AmplifyScience

Traits and Reproduction:

The Genetics of Spider Silk

Investigation Notebook with Article Compilation

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Developed by the Learning Design Group at the University of California, Berkeley's Lawrence Hall of Science.

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Traits and Reproduction: The Genetics of Spider Silk
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Traits and Reproduction:

The Genetics of Spider Silk

Investigation Notebook

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Safety Guidelines for Science Investigations

1. **Follow instructions.** Listen carefully to your teacher's instructions. Ask questions if you don't know what to do.

2. **Don't taste things.** No tasting anything or putting it near your mouth unless your teacher says it is safe to do so.

3. **Smell substances like a chemist.** When you smell a substance, don't put your nose near it. Instead, gently move the air from above the substance to your nose. This is how chemists smell substances.

4. **Protect your eyes.** Wear safety goggles if something wet could splash into your eyes, if powder or dust might get in your eyes, or if something sharp could fly into your eyes.

5. **Protect your hands.** Wear gloves if you are working with materials or chemicals that could irritate your skin.

6. **Keep your hands away from your face.** Do not touch your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals.

7. **Tell your teacher if you have allergies.** This will keep you safe and comfortable during science class.

8. **Be calm and careful.** Move carefully and slowly around the classroom. Save your outdoor behavior for recess.

9. **Report all spills, accidents, and injuries to your teacher.** Tell your teacher if something spills, if there is an accident, or if someone gets injured.

10. **Avoid anything that could cause a burn.** Allow your teacher to work with hot water or hot equipment.

11. **Wash your hands after class.** Make sure to wash your hands thoroughly with soap and water after handling plants, animals, or science materials.

Name: _____ Date: _____

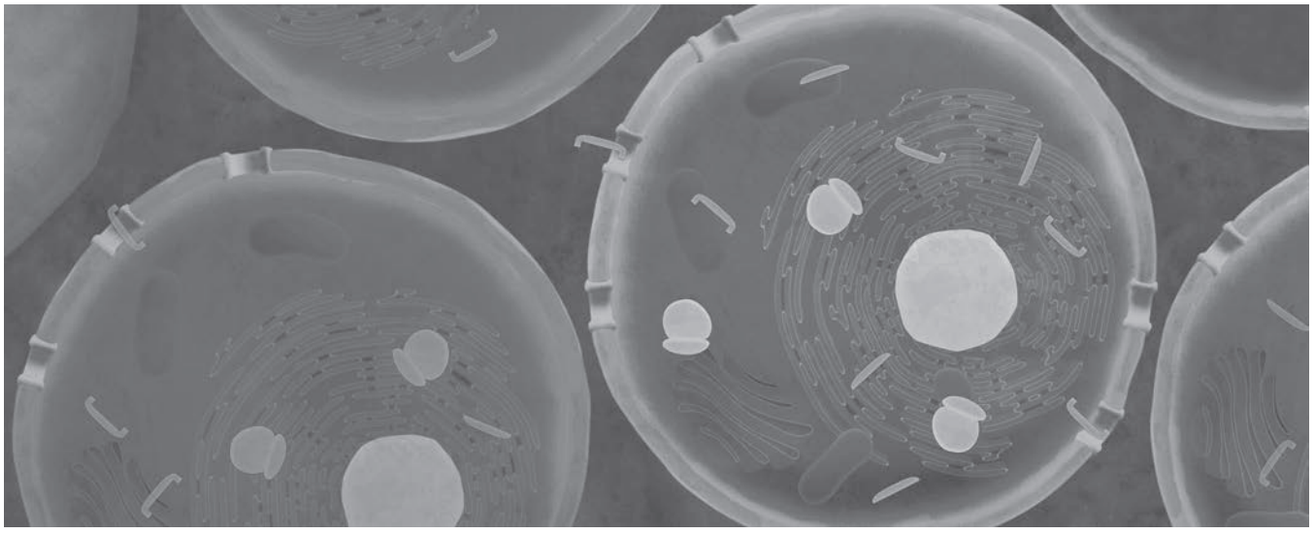
Traits and Reproduction: The Genetics of Spider Silk
Unit Overview

As student genetic researchers at Bay Medical Company, you will be investigating the genetics of spiders. Specifically, you will look at the Darwin's bark spider. This breed has incredibly strong silk, which can be used for medical applications such as creating artificial tendons. However, some Darwin's bark spiders do not produce the right kind of silk. Your job is to determine why. You will use the *Traits and Reproduction* Simulation, physical models, and science articles to investigate why traits can vary even between spiders within the same family. You will also apply what you learn about traits to humans, investigating variation in traits for running ability among members of one family. By the end of the unit, you will know much more about why living things are both similar to and different from each other.

Name: _____ Date: _____

Chapter 1: Exploring Variation in Spider Silk
Chapter Overview

In this chapter, you will begin your role as student researchers, assisting with cutting-edge research about spider silk. The genetic researchers at Bay Medical Company have been studying the Darwin's bark spider, a newly discovered spider species. In particular, they are looking at the spiders' silk. They need your help in investigating why there is variation in the Darwin's bark spiders' silk flexibility. To investigate this question, you will first need to study what determines an organism's traits.



Name: _____ Date: _____

Lesson 1.2: Introducing Spider Silk Research

Bay Medical Company has called you to join their team of student genetic researchers. Their goal is to develop medical uses for silk from the Darwin's bark spider, a newly discovered spider species. In this lesson, you will examine a family tree of Darwin's bark spiders and consider why spiders in the same family can have different traits for silk flexibility. You will then begin exploring the *Traits and Reproduction* Simulation, a tool that will help you learn more about what determines traits in organisms.

Unit Question

- Why do traits vary, and why do they vary even between parents and offspring and among siblings?

Chapter 1 Question

- Why do traits for silk flexibility vary within this family of Darwin's bark spiders?

Vocabulary

- feature
- trait
- variation

Digital Tools

- *Traits and Reproduction* Simulation

Name: _____ Date: _____

Warm-Up

Read each of the statements in the **Anticipation Guide** below. If you agree with the statement, write "agree." If you disagree with the statement, write "disagree." Then, explain your choice for the first statement.

_____ 1. Each person in a family has the same traits. There are no differences in traits between parents and offspring or among siblings.

