that is shown in the hybrid generation. The **recessive trait** is hidden in the hybrid generation and appears in later generations only when no dominant factor is inherited.

Mendel's discoveries about heredity contradicted the theories of his time. He presented his work to other scientists, and in 1866 he published a report about his discoveries. However, most people ignored his work. In 1900 three other scientists who had done similar experiments read Mendel's report. They gave Mendel the credit for discovering that traits are passed from generation to generation. Because of this, Mendel is now known as the Father of Genetics.

	Seed shape	Seed color	Pod color	Pod shape	Plant height	Flower color
Dominant	round	yellow	green	full	tall	purple
Recessive	wrinkled	green	yellow	flat	short	white

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Discussion

What is the difference between purebred plants and hybrid plants? Purebred plants will continue to show the same trait(s) for many generations when pollinated naturally. A hybrid plant is a mixture of two purebred plants with different forms of the same trait.

Why did Mendel cross-pollinate his pea plants? Pea plants are usually self-pollinated. By cross-pollinating, Mendel could combine plants with different purebred traits.

Why do you think Mendel removed the stamens from the second plant after he had added pollen to its pistil? to prevent the plant from self-pollinating

What did Mendel call the generation of plants that he cross-pollinated? the parent generation, or P generation

Discuss the *Diagram of Mendel's short and tall pea plant experiment*.

What trait did the hybrids show after Mendel crossed tall purebred plants with short purebred plants? The hybrids were all tall.

What did Mendel hypothesize about the trait for shortness? He thought that it was still there but just hidden.

How did Mendel find out that the hybrids had a trait for shortness? He allowed them to self-pollinate.

Was his hypothesis correct? yes

What was the ratio of tall plants to short plants? 3:1
Explain. Mendel noticed that he had three tall plants for each short plant.

What were Mendel's conclusions? Possible answers: Traits are inherited in pairs of factors, with each parent giving the offspring one factor. Some traits are hidden in one generation but reappear in following generations.

Discuss ideas about why Mendel's work was ignored for so long.

Why is Mendel now known as the Father of Genetics? The scientists who found Mendel's work gave him the credit for discovering that traits are passed from generation to generation.

Use the chart about pea plant characteristics to discuss Mendel's findings.

Which pod color is dominant? green

Which flower color would probably not appear in the hybrid generation? white

SCIENCE BACKGROUND

Mendel's work

Mendel's work did not receive much notice because it contradicted the theories of his time, and his paper about his findings was published in an obscure journal. Some say another reason his work was ignored was because it seemed to be more about hybrids than about inheritance. People did not initially notice that it was a new discovery. Since he lived and worked in a monastery, he was not able to travel and actively discuss his ideas with other scientists.

Mendel's experiments

Blossom color was not a factor in his initial study of pea plants but was dealt with in his later work. Mendel's initial studies included whether the plants had terminal blossoms (at the end or top of the stem) or axial blossoms (scattered along the stem).

LANGUAGE

Genetics

The term *genetics* comes from the Greek word *genesis*, meaning "origin" or "beginning."

Dominant

The term *dominant* comes from the Latin word *dominus*, meaning "lord" or "rule."

Recessive

The term *recessive* comes from the Latin word *recedere*, meaning "to retreat" or "go back."

Discussion

Why do we usually have two genes for each trait? because we received one set of genes from each parent

What is the difference between dominant and recessive genes? Dominant genes will be expressed if they are present. A recessive gene will be hidden if a dominant gene is present. A recessive gene will be shown only if the person has two recessive genes for that trait.

What term is used to describe a trait that is seen? expressed

If a person has one gene for a bent thumb and one gene for a straight thumb, why will the person have a straight thumb? because the gene for a straight thumb is dominant

What genes must a person have if he has a bent thumb? He must have two recessive genes for a bent thumb.

A person who has freckles has the dominant gene for that trait. If a person does not have freckles, what would you know about that person's genes for this trait? He inherited two recessive genes for this trait. **Why?** because the recessive trait can be shown only if no dominant genes are present

What is the physical appearance of an organism called? phenotype

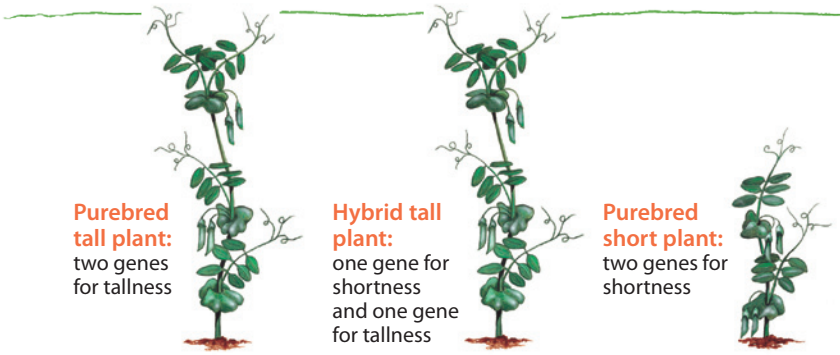
What is the genetic arrangement of an organism called? genotype

Can you tell the genotype of an organism by observing its phenotype? no **Why?** Recessive traits in a genotype may not appear in the phenotype.

Look at the pea plants pictured on page 318. What is the same for the first two plants—the phenotype or the genotype? phenotype

What genotype might a tall pea plant have? It could have two dominant genes for tallness, or it could have one dominant gene and one recessive gene.

All of the pea plants in Mendel's F1 generation were tall even though some of them had a recessive gene for shortness. What does F1 refer to? It indicates that it is the first generation offspring of the particular parents.



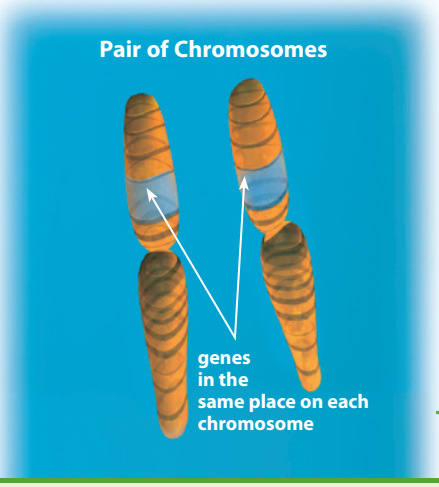
Dominant and Recessive Genes

Today we know that what Mendel called factors are actually genes. Because you received one set of genes from each parent, you have two genes for each trait. Genes for a certain trait, such as the shape of your thumb, are in the same place on each chromosome. A straight thumb is a dominant trait. If a person has one gene for a straight thumb and one gene for a bent thumb, the person will have a straight thumb. The gene for the dominant trait, called the dominant gene, will always be expressed, or shown, if it is present in a person's chromosomes.

The gene for a bent thumb is a recessive gene. It is hidden, or masked, when a dominant gene is present. A person can have a bent thumb only if he has inherited two recessive genes for thumb shape.

In Mendel's experiments, all the pea plants in the F1 generation were tall. Since tallness is dominant for pea plants, each plant was tall even if it had one gene for tallness and one gene for shortness. The plant would be short only if it received two genes for shortness.

You cannot tell by its appearance whether a plant has two genes for tallness or if it has one gene for shortness and one for tallness. The physical appearance of an organism is called its **phenotype** (FEE nuh tipe). The genetic combination, or arrangement of genes within the organism, is its **genotype** (JEN uh tipe).



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SCIENCE BACKGROUND

Forms of genes
The possible matched forms of a trait found on a pair of chromosomes are called alleles. These alleles are often expressed with single letters that can either be uppercase (dominant) or lowercase (recessive). Some traits such as blood type have more than two possible alleles in the population, but each individual can have only two.