_____ 2. Traits, such as your hair or eye color, are determined by the proteins made by cells in your body.

_____ 3. There are two genes that decide each of your traits, and those two genes are always exactly alike.

_____ 4. An offspring cannot have a trait if neither of its parents have it.

_____ 5. All traits are determined by the experiences an organism has or the environment it lives in. For example, you will have the trait of being a strong swimmer if you swim a lot and live in or near the water.

Explain why you agree or disagree with the first statement: Each person in a family has the same traits. There are no differences in traits between parents and offspring or among siblings.

_____

_____

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Name: _____ Date: _____

Introducing Darwin's Bark Spiders

To: Student Researchers
From: Dr. Ada Sattari, Lead Scientist at Bay Medical Company
Subject: Spider Silk Research

BAY MEDICAL COMPANY

I lead the Spider Silk Research Team, a group of genetic researchers. We are working on medical treatments that use silk from the Darwin's bark spider, a newly discovered spider species. These spiders produce very strong silk. We want to see if their silk can be used to make tendons and stitches for humans. For this to work, the silk must be both strong and flexible. A medium level of flexibility is optimum.

Unfortunately, we have discovered that not all Darwin's bark spiders are the same. Some spiders make more flexible silk than others, even spiders in the same family. As student researchers, you will work to explain why traits such as silk flexibility can vary within a family of Darwin's bark spiders.

Name: _____ Date: _____

Introducing Darwin's Bark Spiders (continued)

Darwin's Bark Spider Family Tree

Parent 1: Male
low silk flexibility

Parent 2: Female
medium silk flexibility

Offspring A: Male
low silk flexibility

Offspring B: Female
medium silk flexibility

Offspring C: Male
low silk flexibility

Offspring D: Female
high silk flexibility

Name: _____ Date: _____

Exploring in the Simulation

Part 1

1. Launch the *Traits and Reproduction* Simulation.
2. With a partner, explore and make observations about how the Sim works.

Part 2

1. Working with your partner, compare the spiders' traits for a particular feature.
2. Select the Random Spiders mode via the Global Navigation Menu on the top left corner of your screen.
3. Select a feature (such as silk flexibility or size) from the Feature menu bar.
4. Examine each spider's traits for that particular feature. Then, compare your spiders with your partner's. Do the spiders have different traits for this feature?
5. Select a spider and press on the spider to view its cell. (**Note:** Your spider's trait should not be the same as your partner's.)
6. Compare the cell for the spider you selected with your partner's. What differences do you notice inside the two spiders' cells?

Name: _____ Date: _____

Homework: Revisiting the Anticipation Guide

Review your original response to this statement from the Anticipation Guide on page 6:

Each person in a family has the same traits. There are no differences in traits between parents and offspring or among siblings.

Do you agree or disagree with this statement now? What evidence supports your ideas about the statement?

_____

_____

_____

_____

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_____

Name: _____ Date: _____

Lesson 1.3: Surprising Spider Silk

In order to understand why traits vary, you need to determine why organisms have the traits that they do. In this lesson, you will begin exploring the Investigation Question: *What determines an organism's traits at the molecular scale?* To begin researching this question, you will read about different types of spider silk. You may be surprised to learn that different spiders make different silks, which serve a variety of purposes. After this, you will create models of spider silk strands using physical materials to further examine what determines an organism's traits.

Unit Question

- Why do traits vary, and why do they vary even between parents and offspring and among siblings?

Chapter 1 Question

- Why do traits for silk flexibility vary within this family of Darwin's bark spiders?

Vocabulary

- feature
- function
- protein molecule
- structure
- trait

Name: _____ Date: _____

Warm-Up

You are about to watch the second part of a documentary about how scientists study spider silk. Before watching this video, record any questions you may have.

_____

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_____

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Name: _____ Date: _____

Reading *Surprising Spider Silk*

1. Look at the *Surprising Spider Silk* article set.
2. With your partner, discuss which article you would like to read. You should both select the same one.
3. Read and annotate your selection from the article set, *Surprising Spider Silk*.
4. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
5. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
6. Select the article you read from the list below.

    - ☐ "Spider Silk for Gliding Through the Air"
    - ☐ "Spider Silk for Spitting at Prey"
    - ☐ "Spider Silk for Living Underwater"
    - ☐ "Spider Silk for Super-Sized Webs"

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Modeling Protein Molecules

Part 1: Comparing Silk Protein Molecules

1. Sketch the structure (shape) of the three models of protein molecules.

protein 1	protein 2	protein 3

2. Each protein molecule connects to more protein molecules to form a silk strand. Which type of protein molecule do you think will form the most flexible strand? Explain your answer below.

_____

_____

_____

Part 2: Building and Comparing Silk Strands

1. Build two additional models of each protein molecule so that you have three protein molecules of each type.
2. For each type of protein, try to connect the protein molecules to form silk strands. You must use all of a molecule's connectors to form a strand.
3. Complete the table below to record your observations. In the middle column, indicate if each type of protein molecule could connect to form a silk strand.
4. In the last column, sketch and describe each silk strand.

Proteins in silk strand	Did the proteins connect to form a strand?	Sketch the structure of the silk strand below.
protein 1		
protein 2		
protein 3		

Name: _____ Date: _____

Modeling Protein Molecules (continued)

Compare the flexibility of the protein strands. Which protein do you think formed the most flexible strand? Explain your answer below.

_____

_____

_____

Part 3: Reflecting on the Structure and Function of Protein Molecules

Discuss the questions below with your group. Be prepared to share your ideas with the class.

- Which protein molecule do you think formed the most flexible silk strand?
- How did the structure of the proteins make this strand more flexible?
- Did any protein molecule not connect? How did the structure of this protein molecule affect its function?

Name: _____ Date: _____

Lesson 1.4: Observing Proteins and Variation

In the previous lesson, you used physical models to see how differences in protein molecules can result in different traits for spider silk flexibility. Today, you will use the *Traits and Reproduction* Simulation to learn more about protein molecules and traits. This will help you as you try to explain why Darwin's bark spiders have different silk flexibility traits.

Unit Question

- Why do traits vary, and why do they vary even between parents and offspring and among siblings?

Chapter 1 Question

- Why do traits for silk flexibility vary within this family of Darwin's bark spiders?

Key Concepts

- The function of a protein molecule depends on its structure and how it interacts with other protein molecules.

Vocabulary

- feature
- function
- protein molecule
- structure
- trait
- variation

Digital Tools

- *Traits and Reproduction* Simulation

Name: _____ Date: _____

Warm-Up

Word Bank

molecule	protein	structure	trait

What have you learned so far about why some of the Darwin's bark spiders have different traits for silk flexibility? Use the above words in your response. Refer to the Darwin's Bark Spider Family Tree on page 8 if needed.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Observing Proteins in the Sim

Part 1

Launch the *Traits and Reproduction* Sim. Compare spiders with high, medium, and low silk flexibility.

1. With your partner, find three spiders, each with a different trait for silk flexibility (high, medium, or low). **Note:** If you and your partner have your own devices, you should first each observe two different spiders, one on each device. Then, observe the third spider together. If you are sharing a device, observe all three spiders together.
2. Work with your partner to compare the protein molecules in each of the spider's cells.
3. Record your observations in the data table.
4. Discuss the question below the data table and then record your thinking.

Spider's name	Silk flexibility trait	Protein molecule structure

Look at the Protein To Trait Example for silk flexibility. How do the differences in proteins lead to different traits for silk flexibility?

_____

_____

_____

_____

Name: _____ Date: _____

Observing Proteins in the Sim (continued)

Part 2

Launch the *Traits and Reproduction* Sim.

1. With your partner, select a feature. Find three spiders with different traits for this feature. If you and your partner have your own devices, you should first each observe two different spiders, one on each device. Then, observe the third spider together.
2. Record your observations in the data table.
3. Discuss the question below the data table and then record your thinking.

What feature did you choose to observe? _____

Spider's name	Trait	Protein molecule structure

Look at the Protein to Trait Example for the feature you chose. How did the differences in proteins lead to different traits for this feature?

_____

_____

_____

_____

Name: _____ Date: _____

Modeling Silk Flexibility

Modeling Proteins and Traits for Silk Flexibility

You have been investigating the question: *What determines an organism's traits at the molecular scale?* Use the Modeling Tool activity: Silk Flexibility Model to show your thinking about this question. Follow the instructions below.

Goal: Show how different protein molecules determine each spider's traits for the silk flexibility feature.

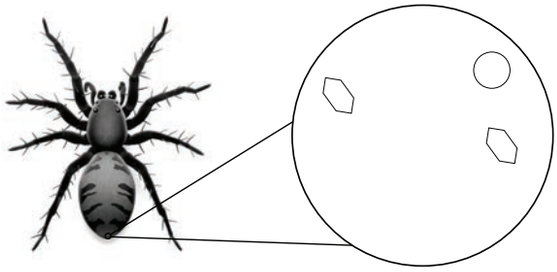
Do:

- Draw the protein molecules each spider would have for silk flexibility inside their cells. Annotate the diagram to explain why the proteins lead to these traits.

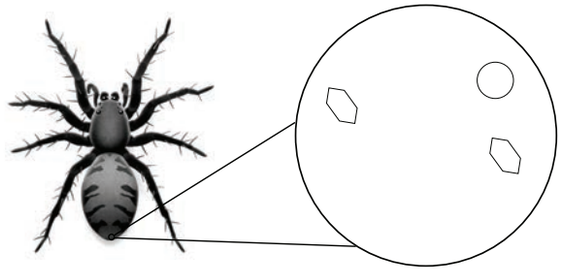
Name: _____ Date: _____

Modeling Silk Flexibility (continued)

Silk Flexibility Model

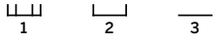


Spider A
high silk flexibility



Spider B
low silk flexibility

protein molecule options



Name: _____ Date: _____

Homework: Reflecting on What You Have Learned About Traits

The sisters in the picture below do not look very similar. They have different traits for various features. Use what you have learned about traits to answer the question below.

Identify a feature for which each sister has a different trait. Indicate the feature you selected and the corresponding traits below.

Feature: _____

Traits for this feature: _____

Word Bank

protein molecule	structure	trait	variation

Why do these sisters have different traits? Use the above words in your response, describing what would determine these traits at the molecular scale.

_____

_____

_____

Name: _____ Date: _____

Lesson 1.5: Investigating Proteins and Traits

You have learned that proteins determine an organism's traits. Imagine what would happen if you could add different proteins to an organism's cells. What changes would you expect to see? Today, you will use the Sim to find out. You will apply what you learn about proteins and traits to humans, learning how a protein in your cells might affect how fast you run.

Unit Question

- Why do traits vary, and why do they vary even between parents and offspring and among siblings?

Chapter 1 Question

- Why do traits for silk flexibility vary within this family of Darwin's bark spiders?

Key Concepts

- The function of a protein molecule depends on its structure and how it interacts with other protein molecules.
- Differences in the structure of protein molecules affect how they connect to other protein molecules. This can result in different traits.
- The structure of molecules determines how they function at a molecular scale, which determines the properties of the object they make up.

Vocabulary

- evidence
- feature
- function
- protein molecule
- structure
- trait
- variation

Digital Tools

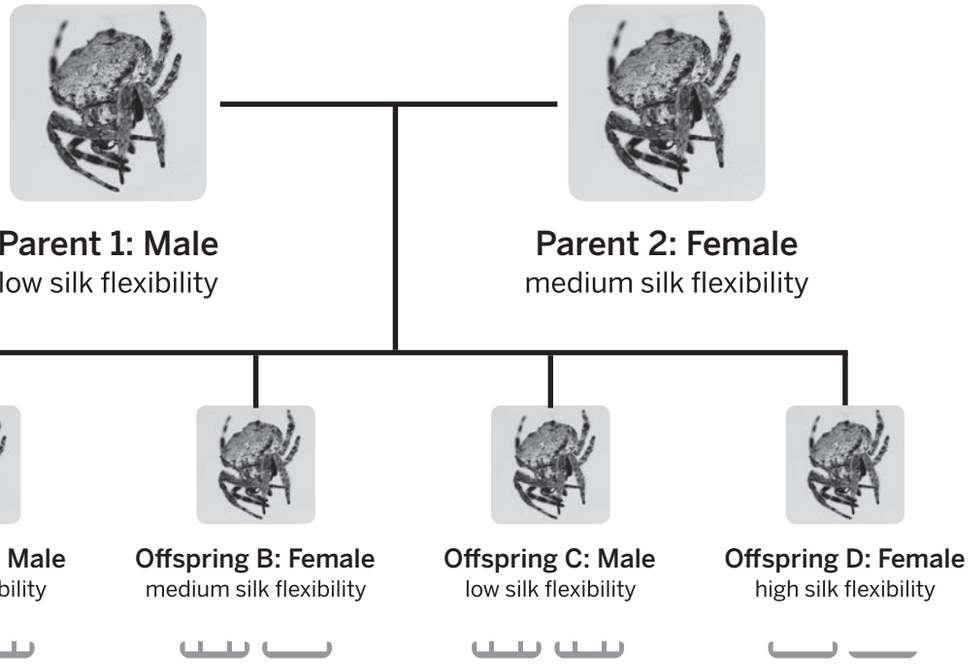
- *Traits and Reproduction* Simulation

Name: _____ Date: _____

Warm-Up

Dr. Sattari and the genetic researchers at Bay Medical Company have determined the proteins of each spider offspring. Review the results and then answer the question below.