Codominant cattle
The term *roan* describes the markings of cattle that have a mixture of both white and colored hairs on their bodies. A pair of codominant genes is the cause for most types of roan coloration.

Incomplete dominance
Incomplete dominance happens when an allele for a specific trait is not completely dominant over the other allele, resulting in a combined phenotype for that trait. This occurrence is commonly seen in flowers, such as snapdragons. In humans, this can happen when a child receives a gene for curly hair from one parent and a gene for straight hair from the other parent. Instead of being either curly or straight, the child's hair would be wavy, a blend of the two textures.

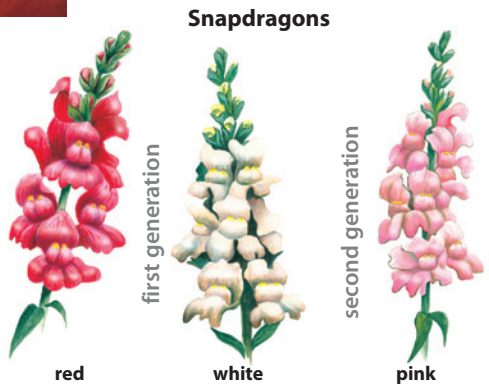
being expressed. For example, some cattle have both red and white hairs. The gene for red hair and the gene for white hair are codominant. Both genes are expressed instead of one being recessive, or hidden.

At other times some genes blend together. This is called **incomplete dominance**. Red snapdragon flowers crossed with white snapdragons produce pink snapdragons. When crossed, the hybrid pink flowers produce some red, some pink, and some white flowers.

In some later experiments, Mendel tested the color of pea plant flowers by crossing a purebred purple-flowered plant with a purebred white-flowered plant. The dominant trait, purple, masked the recessive trait of white flowers in the hybrid generation. However, the purple hybrid flowers produced some white flowers.

The phenotypes of the purebred purple flowers and the hybrids were the same. Both sets of plants showed purple flowers. However, their genotypes were different. The purebred flowers had two dominant genes for purple color. The purple hybrids, though, had one dominant gene for purple and one recessive gene for white.

Sometimes genes are not just dominant and recessive. Some genes are **codominant**, with both genes



QUICK CHECK

1. What did Mendel conclude from his research on pea plants?
2. What is the difference between a phenotype and a genotype?

Pheno

The prefix *pheno-* means "to show or display." Another word with this prefix is *phenomenon*. A phenomenon is a fact or occurrence, often unusual, that is perceived through the senses.

Crossing flowers

Be sure the student understands that questions or statements referring to crossing, such as red snapdragons being crossed with white snapdragons, are referring to cross-pollination. The purebred red flowers are cross pollinated with purebred white flowers, resulting in the hybrid pink flowers.

Discussion

When Mendel crossed purebred purple-flowered pea plants with purebred white-flowered pea plants, why did all the new plants end up with purple flowers? Purple is the dominant trait for pea plant flower color.

How were the genotypes of the purple purebred flowers and the purple hybrids different? The purple purebred flowers had two dominant genes for purple color. The purple hybrid flowers had one dominant gene for purple color and one recessive gene for white color.

Are genes always strictly dominant and recessive? no

Which term describes instances when both genes are expressed instead of one being dominant and the other recessive? codominant

What is an example of codominance? Possible answer: cattle that have both red and white hairs

What is incomplete dominance? when genes seem to blend together in one generation

Which type of plant sometimes shows incomplete dominance? snapdragons

Which color is produced when red snapdragons and white snapdragons are crossed? pink

Which color is produced when the hybrid pink flowers are crossed? white, red, and pink

Answers

1. Traits are inherited in pairs of factors, with each parent giving the offspring one factor. He also found that some traits are hidden in one generation but reappear in following generations.
2. The phenotype is simply the organism's physical appearance, but the genotype is the arrangement of genes in the organism.

Activity Manual

Reinforcement, page 215

Lesson 153

Student Text pages 320–23
Activity Manual pages 216–18

Objectives
- Predict genetic probability using a Punnett square
- Interpret a pedigree chart
- Identify some traits as sex-linked

Materials
- family tree
- *Tracing Traits* (IA), for display or for each student

Vocabulary
pedigree
sex-linked trait

Introduction
Display a family tree.

What is the purpose of a family tree? to trace one's ancestors

In today's lesson, you will be learning about something similar to a family tree.

Teach for Understanding
Purpose for reading
Why are Punnett squares useful?

What is a pedigree?

Discussion
What are Punnett squares? diagrams used to show possible genetic outcomes

Why did Reginald Punnett use these squares? to make Mendel's charts easier to understand

A parent has two genes for each trait. How many genes for each trait will a parent pass on to a child? one

What do the letters on the outside of a Punnett square represent? each parent's genotype for that trait

What does a capital letter represent? the dominant gene

What does a lowercase letter represent? the recessive gene

Punnett squares

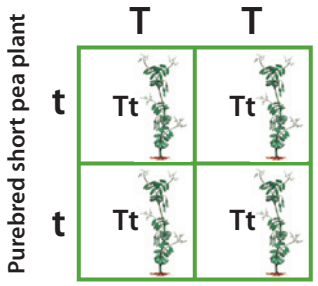
When Mendel's research was rediscovered, scientists studied his results carefully. Mendel had written some of his ideas about possible genetic combinations in chart form. Reginald Punnett (PUN net), an English geneticist, was especially interested in Mendel's charts. Punnett used squares to make Mendel's charts easier to understand. Punnett squares show the genetic possibilities of a particular trait that can result for the offspring of a specific set of parents.

To use a Punnett square, geneticists write one parent's genotype at the top of the Punnett square. The other parent's genotype is written at the left edge of the Punnett square. Geneticists use letters to represent the genes. An uppercase letter represents the dominant gene, and a lowercase letter represents the recessive gene. Although each parent has two genes for a trait, a parent can give only one gene for that trait to his or her offspring.

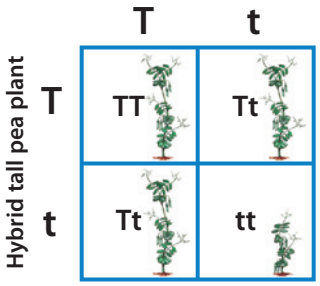
Geneticists take one gene from the top and one gene from the side to fill in the small boxes in the Punnett square. The four boxes show the possible genotypes for the offspring of the parents. For example, when a purebred tall pea plant (*TT*) is crossed with a purebred short pea plant (*tt*), all of the offspring will have the phenotype, or appearance, of tallness. The boxes in the Punnett square show that each offspring has a dominant gene.

However, if two hybrids are crossed, the results are very different. The Punnett square shows that there is one chance in four that a plant will have two recessive genes. The plant with two recessive genes will be the only short pea plant, although three of the four plants will carry the recessive gene. Notice in the Punnett square that the dominant gene is listed first in the boxes no matter which parent it comes from.

Purebred tall pea plant



Hybrid tall pea plant



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TEACHER HELPS

Letter choice
Any letter can be used to represent genes in a Punnett square. However, it is usually better to use a letter that can be easily distinguished between its uppercase and lowercase.

Punnett squares and offspring
Each of these Punnett squares shows four possible genetic combinations for one offspring. The squares do not show that the parents will have four offspring. For example, if a cat has four kittens, she may not have a kitten with each of the genetic combinations represented. Some kittens may have the same combination. Some of the combinations may not appear in any of the kittens.

SCIENTIST

Reginald Punnett
Punnett squares were named for the English geneticist, Reginald Punnett (1875–1967). In 1905 he wrote the first genetics textbook. In 1910 he became the first professor of genetics at Cambridge University. He researched worms, sweet peas, maize, and poultry.