Darwin's Bark Spider Family Tree



The genetic researchers at Bay Medical Company are interested in spiders with the trait for medium silk flexibility. They think this silk can be used for medical purposes such as for making stitches and for creating artificial tendons. *Why do you think offspring B has the medium silk flexibility trait?*

_____

_____

_____

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Name: _____ Date: _____

Darwin's Bark Spider Claims

Question: *Why do traits for silk flexibility vary within this family of Darwin's bark spiders?*

Claim 1: The offspring have **mutations** that affect their traits.

Claim 2: The offspring's traits depend on **which parent the offspring received more traits from.**

Claim 3: The offspring received **different combinations of traits from their parents.**

Name: _____ Date: _____

Testing Protein to Trait Predictions

Launch the *Traits and Reproduction* Sim. Use the Sim to investigate how adding proteins affects spiders' traits. Then, record your results in the data tables below.

Greg: Silk Flexibility

Record observations: What traits and proteins does Greg have for the silk flexibility feature?	**Make a prediction:** Do you think adding protein 1 will change Greg's trait? Why or why not?	**Test your prediction:** Did you observe a change? If so, record the new trait you observed.

Greg: Second Prediction for Silk Flexibility

Record observations: What traits and proteins does Greg have for the silk flexibility feature?	**Make a prediction:** Do you think adding protein 2 will change Greg's trait? Why or why not?	**Test your prediction:** Did you observe a change? If so, record the new trait you observed.

Ruby: Body Color

Record observations: What traits and proteins does Ruby have for the body color feature?	**Make a prediction:** Do you think adding protein 1 will change Ruby's trait? Why or why not?	**Test your prediction:** Did you observe a change? If so, record the new trait you observed.

Otis: Stripe Color

Record observations: What traits and proteins does Otis have for the stripe color feature?	**Make a prediction:** Do you think adding protein 1 will change Otis's trait? Why or why not?	**Test your prediction:** Did you observe a change? If so, record the new trait you observed.

Name: _____ Date: _____

New Message from Dr. Sattari

To: Student Researchers
From: Dr. Ada Sattari, Lead Scientist at Bay Medical Company
Subject: Research on Human Muscle Proteins

BAY MEDICAL COMPANY

At Bay Medical Company, we are working on several projects. So far, you have been helping us with our spider silk research. However, we now want to introduce you to another project. One of our teams is conducting research on human muscle proteins. I want your team to take a look at the initial findings from their work with a protein called ACTN3 (ak-tin-in three).

ACTN3 protein molecules connect muscle fibers, helping them contract more rapidly. As a result, the researchers think this protein might help people run faster. The researchers want to know what you think about the results of a test they just completed. They wonder if they should continue investigating this protein.

Name: _____ Date: _____

Write and Share Routine: Student 1: Human Muscle Protein

Read the information below about the test conducted by Bay Medical Company. Then, answer the question.

The test: To understand if the ACTN3 protein affects running ability, researchers conducted a test. They recruited a group of competitive runners and measured the level of ACTN3 protein molecules each runner had in their bodies. Then, they had the runners participate in a sprint (a short-distance run). During the test, the runners sprinted as fast as they could for 100 meters.

Evidence: Scientists found that the runners who sprinted the fastest had the highest amount of ACTN3 protein molecules in their bodies.

Do you think that this evidence shows that the ACTN3 protein determines running ability? Explain your ideas using the words *protein, trait,* and *feature* in your response.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Write and Share Routine: Student 2: Human Muscle Protein

Read the information below about the test conducted by Bay Medical Company. Then, answer the question.

The test: To understand if the ACTN3 protein affects running ability, researchers conducted a test. They recruited a group of competitive runners and measured the level of ACTN3 protein molecules each runner had in their bodies. Then, they had the runners participate in a sprint (a short-distance run). During the test, the runners sprinted as fast as they could for 100 meters.

Evidence: Scientists found that the runners who sprinted at an average pace had half the amount of ACTN3 protein molecules as the runners who sprinted the fastest.

Do you think that this evidence shows that the ACTN3 protein determines running ability? Explain your ideas using the words *protein, trait,* and *feature* in your response.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Write and Share Routine: Student 3: Human Muscle Protein

Read the information below about the test conducted by Bay Medical Company. Then, answer the question.

The test: To understand if the ACTN3 protein affects running ability, researchers conducted a test. They recruited a group of competitive runners and measured the level of ACTN3 protein molecules each runner had in their bodies. Then, they had the runners participate in a sprint (a short-distance run). During the test, the runners sprinted as fast as they could for 100 meters.

Evidence: Scientists found that the runners in the test who sprinted the slowest had no ACTN3 protein molecules in their bodies.

Do you think that this evidence shows that the ACTN3 protein determines running ability? Explain your ideas using the words *protein, trait,* and *feature* in your response.

_____

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_____

Name: _____ Date: _____

Homework: Revisiting the Anticipation Guide

Review your original response to this statement from the Anticipation Guide on page 6:

Traits, such as your hair or eye color, are determined by the proteins made by cells in your body.

Do you agree or disagree with this statement now? What evidence supports your ideas about the statement?

_____

_____

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_____

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

Scientists investigate in order to figure things out. Are you getting closer to figuring out why the spider family's traits vary?

1. I understand why spiders with different proteins in their cells will have different traits. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

2. I understand the role that genes play in making proteins. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

3. I understand why some spider offspring have one type of protein, and others have two types of proteins for silk flexibility. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding (continued)

4. I understand how sexual reproduction results in variation in the spider offspring's traits. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

5. What do you still wonder about why traits vary?

_____

_____

_____

Name: _____ Date: _____

Chapter 2: Examining Spider Genes
Chapter Overview

Congratulations! You have now learned how proteins determine traits. In this chapter, you will continue to study the Darwin's bark spider while you investigate why organisms have different proteins. As you do so, you will explore the role of genes in the production of proteins.

Name: _____ Date: _____

Lesson 2.1: "Hemophilia, Proteins, and Genes"

Your research has shown that Darwin's bark spiders have different traits for silk flexibility because they have different proteins for this feature. But why do some Darwin's bark spiders make certain kinds of proteins while other spiders make a different kind of protein? Dr. Sattari has sent an article for you to read about a disease caused by differences in how humans make proteins in their cells. After reading, you will be able to apply what you have learned to explain why spiders make different types of proteins.

Unit Question

- Why do traits vary, and why do they vary even between parents and offspring and among siblings?

Chapter 2 Question

- Why do Darwin's bark spiders make different proteins for silk flexibility?

Vocabulary

- feature
- function
- gene
- protein molecule
- structure
- trait
- variation

Digital Tools

- *Traits and Reproduction* Simulation

Name: _____ Date: _____

Warm-Up

Why do organisms make different proteins? A Darwin's bark spider makes proteins that result in spider silk with high flexibility. A different Darwin's bark spider makes proteins that result in spider silk with low flexibility. Using the space below, explain why you think this happens.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Reading "Hemophilia, Proteins, and Genes"

1. Read and annotate the article "Hemophilia, Proteins and Genes."
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Homework: Exploring Genes in the Sim

Launch the Sim. Then, follow the steps below.

1. Press on any spider.
2. Select a feature. Notice the traits and proteins the spider has for this feature.
3. Press on the black boxes in the upper right corner of the screen to change the gene versions.
4. Look for evidence that genes are instructions for proteins. Then, answer the questions below.

What did you observe in the cell when you changed the spider's gene versions?

_____

_____

_____

Do you think what you observed is evidence that genes are instructions for proteins? Why or why not?

_____

_____

_____

Name: _____ Date: _____

Lesson 2.2: Gathering Evidence About Genes

In the "Hemophilia, Proteins, and Genes" article, you read that genes are instructions for making proteins. But what does that really mean? What role do genes play in making proteins? Today, you will use physical materials to model how organisms make the protein molecules that determine their traits.

Unit Question

- Why do traits vary, and why do they vary even between parents and offspring and among siblings?

Chapter 2 Question

- Why do Darwin's bark spiders make different proteins for silk flexibility?

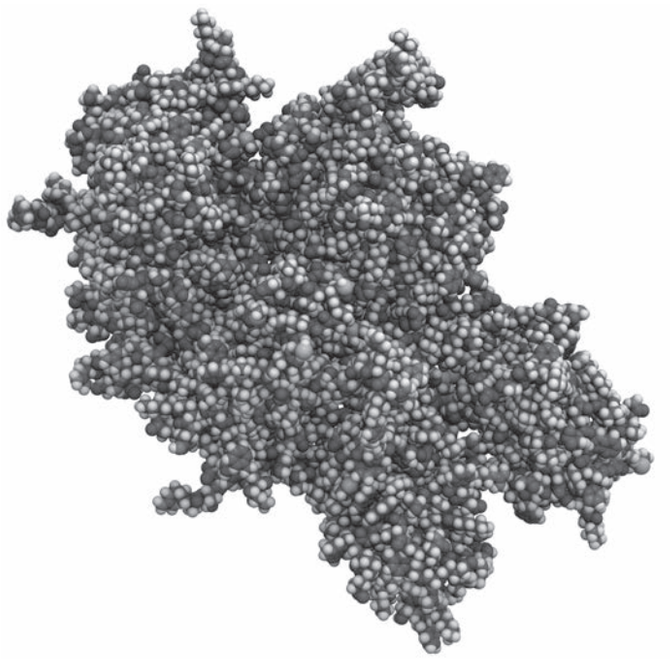
Vocabulary

- feature
- function
- gene
- gene version
- mutation
- protein molecule
- structure
- trait

Name: _____ Date: _____

Warm-Up

Review the diagram below from the "Hemophilia, Proteins, and Genes" article. Then, answer the question.



There are 13 different clotting factor proteins. This model represents a molecule of one of these proteins—the one most hemophilia patients are missing.

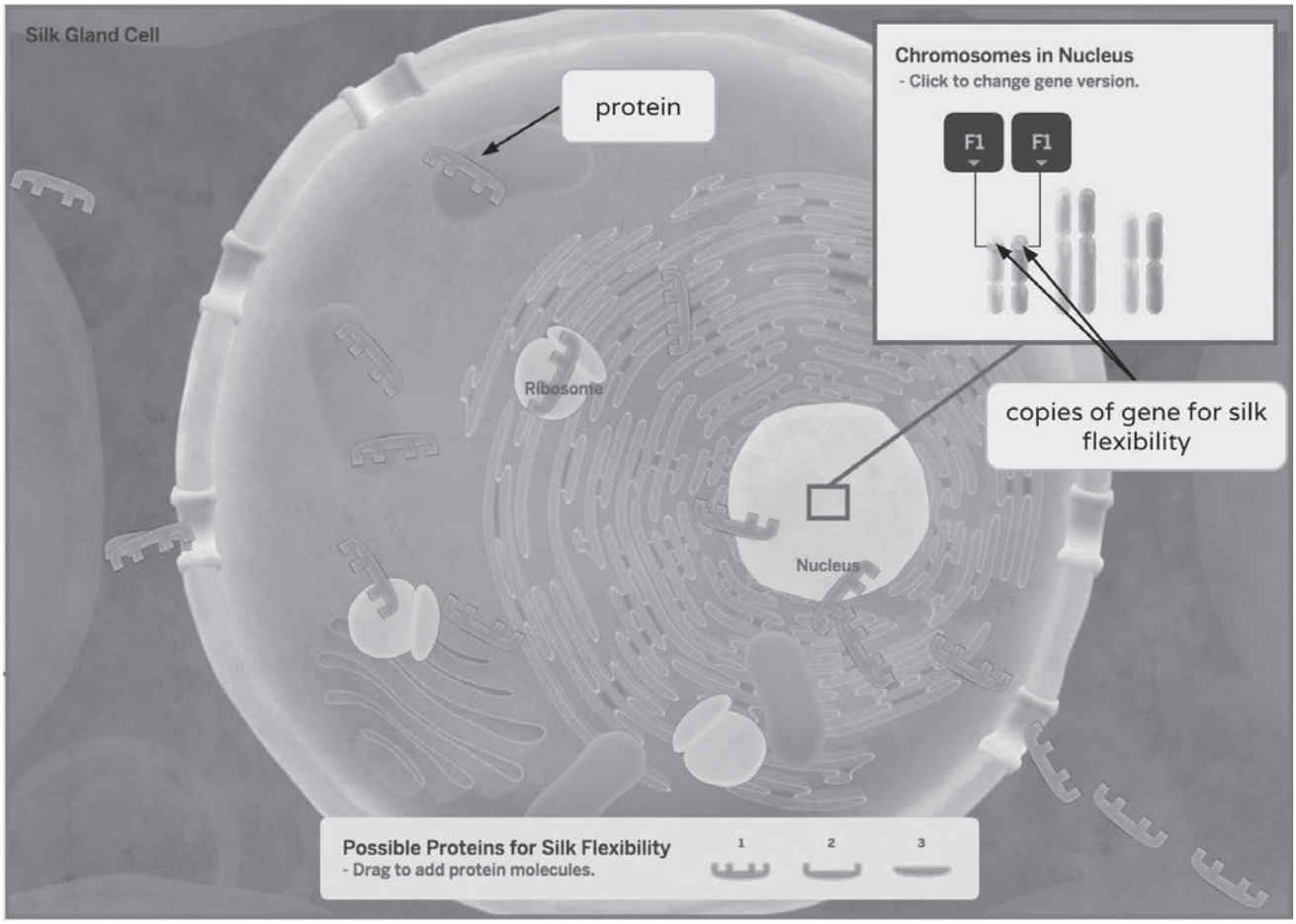
Genes provide instructions for making clotting factor proteins. The diagram to the left is an example of just one of hundreds of thousands of different proteins made in the cells of your body. What other types of proteins do you think your body makes? List your ideas below.