Punnett squares show the probability of a certain outcome. For example, what would be the probability of parents whose hairlines form widow's peaks having a child with a straight hairline? Notice that one of the parents has a recessive gene for a straight hairline. Use an uppercase *W* to represent the dominant gene of a widow's peak. The lowercase *w* represents the recessive gene of a straight hairline.

Purebred for widow's peak

Hybrid for widow's peak	W	W
W	WW	WW
w	Ww	Ww

There is no possibility that a child of this couple would have a straight hairline. All the children would carry the dominant gene for a widow's peak and, therefore, would show that trait. However, unlike the offspring of the two hybrid pea plants, the probability is that only two of these offspring, or 50 percent, would carry the recessive gene to the next generation.

Several different genes control the color and length of a cat's fur, but the gene for short hair is dominant. What would be the probability of producing a longhaired kitten if one parent has short hair with a recessive gene for long hair and the other parent is longhaired? *H* represents the dominant gene for short hair, and *h* represents the recessive gene for long hair. The kitten would have a 50 percent probability of having long hair.

Hybrid for short hair

Purebred for long hair	H	h
h	Hh	hh
h	Hh	hh

Discussion

Discuss the Punnett squares pictured on Student Text pages 320–21.

Look at the Punnett square for purebred short and tall pea plants. How many offspring shown carry a dominant gene? all of them

Would these plants be tall or short? tall **Why?** If both dominant and recessive genes are present, the dominant gene will be expressed in the phenotype.

Look at the Punnett squares for hybrid tall pea plants. Which letters represent the parents' genes? Tt and Tt

What do these letters tell us about each parent's genotype? Possible answers: Both parents are hybrid pea plants. They each have one dominant gene and one recessive gene for height.

What is the probability that the offspring will show the dominant trait? 3 out of 4, or 75%

What is the probability that one of these new plants will be short? 1 out of 4, or 25%

Look at the Punnett square for widow's peak. Which letters represent the parents' genes? WW and Ww

What is the probability that the offspring will show the dominant trait of having a widow's peak hairline? 4 out of 4, or 100%

How are the probable offspring in this Punnett square different from those in the Punnett square for hybrid tall pea plants? Possible answer: Three offspring in the square for pea plants carry the recessive gene. Only two offspring in the square for widow's peak carry the recessive gene.

Why is there a difference? For the pea plants, both parents have both the dominant gene and the recessive gene. For the widow's peak, one parent has two dominant genes and the other has one dominant gene and one recessive gene.

Look at the Punnett square for cat hair. Which letters represent the parents' genes in this Punnett square? Hh and hh

What is the probability that a kitten will have the recessive trait of long hair? 2 out of 4, or 50%

DIRECT A DEMONSTRATION

Practice Punnett squares

Having freckles is a dominant trait. Using *F* for with freckles and *f* for without freckles, complete several Punnett squares with the class. Possible parent combinations include *Ff* and *ff*, *FF* and *ff*, *FF* and *Ff*, or *Ff* and *Ff*.

	F	f
f	Ff	ff
f	Ff	ff

	F	F
f	Ff	Ff
f	Ff	Ff

	F	F
F	FF	FF
f	Ff	Ff

	F	f
F	FF	Ff
f	Ff	ff

Discussion

What is a pedigree? a chart that traces a trait through many generations

What is the difference between the circles and squares on a pedigree? Circles represent females, and squares represent males.

Look at the *Pedigree for Tongue Rolling*. Why are some symbols shaded in this pedigree? Shaded symbols show the people who possess the recessive trait. On this pedigree they show those who cannot roll their tongues.

What are the names of Leon and Beverly's children? Anna, David, Paul, and Amy

How does this pedigree show the relationship of the parents in one generation to their children in the next generation? with vertical lines

What would be two possible genotypes for the father, Leon, in this family tree? He could have two dominant genes (*RR*) for tongue rolling or one dominant gene and one recessive gene (*Rr*).

Since the mother, Beverly, cannot roll her tongue, what must be true about her genotype? She must have two recessive genes (*rr*).

How many of Leon and Beverly's children can roll their tongues? 3

Since their son Paul cannot roll his tongue, is Leon's genotype two dominant genes or one dominant gene and one recessive gene? one dominant gene and one recessive gene (*Rr*) **How do you know this?** Paul must have two recessive genes (*rr*) for the recessive trait to be expressed.

Continue asking questions as time allows.

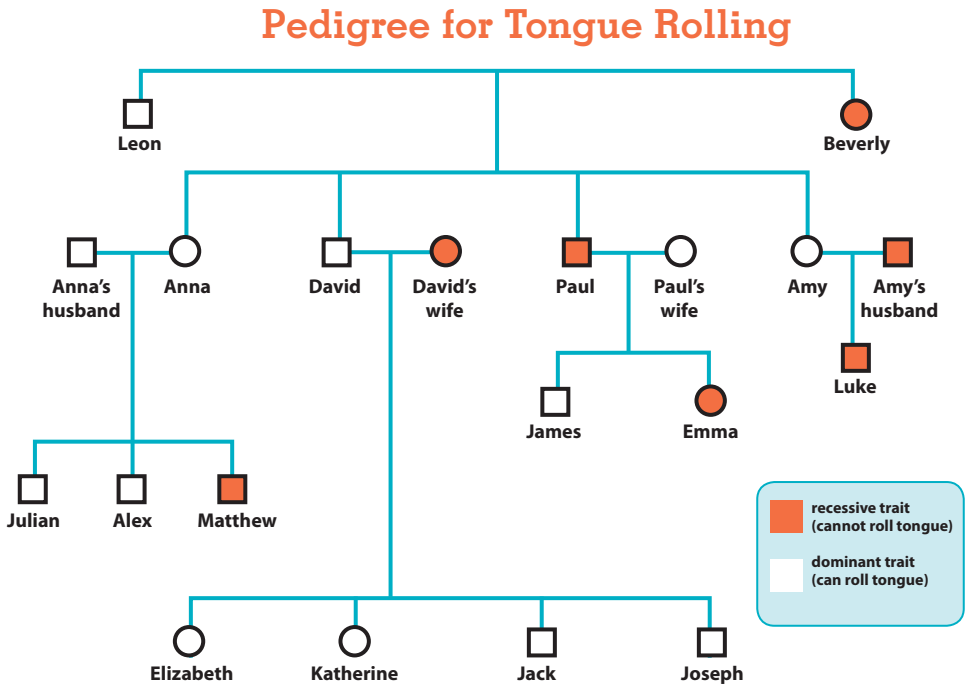
A pedigree shows how children's traits are related to their parents' traits. When a person accepts Christ as Savior, he becomes a child of God. His traits should show the world that God is his Father. [Bible Promise: D. Identified in Christ]

Complete *Tracing Traits* from the Teacher's Toolkit CD together or assign it for individual student practice.

Pedigrees

You probably have heard of pedigreed dogs or cats. The ancestors of these animals are recorded for many generations so that their traits can be traced. A **pedigree** is similar to a family tree, but instead of tracing people, it traces a particular trait. By using lines and symbols on a chart, we can demonstrate how dominant and recessive traits show up in each generation.

For example, the following pedigree traces the trait of tongue rolling through three generations. The circles on the pedigree indicate females, and the squares represent males. The horizontal lines signify marriage. Vertical lines connect the parents to their children. Shaded symbols show that the person cannot roll his tongue. Symbols that are not shaded show that the person possesses the dominant trait, tongue rolling. The family members who can roll their tongues have either two dominant genes or one dominant gene and one recessive gene for this trait.



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SCIENCE BACKGROUND

Carrier
A person who has a gene that is not expressed is called a *carrier*. In sex-linked traits, the mother is often a carrier.