Name: _____ Date: _____

Modeling How Proteins Are Made in the Cells

Do genes build proteins, or are genes only the instructions for building proteins? You will work in a group of four to model the role genes play in building proteins.

1. The envelope represents the nucleus. Each instruction inside the envelope represents one copy of a gene.
2. Two students will serve as readers. The other pair will serve as ribosomes.
3. The pair of readers should each take one of the instructions from the envelope and read it aloud to one of the student ribosomes.
4. The ribosome that receives the instruction should build the protein molecules accordingly.
5. After completing this activity, discuss and answer the reflection questions on the next page.



Name: _____ Date: _____

Modeling How Proteins Are Made in the Cells (continued)

1. In this modeling activity, what do each of the items below represent?

envelope: _____

instructions: _____

students building the protein molecules: _____

2. Compare your two protein molecules. Are they the same or different? Why?

_____

_____

_____

3. Select the claim about genes' role in building proteins that best fits considering the modeling activity you have just completed. (check one)

   ☐ **Claim 1:** Genes provide instructions and build proteins.

   ☐ **Claim 2:** Genes provide instructions for making proteins, but they do not build the proteins themselves.

Name: _____ Date: _____

Modeling Mutations

What happens when there is a change to a gene? Using the protein molecules from the last activity, you will now model what happens when there is a mutation.

1. Take apart the protein molecules from the last activity.
2. Now, switch roles so that the readers are now ribosomes, and ribosomes are now readers.
3. The teacher will give each reader a new step. This represents a mutation in the gene. Place the new step over the indicated step number from your previous instructions.
4. Try to follow the new instructions to build a new protein. You can only add pieces to your protein if you are able to follow the instructions exactly.
5. Record your observations below.

The change in the instruction caused the protein to:

- ☐ be incomplete. (We couldn't finish building the protein.)
- ☐ no longer exist.
- ☐ have a different structure.
- ☐ have the same structure.

Name: _____ Date: _____

Lesson 2.3: Investigating Gene Copies

You may have noticed that sometimes organisms only have one type of protein for a feature; other times, they have two. Why is this the case? In Lesson 2.3, you will use the Sim and return to a portion of the "Hemophilia, Proteins, and Genes" article to help you answer this question.

Unit Question

- Why do traits vary, and why do they vary even between parents and offspring and among siblings?

Chapter 2 Question

- Why do Darwin's bark spiders make different proteins for silk flexibility?

Key Concepts

- Genes are instructions for proteins.
- Each gene version provides a unique instruction to make a specific protein molecule in an organism's cells.

Vocabulary

- feature
- function
- gene
- gene version
- heterozygous
- homozygous
- mutation
- protein molecule
- structure
- trait
- variation

Digital Tools

- *Traits and Reproduction* Simulation

Name: _____ Date: _____

Warm-Up

In a moment, you will watch the video *Mutations and New Traits.* Before watching the video, list one or two questions you may have about mutations. Alternatively, you can list a few things you already know about mutations.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Investigating Gene Copies in the Sim

Mission 1: Comparing Spiders

Use the Sim to gather evidence about why some organisms make one type of protein for a feature while other organisms make two.

1. Launch the Sim.

2. Decide who will be Partner A and who will be Partner B.

3. Choose a feature to focus on. You can select any feature except body size.
   - **Partner A:** By observing the cells for each spider, find a spider that makes only one type of protein for your selected feature.
   - **Partner B:** By observing the cells for each spider, find a spider that makes two types of proteins for your selected feature.

4. Record your results below.
   - feature we observed: _____
   - name of spider that makes one type of protein for this feature: _____
   - name of spider that makes two types of protein for this feature: _____

5. List ideas for why you think Partner A's spider makes one type of protein while Partner B's spider makes two types of proteins for this feature.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Investigating Gene Copies in the Sim (continued)

Mission 2: Changing Spiders' Genes

1. Launch the Sim.
2. Work with your partner to change your spiders' genes so that both spiders produce the same proteins for the feature you selected.
3. Discuss what changed and what you noticed. Use the discussion questions below as guidance.
   - What did you do to make the spiders produce the same proteins?
   - How did this change affect the spiders' traits?

Describe what you did and observed in the Sim.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Second Read of "Hemophilia, Proteins, and Genes"

You are investigating the question: *Why do some organisms make one type of protein for a feature and other organisms make two?*

1. Read and annotate the first paragraph of the "Causes of Hemophilia" section of the "Hemophilia, Proteins, and Genes" article. Identify evidence that helps you answer the above question.
2. Review the Homozygous/heterozygous diagram from the article. Annotate the image.

Name: _____ Date: _____

Reflecting on the Investigation Question

Use evidence from the Simulation and the "Hemophilia, Proteins, and Genes" article to answer the Investigation Question.

Word Bank

copies	gene	gene version	heterozygous
homozygous	protein	trait	

Why do some organisms make one type of protein for a feature while other organisms make two? Use the above words in your response.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Making Connections to Science Ideas

Think of another science topic you have studied in the past. How does that topic connect to what we are learning about in this unit? Be creative! See if you can make connections between genes, proteins, and traits and what you already know about one of the topics below.

- organisms
- ecosystems
- molecules
- energy
- forces
- Earth (or its atmosphere and oceans)
- a science topic not listed here

List the science topic you have selected here: _____

Write a description of the connection between this science topic and what you have studied so far.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 2.4: Applying Ideas About Genes

Bay Medical Company is counting on you to help them explain why the Darwin's bark spiders have different traits for silk flexibility. Today, you will reflect on what you have learned in Chapter 2. You will use the Modeling Tool to create a new model that better explains the variation in the spider family. You will also apply what you have learned to think more deeply about the ACTN3 protein—the human muscle protein that genetic researchers think is related to the trait for running ability.

Unit Question

- Why do traits vary, and why do they vary even between parents and offspring and among siblings?

Chapter 2 Question

- Why do Darwin's bark spiders make different proteins for silk flexibility?

Key Concepts

- Genes are instructions for proteins.
- Each gene version provides a unique instruction to make a specific protein molecule in an organism's cells.
- An organism has two copies of a gene for each feature.
- The two copies of a gene for each feature can be the same version (homozygous) and provide instructions for only one type of protein.
- The two copies of a gene for each feature can be different versions (heterozygous) and provide instructions for two types of proteins.

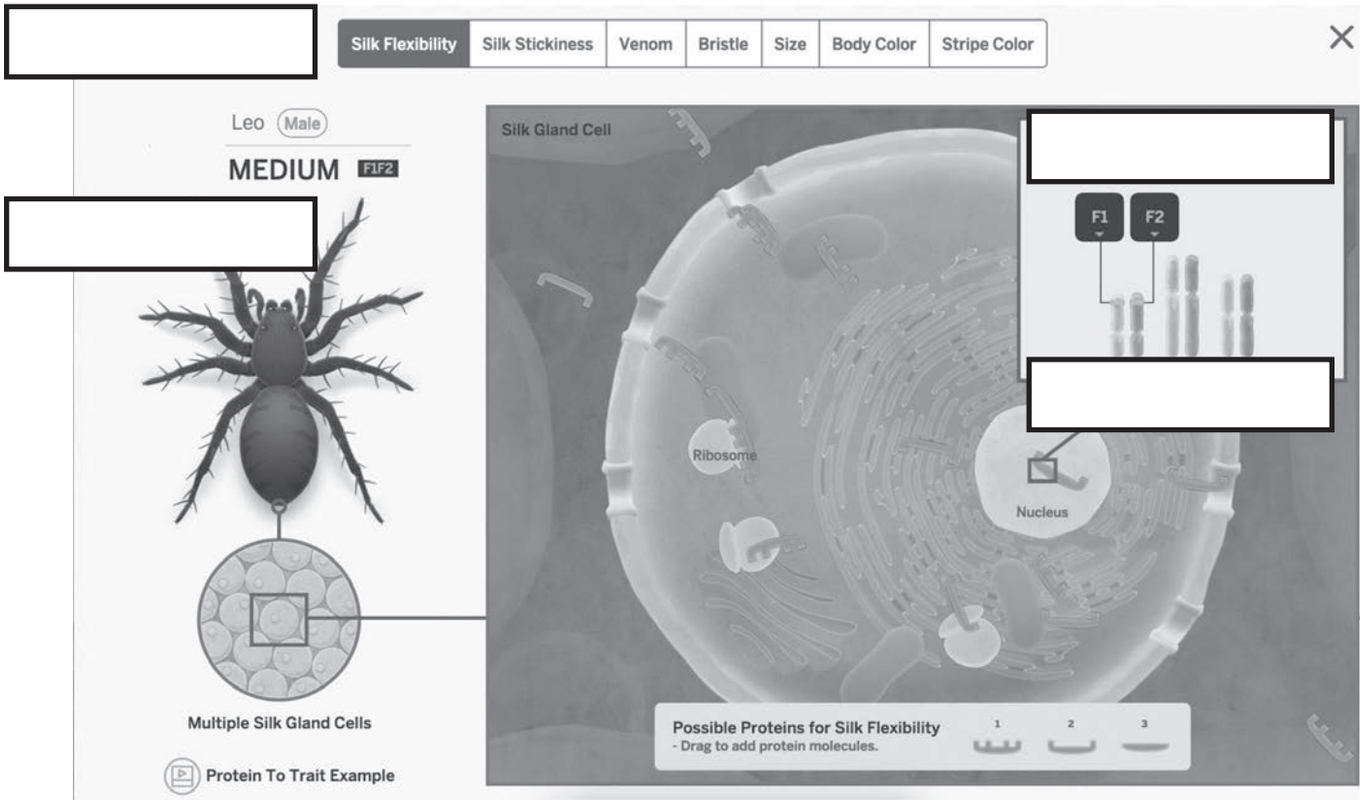
Vocabulary

- feature
- function
- gene
- gene version
- heterozygous
- homozygous
- mutation
- protein molecule
- structure
- trait
- variation

Name: _____ Date: _____

Warm-Up

Label the diagram with the words provided below.



Word Bank

copies of genes	feature	gene versions	trait

1. The spider in the diagram above has _____ gene versions for the silk flexibility trait.
   a. homozygous
   b. heterozygous

Name: _____ Date: _____

Modeling Variation in Spider Offspring

In Chapter 2, you have been investigating the relationship between genes and traits. Use the Modeling Tool activity: Variation in Spider Offspring Model to show how your current thinking applies to the Darwin's bark spider offspring. Follow the instructions below.

Goal: Show why the spider offspring have different traits for silk flexibility.