Colorblindness
There are many forms of colorblindness. Colorblindness can affect both genders, although it occurs more frequently in males. People who are colorblind have usually learned coping skills that help them function, such as relying on the position of the stoplight instead of just color. They may use a specific label or mark to help them identify colors of clothing or crayons. Students who are colorblind may have difficulty reading text on colored backgrounds but find it easier to read the text on a white background when there is more contrast between the color of the text and the color of the background.

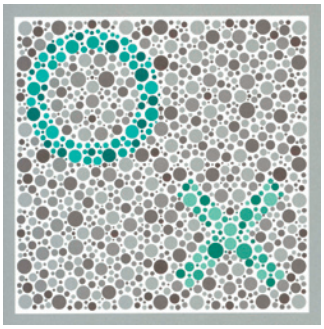
TEACHER HELPS

Use a Punnett square
To identify possible genotypes from a pedigree, it may be helpful to use Punnett squares.

From mother to son

Some traits are passed from mothers to sons. Although the daughters of the family may inherit a gene for that trait, the trait is usually visible in the sons only. Traits like these are called **sex-linked traits**.

One of the most common sex-linked traits is colorblindness. People who are colorblind usually have trouble distinguishing between red and green. In some instances, people with the trait for colorblindness also have difficulty with blue and yellow. In severe cases, people cannot distinguish any colors. These people see everything in shades of black and white.



Colorblindness test—People with normal color vision see two colored symbols, an X and an O, among the dots. People with an inherited color vision deficiency see only an X, only an O, or neither symbol. This sample is for demonstration only. Photo courtesy of Jay Neitz.

Another sex-linked trait is hemophilia (hee muh FIL ee uh), an illness that prevents a person's blood from clotting properly. Proteins in the blood that help to stop bleeding are either missing or not working properly. Falls and bumps often bring great danger by causing internal bleeding. The disease cannot be cured, but with proper medical care, people with hemophilia can live healthy lives.

SCIENCE & HISTORY

Queen Victoria, ruler of England from 1837 to 1901, was a carrier for hemophilia. One of her sons had hemophilia, and some of her daughters were carriers for the disease. As her daughters married, the trait spread to other European royal families. One of her best known descendants was the son of her grandaughter, the Empress Alexandra of Russia. Alexis Romanov, heir to the Russian throne, had hemophilia. He and his parents and sisters were murdered during the Russian revolution.

QUICK CHECK

1. Why do geneticists use Punnett squares?
2. Why are traits like hemophilia and colorblindness called sex-linked traits?

SCIENCE MISCONCEPTIONS

Kinds of blindness

Blindness and colorblindness are not the same. People with colorblindness are not blind. They just cannot see all colors.

Sex-linked traits

If desired, use a Punnett square to discuss sex-linked traits. Most people have 23 pairs of chromosomes that total 46 chromosomes. Each chromosome contains genetic information, such as hair color or eye color. One pair of chromosomes indicates whether the person is male or female. Females have two large X-shaped chromosomes and males have an X and a Y chromosome. Since the Y chromosome is smaller than the X chromosome, the X and Y chromosomes for males do not have genes that match up in pairs. As a result, males that carry a recessive gene on the X chromosome will show that trait because there is no possibility of having a dominant gene to cancel it. Traits like these are called sex-linked traits. These traits are passed from mothers to sons. Although the daughters of the family may inherit a gene for that trait, the trait is usually visible in the sons only.

Discussion

What are sex-linked traits? traits that are passed from mothers to sons

What are two of these traits? colorblindness and hemophilia

Which two colors do most colorblind people have trouble distinguishing? red and green

What are some things that might be difficult for someone who is colorblind? Possible answers: matching clothes, coloring a picture, or driving

What is hemophilia? an illness that prevents a person's blood from clotting properly

Is hemophilia a contagious disease? no **Explain.** A person cannot catch it from someone. It is inherited.

Discuss *Science & History*.

Which sex-linked trait was passed through Queen Victoria's family? hemophilia

Some of Queen Victoria's daughters were described as carriers for the disease of hemophilia. What does the term *carrier* mean? The daughters had the gene for hemophilia but did not suffer from the disease.

Medical questionnaires often ask for medical information about parents and grandparents. Why do you think doctors ask questions about parents and grandparents on a patient's questionnaire? Since some medical problems are hereditary, it would be helpful to know whether there are any family traits that might affect the patient.

Answers

1. Punnett squares show the genetic possibilities that could result for the offspring and the probability of a certain outcome.
2. These traits are passed from mothers to sons. Daughters do not usually inherit these traits, but they may be carriers of them.

Activity Manual

Reinforcement, page 216

Review, pages 217–18

These pages review Lessons 152 and 153.

Assessment

Quiz 13-B

The quiz may be given any time after completion of this lesson.

Objectives
- Use Punnett squares to predict genotypes
- Construct paper pets based on predicted genotypes

Materials
- See Student Text page
- *Parental Genotype Cards* (IA), reproduced and cut apart (enough for 2 cards per student)

Introduction

Why do puppies or kittens not look exactly like their parents? Since offspring receive genes from each parent, each puppy or kitten is a genetic mixture of both parents.

Today you will use genetic information of two parents to determine the possible genotypes of their offspring.

Teach for Understanding

Purpose for reading
The student should read all of the pages before beginning the activity.

Procedure
Distribute pairs of *Parental Genotype Cards*. Help the student determine which traits are dominant and which are recessive.

Demonstrate procedures as necessary. The student may need to complete a practice Punnett square before completing those relating to his pets.

ACTIVITY

Paper Pet Genetics

Process Skills
- Making and using models
- Inferring
- Interpreting data
- Communicating

Sometimes when a baby is born you will hear people comment on his heredity. They may say things like, "He has a nose just like his father's," or, "He's definitely got the Tucker ears." No baby will have all the traits of one parent. He will have traits from both parents.

As the child grows, more family traits become evident. He may be athletic like his mother and tall like his father. Maybe his hair will be curly like his grandfather's hair, but instead of being brown, it might be red like his grandmother's hair.

For this activity you will be given two genotypes to use as "parents" for your paper pet. Each parent will have genes for four traits. Based on the parental genotypes, you must construct the faces of three paper pets that could be the offspring of those "parents." Each paper pet must be unique, having its own genotype.

Materials
blue, green, yellow, and orange construction paper
compass or large circle pattern
centimeter ruler
scissors
glue
crayons or markers
parental genotype card
Activity Manual

Procedure
1. Look at the two parental genotypes provided by your teacher. Use the chart in your Activity Manual to determine whether each trait of your "parents" is dominant or recessive.
2. Begin with the genes for color. Prepare a Punnett square using the parental genotypes for color. Choose a color for your first offspring based on the results in your square.

TEACHER HELPS

Review vocabulary
Review and discuss the following terms as necessary.

genotype—the arrangement of genes in an organism; its genetic combination

phenotype—the physical appearance of an organism

Punnett square—a chart that shows the genetic possibilities of a certain trait that can result for the offspring of a specific set of parents

dominant gene—a gene that will always be expressed if it is present in an organism

recessive gene—a gene that will not be expressed in an organism if any dominant genes are present

Cards
Each parental genotype card represents one parent.

Order of tasks
You may choose to have the student complete all four Punnett squares before handling the other materials.

Use of color
The student may find it helpful to color the pictures on his cards to reflect the phenotypes.

3. Complete a Punnett square for face shape. Cut the shape of the face based on the results in your square. The face should be at least 10 cm wide.
4. Complete a Punnett square for eye shape. Use yellow paper and cut the shape of the eyes based on the results in your square.
5. Complete a Punnett square for ear shape. Use orange paper and cut the shape of the ears based on the results in your square.
6. Draw any remaining facial details you like.
7. Use the Punnett squares you have completed to construct two more paper pet offspring. Remember that each paper pet must be different in some way.
8. Present your paper pets to the class. Be prepared to explain the traits you used.

Conclusions

- What would happen to the possible offspring if you added another trait?

Follow-up

- Choose a single trait and show the pedigree for it using your "parents" and offspring.
- Choose a "mate" for each offspring, and continue the pedigree for another generation.

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Look at the *Genetic Information* chart on Activity Manual page 219. Which face color is dominant? blue

Face color is represented with the letter B. How will we show whether face color is dominant? B **recessive?** b

Since Punnett squares show possible genetic outcomes, many different answers are possible. However, the choices of color and shape should be based on one of the outcomes shown in the Punnett square. The size of the paper pets will vary, depending on student preference.

The activity only requires the student to make the offspring, but if desired, the student could make the parents first before completing the offspring. Completed parents and offspring could be glued onto a large sheet of paper and displayed.

Allow students to show their paper pets to the class and explain why they chose specific traits for them.

Conclusions

In what ways do your pets resemble their parents?

Do any of your pets look exactly the same as pets from other parents? probably not **Why?** The genotypes of the parents are different.

Would there be greater or less variety in the offspring if you added another trait? greater

Use the questions in the Science Process Skills to discuss making and using models.

Activity Manual

Activity, pages 219–20

Assessment

Rubrics

Select the prepared rubric, or design a rubric to include your chosen criteria.

SCIENCE PROCESS SKILLS

Making and using models

Scientists use models to teach concepts about things that are too large or too small to be seen easily.

How are models used in this activity? Possible answer: Each pet shows how dominant and recessive traits show up in offspring.

Are your pets accurate models? not really **Why?** Possible answers: Few traits are controlled by only a single gene. Real organisms have more than four genes.

Lesson 155

Student Text pages 326–29
Activity Manual page 221

Objectives
- Identify and discuss some common genetic diseases and disorders
- Explain why genetic diseases are not easy to cure
- Name examples of genetic engineering

Materials
- road map

Vocabulary
sickle cell anemia
cystic fibrosis
Down syndrome
genetic engineering

Introduction
Display the road map.

Why do we use maps? Possible answer: to find the location of a place

When scientists figure out the DNA pattern of an organism, the pattern is called a DNA map. Why do you think it is called a map? Possible answer: The DNA map shows where the genes in the DNA are located.

A DNA map may be used to identify individual organisms, but in this lesson we will discover other ways DNA mapping is used.

Teach for Understanding
Purpose for reading
How are genetic diseases different from contagious diseases?

What is genetic engineering?

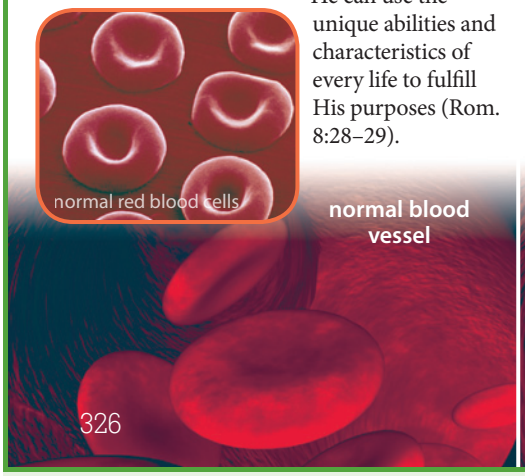
Discussion
What are some genetic diseases? Possible answers: sickle cell anemia, cystic fibrosis, Down syndrome

Why are these diseases called genetic diseases? They are inherited. They are not contagious diseases.

Genetic Disorders and Diseases

Some diseases, such as sickle cell anemia and cystic fibrosis, are inherited. These diseases are not contagious, so they cannot be spread from person to person. Instead, they are genetically passed from parent to child. Sometimes the gene that causes the disorder or disease is recessive. That means that in order for a child to inherit the disease, he must receive a recessive gene from each parent. However, a single dominant gene can also cause some genetic disorders. Scientists have identified the genes that cause many of these inherited diseases. Although much research has been done, many of these diseases have no known cure.

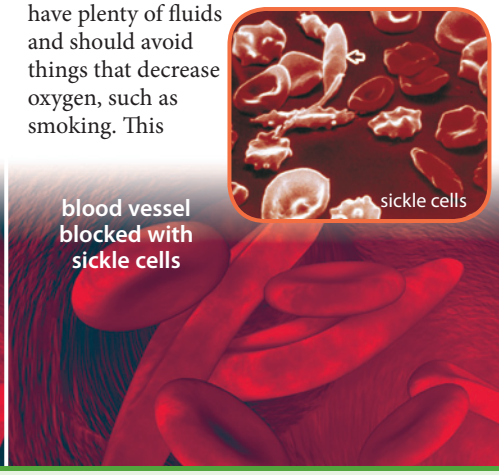
It is important to remember that disorders and diseases, including genetic ones, were not part of God's perfect creation. It was only after Adam's sin that death and suffering entered the world. However, genetic diseases are not mistakes. They are part of God's plan. He can use the unique abilities and characteristics of every life to fulfill His purposes (Rom. 8:28–29).



Sickle cell anemia

All people have both red and white blood cells. Red blood cells pick up oxygen from the lungs and carry it throughout the body. Normal red blood cells are round and flexible. They can bend and move easily through narrow blood vessels in the body. A person who has **sickle cell anemia** has some red blood cells that are hard and curved, like a farmer's sickle. These sickle-shaped blood cells can get stuck in the body's blood vessels. When blood vessels are blocked, oxygen cannot get to all parts of the body. This causes pain in the place where the blood vessel is blocked. It also may cause other health problems if the blood vessels remain blocked for too long.

Sickle cells are very fragile and can break apart easily. This causes the person to have *anemia*, or not enough red blood cells. Without enough red blood cells, a person's body does not get the oxygen it needs. The person often feels tired and gets infections easily. A person with sickle cell anemia needs to have plenty of fluids and should avoid things that decrease oxygen, such as smoking. This



SCIENCE BACKGROUND

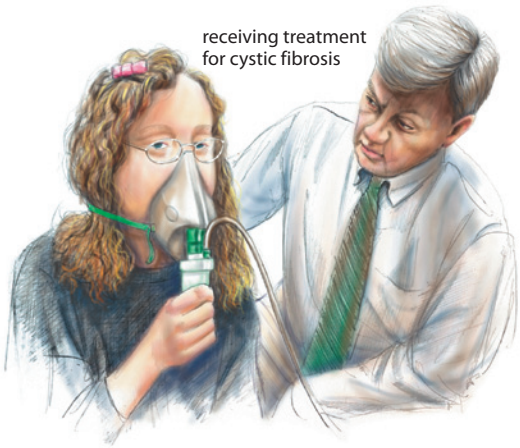
Sickle cell anemia
The part of the red blood cell that picks up oxygen and moves it throughout the body is the hemoglobin molecule. When sickle cell anemia is present, the hemoglobin molecules harden into rods and clump together. This makes the blood cells sickle shaped.

The only known cure for sickle cell anemia is a bone marrow transplant. However, usually only a brother or sister who does not have the disease is a close enough match to donate bone marrow. The surgery can also add complications with other medicines or increase the risk of other health problems.

TEACHER HELPS

Encourage kindness
Genetic diseases are not contagious. It is important to be kind and courteous toward everyone, including those who have genetic disorders or diseases. Be sensitive to students who may have genetic diseases. Some students may wish to share information about their diseases, but others may prefer that the rest of the class not know about their situations.

disease is most often found in people of African descent and in people from countries around the Mediterranean Sea. Blood tests can determine whether or not a person has inherited this disease.


receiving treatment for cystic fibrosis

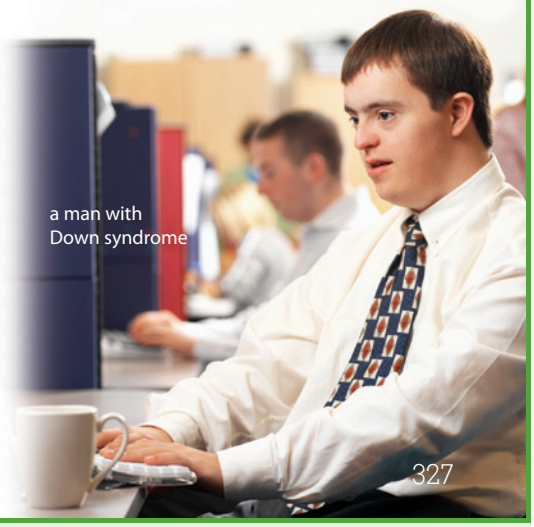
Cystic fibrosis

Cystic fibrosis (SIS-tic fye-BROH-sis) is a genetic disease that affects the lungs and digestive system. It is found primarily in people of European descent. A person with cystic fibrosis has mucus that is thicker than normal. This thick mucus clogs the lungs and air passages, increasing the chances of infection. Someone who has cystic fibrosis may cough often and tire quickly.

This disease can also affect the digestive system. It prevents food from being fully digested, so the body does not receive enough nutrients. People with cystic fibrosis often take medicines with their meals to help their bodies absorb more nutrients. No cure for this disease has been found, but new treatments and medicines help people with cystic fibrosis live longer, healthier lives.

Down syndrome

A person who has the genetic disorder **Down syndrome** often has an extra chromosome. Most people receive 23 chromosomes from each parent—46 in all. Sometimes, though, one of the chromosomes makes an extra copy of itself, giving the person 47 chromosomes. This extra chromosome may cause developmental disabilities, such as delayed motor and language skills. People with Down syndrome do not all show the same symptoms, but many have hearing and vision problems, learning disabilities, or heart problems. With early training, many people with Down syndrome live productive lives.


a man with Down syndrome

Discussion

Were disorders and diseases part of God's perfect creation? no **What caused them to become a part of our world?** Adam's sin brought death and suffering into the world.

News stories about people with genetic diseases often evoke our emotions, causing us to feel sad or determined to help find a cure. Are genetic diseases mistakes? no

Remind the student that God does not make mistakes. He has planned every detail of each person's life and given each of us exactly the abilities and characteristics needed to fulfill His purpose for our lives. Read and discuss Romans 8:28–29; 2 Peter 1:3; Psalm 139:14–16; and Jeremiah 1:5 as time allows.

What is different about the red blood cells of a person with sickle cell anemia? Some of the red blood cells are hard and curved like sickles instead of being round and flexible.

Why does this sickle shape cause problems? The blood cells can get stuck in the body's blood vessels and prevent oxygen from getting to all parts of the body.

What happens when a person's body does not have enough red blood cells? Possible answers: The person has anemia. They feel tired and get infections easily.

Which two parts of the body are most often affected by cystic fibrosis? the lungs and the digestive system

Recessive genes cause both cystic fibrosis and sickle cell anemia. In order for a child to inherit one of these diseases, would he need to inherit a recessive gene from one or both parents? both **Why?** Recessive genes can be expressed only if no dominant gene is present for that trait.

How many chromosomes do most people have? 46

How many chromosomes might a person with Down syndrome have? 47

What kinds of difficulties might a person with Down syndrome have? Possible answers: delayed motor and language skills; vision and hearing problems; learning disabilities; heart problems

SCIENCE BACKGROUND

Down syndrome
Down syndrome is not always caused by an extra chromosome. Some rare cases of Down syndrome are caused by other chromosomal irregularities. Some people with Down syndrome may have some cells with the normal count of 46 chromosomes and other cells that have 47 chromosomes.

Huntington's disease
Huntington's disease is another genetic disorder that attacks the nervous system and the brain. It gradually takes away a person's ability to walk, talk, think, and reason. Most of the time, the disease does not begin until adulthood. Unlike many genetic disorders, Huntington's disease is caused by one dominant gene.

WRITING

Naming diseases
Many genetic diseases and disorders are named for the doctor or scientist who first diagnosed or identified the disease. The student could research Down syndrome, Huntington's disease, or another disease to determine how the disease got its name.

Discussion

How many genetic diseases have been identified and named? over 5,000

Explain why doctors and scientists cannot quickly fix a gene or add in a missing gene to cure genetic diseases. Answers will vary, but should include the idea that the human body has thousands of genes of various sizes. Identifying the gene that is not working correctly is difficult, as is inserting a gene into exactly the right place on the chromosome.

What is involved in genetic engineering? Genetic engineering involves changing a gene or moving some of one organism's genes into another organism.

What are some reasons for genetic engineering? Possible answers: to produce desired results from animals and plants (providing food, increasing resistance to disease, being able to better tolerate heat and drought); to have a plant produce its own insecticide; to make food more nutritious

How are some genetic diseases treated? through gene therapy

What can be dangerous about gene therapy? Possible answer: If a gene gets put back in the wrong place, new problems could happen.

What are some other ways that genetic research has helped people with genetic diseases? Possible answers: bacteria producing insulin for diabetics; new treatments for hemophilia and burn patients

Discuss *Fantastic Facts*.

Why did scientists make a fly that had so many eyes? They wanted to find out which genes controlled the development of certain body parts. They also wanted to find ways to help solve human visual problems.

Man's natural curiosity is a gift from God. That curiosity often results in new ideas that help others.

Besides doctors, what other professionals might use genetic information? Accept any reasonable answers. Possible answers are farmers, animal breeders, and horticulturists.

How would animals that are able to resist disease or are better able to tolerate heat and drought be beneficial to man? They can live and provide food and resources for people in areas where food is scarce.

Genetic Engineering

More than 5,000 genetic disorders and diseases have been identified and named. Doctors and scientists know that these diseases occur when certain genes are not working correctly or are missing. However, a scientist cannot quickly fix a gene or add a missing gene. Before a scientist can change a gene, he has to find the one that is not working correctly. The DNA packed inside a person's chromosomes is divided into many different genes. Scientists estimate that there are 30,000–40,000 genes of various sizes. Remember that DNA is made up of a sequence of four bases. Some genes have fewer than 10,000 base pairs, while others have more than two million.

Genetic engineering involves changing a gene or moving some of one organism's genes into another organism. Changing a gene can be risky. With so many genes of different sizes, it is hard to get the gene back into exactly the right place on the chromosome. Putting a gene into the wrong place can result in many new problems. However, genetic engineering is done for a variety of reasons.

One type of genetic engineering uses gene therapy to treat some genetic diseases. Doctors can substitute a healthy gene for one that is not working properly. Even though gene therapy does not cure the disease, it has helped many cystic fibrosis patients. Also, scientists have discovered a way to add a gene to bacteria that makes the

bacteria produce insulin for diabetics. Other treatments developed as a result of genetic research benefit people suffering from hemophilia or burns.

Some scientists are trying to find ways to manipulate, or change, the genes of certain animals to produce desired results. For example, genetically engineered fish grow large in a short period of time to provide more food for people. Scientists are also looking for ways to produce livestock that are more resistant to disease or better able to tolerate heat and drought. These animals would then be able to live and provide food for people in areas where food is scarce.

FANTASTIC FACTS

Some scientists wanted to know which genes controlled the formation of certain body parts, such as legs, livers, and eyes. They experimented with fruit flies and found a gene that controls eye development. Using this gene, they created a fly that had fourteen eyes on its wings, antennae, and legs. They hope to use this discovery to help solve human vision problems.

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SCIENCE BACKGROUND

Genetic engineering
Genetic engineering is a topic that can generate strong feelings and pose ethical questions. Some feel that new discoveries will help end world hunger and will help people live healthier lives. Others are concerned about the long-term safety and results of these new discoveries. Concerns also arise over the access and use of the genetic records of individuals.

TECHNOLOGY

Glowing fish
One of the most recent genetic engineering projects added a fluorescence gene to zebra fish. These fluorescent fish have been used to help detect pollutants and are also sold as aquarium fish.

Need for discernment
Any new technology or discovery will have positive and negative aspects. Genetic engineering is an example of this. Wise discernment and judgment are needed to determine if the benefits of using the technology outweigh the potential problems.

Other scientists have studied plants. Some scientists try to find ways to change the genes of a plant so that the plant will require less water. These plants, then, could be grown during droughts. Others have invented a cotton plant that produces its own insecticide. To do this, scientists inserted a gene that makes the plant produce poisons to kill the insect pests. Farmers who plant this type of cotton can use fewer chemical pesticides on their crops.

Sometimes the genes added by scientists are from plants that are very different from each other. For instance, by adding genes from bacteria and a daffodil to rice, scientists can make a type of rice that helps the human body produce more vitamin A. Scientists even found that adding a wheat gene to corn made corn plants taste bad to the insects that would usually eat them.

Genetic engineering has the potential to be both beneficial and harmful, depending on how it is used. Some people think that money for genetic engineering is often spent on unnecessary research. Others are concerned that new changes might result in unexpected problems. For example, plants that grow their own pesticides might also kill some beneficial insects. There is also concern that genetically modified plants and animals that are used as food for humans could cause allergic reactions or other health risks.

These concerns are valid. A Christian has the responsibility to use his knowledge wisely in ways that glorify God. Understanding genetics allows us to appreciate the complexity of God's creation.

QUICK CHECK

1. How are genetic diseases different from other diseases?
2. What are some examples of genetic engineering?

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Discussion

Why would it be useful for a plant to need less water? The plant could be grown during droughts and possibly provide food for either animals or humans.

What would be another benefit of a plant's needing less water? Possible answer: It could be grown in dry places, such as deserts, that do not receive much water.

How did scientists get a cotton plant to grow its own insecticide? They inserted a gene that made the plant produce poisons that would kill insect pests.

How would this be beneficial? Farmers who plant this type of cotton can use fewer chemical pesticides.

What was added to a type of rice that would help the human body produce more vitamin A? genes from bacteria and from a daffodil

Why did scientists add a wheat gene to some corn plants? to make the corn taste bad to the insects that would normally eat and destroy it

What are some concerns that some people have about genetic engineering? Possible answers: money being spent on unnecessary research; unexpected problems

Discuss how some people debate whether some of the different uses for genetic engineering are wise uses of God's resources. Challenge the student to form a position based on a Christian worldview.

Answers

1. Genetic diseases are inherited from one's parents. They are not contagious diseases.
2. Possible answers: to treat genetic diseases; to produce desired results from animals and plants (providing food, increasing resistance to disease, being able to better tolerate heat and drought), to have a plant produce its own insecticide; to make food more nutritious

SCIENCE BACKGROUND

Testing on animals

Many people oppose planting test crops and testing new things on animals. However, new discoveries cannot be considered safe and beneficial without testing of some sort. Things need to be tested to determine if they are safe to use, but often the public does not want to test them until they are proven safe.

Activity Manual

Review, page 221

This page reviews Lesson 155.

Assessment

Quiz 13-C

This quiz may be given any time after completion of this lesson.

Objectives

- Explain why thale cress is considered a model plant
- Describe how thale cress has been used in genetic engineering
- Recognize that scientists use the same basic methods that Mendel used

Introduction

Plants cannot communicate in the same ways that humans do. How can a gardener determine the health of his plants? Possible answers: by checking the condition of the leaves and stems; checking whether or not the plant bears fruit or produces seeds; checking the roots; or checking the condition of the soil

Genetic engineering has provided other ways for scientists to monitor the health of plants. Today we will discover how a common little weed is very useful to scientists.

Teach for Understanding

Purpose for reading

Why is thale cress useful for genetic research?

What was added to thale cress to cause the plant to glow?

Discussion

What common weed have scientists often experimented with? *Arabidopsis thaliana*, or thale cress

Why is this plant considered a model plant? Possible answers: Thale cress is similar to many other plants, has a simple DNA structure, is small, matures quickly, and produces many seeds.

How many genes does a thale cress plant have? 25,000

These genes are made up of millions of DNA base pairs. Why do you think scientists consider this plant to have a small amount of DNA? Other organisms have many more genes and base pairs.

Scientists have added different genes to thale cress. What did the firefly gene cause the plants to do? glow

TECHNOLOGY

A Useful Weed

Weeds are not usually considered useful to humans. They are often pulled up and removed from gardens. However, one small weed from the mustard plant family has been very useful to scientists. Genetics researchers call *Arabidopsis thaliana*, or thale cress, the "model plant" because it is very similar to many other plants. It has a simple DNA structure, matures quickly, and produces many seeds. Just by studying this simple weed, scientists have learned many things about how plants function and develop.

In the year 2000, scientists were able to map the plant's genome (JEE nohm), or genetic information. Thale cress has about 25,000 genes and approximately 140 million base pairs of DNA. Because scientists know exactly what DNA the weed has, they can insert special marker genes from other organisms into its genetic structure. Scientists have discovered that adding some of these genes can make the plants glow under certain conditions.

Scientists altered some thale cress plants so that they glow when they are unhealthy. The scientists inserted a firefly's gene where the plant's defensive responses genes were located. Then they infected a group of genetically altered plants with a virus and observed the results. The plants that glowed the least were cross-pollinated with each other to produce plants that have a higher resistance to disease.

Scientists have also inserted a gene from a firefly into thale cress DNA to make the plant glow when it is cold. The harder it was for the plant to grow because of the cold, the more it glowed. Scientists took the plants that glowed the least and cross-pollinated them to produce a plant that resists the cold. Because scientists have mapped

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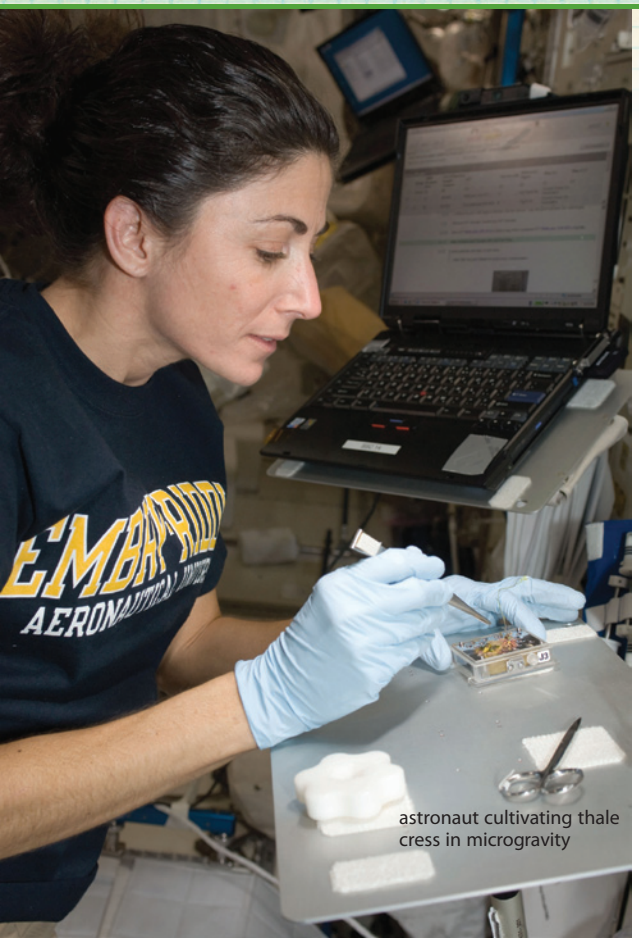
SCIENCE BACKGROUND

Plants in space

Arabidopsis thaliana plants have also been in space. Thirty-six plants were sent to space aboard the space shuttle *Columbia* in 1999. These plants were genetically engineered with a gene that would cause a strain on any plant that experienced stress. The scientists, a team of researchers from the University of Florida, used the plants to test stresses such as carbon dioxide levels, temperature, and extreme light.

Another use for thale cress

For a while, researchers tried to find ways to use modified thale cress plants to detect land mines. The plant was meant to turn red when its roots were exposed to nitrous oxide. Initially, trials were successful in controlled environments, but when tested, the plants did not perform as expected and the company funding the tests decided the expense was too great to continue the research.



astronaut cultivating thale cress in microgravity

the whole genome, they can now isolate the cold-resistant gene and put it into other plants.

Other studies have been done to see how cold weather affects plants. Recently researchers found that a gene in thale cress, called the Spatula gene, could help plants adjust to cooler conditions. This gene causes plants to grow less when the weather is cooler. Scientists discovered that plants with the Spatula gene removed or limited had more leaf growth than normal during cooler temperatures. Scientists hope to use this knowledge to extend the growing season of other plants.

Scientists have also added genes from thale cress to other plants. Thale cress has genes that allow the plant to tolerate higher salt levels than other plants can. Plants take up water through their roots, and the water goes to all parts of the plant. If the water is very salty, the excess salt can harm the leaves of plants. These thale cress genes direct the plants to remove the salt from the water before it can harm them. Scientists have added these genes to rice and tomatoes as they look for ways to enable plants to grow in a wide variety of soils.

These are not the only things that scientists have learned from thale cress. Research has been done to see how these plants respond to stresses in space, such as changes in light and carbon dioxide. Among other things, scientists have also learned which gene controls how the plants develop flowers and how plant embryos develop. A little common weed has many uses.

DIRECT AN ACTIVITY

Controlling growing variables

Materials: 6 similar plants (such as petunias or marigolds), 6 pots, soil, sand, gravel

Plant 4 plants in pots with soil. Label the pots as dry, moist, cold, and dark. Plant another plant in sand and the last plant in gravel. Label these pots as sand or gravel.

Place the plants labeled *sand*, *gravel*, *dry*, and *moist* in a warm, bright location. Place the plant labeled *cold* in a refrigerator and the plant labeled *dark* in a cupboard.

Water all the plants except the one labeled *dry*. Keep these plants moist throughout the activity. Observe the plants for 2–4 weeks. Record observations. Compare results.

Which plant or plants thrived?

Which conditions seem the most ideal for that type of plant to grow?

Discussion

What were two reasons that the plants glowed? They were either unhealthy or cold.

Why did scientists want to identify the unhealthy plants? so they could cross pollinate the healthier ones to produce plants with a higher resistance to disease

What was the purpose for wanting plants to glow when it was cold? to identify plants that could be crossed to produce a plant that resists cold temperatures

How is what scientists do to produce cold- or disease-resistant plants similar to Mendel's experiments with pea plants? Possible answer: Mendel cross-pollinated plants that had certain traits in order to produce plants with the traits that he wanted. Today's scientists also cross-pollinate plants to produce plants with the traits that they want.

How is their experimentation different? Possible answer: The marker genes cause the plants to glow, so today's scientists can determine quickly whether or not the plant possesses the desired traits. Mendel had to continue cross-pollinating throughout several generations before he could be certain that the plants had the traits he wanted.

What are some other conditions that researchers are studying with thale cress? adding a gene to help plants adjust to cooler conditions, helping plants to tolerate higher salt levels

Why is it beneficial to some plants to be able to grow more during cool temperatures? Their growing season would be longer; the plant could get larger faster.

How do the genes added from thale cress benefit a plant growing in salty water? The genes tell the plant to remove the salt from the water before it harms their leaves.

Thale cress is a common little weed that has many uses. If you had the ability to do genetic engineering, what would you experiment with? What precautions would you take? Answers will vary.

Activity Manual

Technology, page 222

Objectives
- Recall concepts and terms from Chapter 13
- Apply knowledge to everyday situations

Introduction
Material for the Chapter 13 Test will be taken from Student Text page 332 and Activity Manual pages 211–12, 217–18, 221, and 223–24. You may review any or all of the material during the lesson. Questions similar to Solve the Problem or the ones in Thinking It Through, Activity Manual pages 223–24, may appear on the test.

You may choose to review Chapter 13 by playing "Sketch a Face" or a game from the Game Bank on the Teacher's Toolkit CD.

Teach for Understanding
Diving Deep into Science
Information on this page reflects the vocabulary and concepts the student should know for the test.

Solve the Problem
In order to solve the problem, the student must apply material that he has learned. The student should attempt the problem independently. The answer for this Solve the Problem is based on the material on Student Text pages 318–19. Answers will vary and may be discussed.

Activity Manual
Review, pages 223–24
These pages require written responses to application questions.

Lesson 158

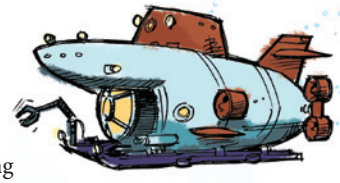
Objective
- Demonstrate knowledge of concepts taught in Chapter 13

Assessment
Tests, Chapter 13

DIVING DEEP INTO SCIENCE

Words to Know
trait
gene
DNA
heredity
purebred plant
hybrid
dominant trait
recessive trait
phenotype
genotype
codominant
incomplete dominance
pedigree
genetic engineering

Key Ideas
Relationship between chromosomes, DNA, and genes
Examples of inherited traits
Contributions of James Watson and Francis Crick
Structure of a DNA molecule
Contributions of Gregor Mendel
Mendel's experiments with peas
Differences between dominant and recessive genes
Using Punnett squares
How to read a pedigree
Examples of sex-linked traits
Characteristics and examples of genetic diseases
Advantages and disadvantages of genetic engineering



Solve the Problem
Elena really enjoys the pink snapdragons in her yard. One year she decided to try to pollinate two of the plants herself to get the plants to produce seeds. She saved the seeds and planted them the next year. What a disappointment! Instead of all pink snapdragons, she had red, white, and pink flowers. Can you think of a reason Elena did not get all pink snapdragons?

Pink snapdragons are hybrids caused by incomplete dominance. The traits for red flowers and white flowers are still there but are not expressed. When pink snapdragons are cross-pollinated with other pink hybrid snapdragons, the traits for red flowers and white flowers are expressed as well as the traits for pink flowers.

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Review Game
Sketch a Face
Prepare a set of 20 gene cards. Make 2 cards for each of the following dominant traits: square face, round eyes, triangle ears, round nose, and curved-line mouth. Make 2 cards for each of the following recessive traits: round face, oval eyes, semicircle ears, square nose, and straight-line mouth. You may choose to use different colored inks to label the dominant and recessive gene cards or to display a chart that identifies the dominant and recessive traits.

Divide the class into two teams. Shuffle the cards and place them face down. When a student answers a review question correctly, he draws one of the gene cards. Whenever a team has two gene cards for the same trait, the team should determine the phenotype of that facial feature and draw it on the board. If at least one of the cards is a dominant gene, then the facial feature should be the dominant trait. After a team member has drawn that facial feature, place the gene cards in a discard pile. Any other gene cards drawn by that team for the same trait should also be placed in the discard pile. Shuffle the discard pile and add those cards back to the other cards as needed. The first team to draw a complete face wins.

Teacher Notes