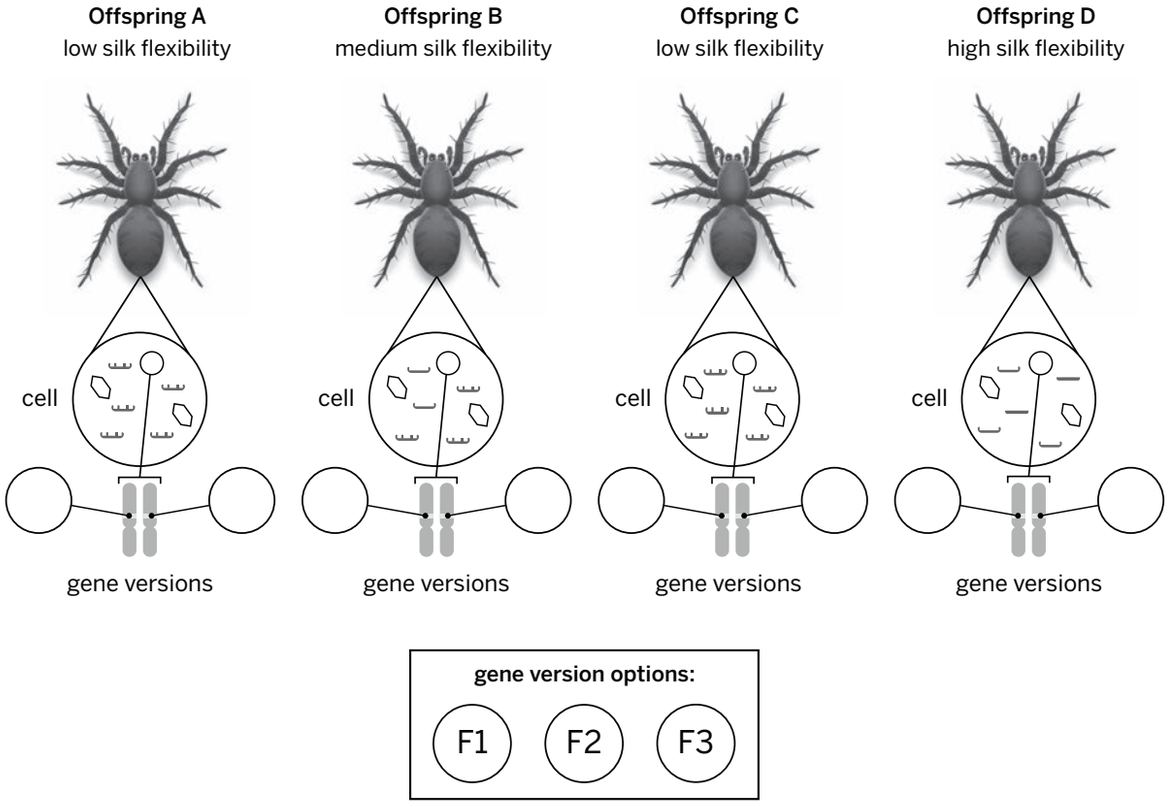
Do:

- Carefully review the proteins each spider has. Use this information to decide which gene versions they have.
- Add annotations to explain why each spider has the gene versions you recorded and how the gene versions you recorded result in different traits for silk flexibility among the offspring.

Tips:

- Try to use the following science words in your annotations: *gene versions*, *heterozygous*, *homozygous*, *traits*, and *proteins*.

Variation in Spider Offspring Model



Name: _____ Date: _____

New Message from Dr. Sattari

To: Student Researchers
From: Dr. Ada Sattari, Lead Scientist at Bay Medical Company
Subject: New Data About ACTN3

BAY MEDICAL COMPANY

The genetic researchers at Bay Medical Company are making progress in their research on the ACTN3 protein. They have identified two commonly known gene versions that help determine the traits for the feature of running ability: A1 and A2. A1 instructs for the ACTN3 protein. This is the protein that helps muscles contract more rapidly so runners can go faster.

Please use this new information to make predictions about runners in different scenarios.

Name: _____ Date: _____

Write and Share Routine: Student 1: Genes and ACTN3 Proteins

Read the information below about the test conducted by Bay Medical Company. Then, answer the question below.

The test: As you read in Dr. Sattari's message, genetic researchers at Bay Medical Company have identified two gene versions for running ability: A1 and A2. A1 instructs for the ACTN3 protein. Researchers tested three runners to see what proteins they had in their cells.

Evidence: For the running ability feature, runner 1 had only ACTN3 proteins in her cells.

Based on the proteins that were found in runner 1's cells, what can you say about her genes? Explain your ideas using the following words: *gene versions*, *heterozygous*, and *homozygous*.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Write and Share Routine: Student 2: Genes and ACTN3 Proteins

Read the information below about the test conducted by Bay Medical Company. Then, answer the question below.

The test: As you read in Dr. Sattari's message, genetic researchers at Bay Medical Company have identified two gene versions for running ability: A1 and A2. A1 instructs for the ACTN3 protein. Researchers tested three runners to see what proteins they had in their cells.

Evidence: For the running ability feature, runner 2 had ACTN3 as well as another type of protein in his cells.

Based on the proteins that were found in runner 2's cells, what can you say about his genes? Explain your ideas using the following words: *gene versions*, *heterozygous*, and *homozygous*.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Write and Share Routine: Student 3: Genes and ACTN3 Proteins

Read the information below about the test conducted by Bay Medical Company. Then, answer the question below.

The test: As you read in Dr. Sattari's message, genetic researchers at Bay Medical Company have identified two gene versions for running ability: A1 and A2. A1 instructs for the ACTN3 protein. Researchers tested three runners to see what proteins they had in their cells.

Evidence: Runner 3 had no ACTN3 protein in her cells. A different protein for the running ability feature was found.

Based on the proteins that were found in runner 3's cells, what can you say about her genes? Explain your ideas using the following words: *gene versions*, *heterozygous*, and *homozygous*.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Revisiting the Anticipation Guide

Review your original response to this statement from the Anticipation Guide on page 6:

There are two genes that decide each of your traits, and those two genes are always exactly alike.

Do you agree or disagree with this statement now? What evidence supports your ideas about the statement?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Reading "Exploring the Human Genome"

You have learned a lot about genes, proteins, and traits. Read and annotate the "Exploring the Human Genome" article to learn more about current scientific research about genes, proteins, and traits. Then, answer the questions below.

What is the Human Genome Project?

_____

_____

_____

What have scientists learned from the Human Genome Project?

_____

_____

_____

How is the Human Proteome Project different from the Human Genome Project?

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

Scientists investigate in order to figure things out. Are you getting closer to figuring out why the spider family's traits vary?

1. I understand why spiders with different proteins in their cells will have different traits. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

2. I understand the role that genes play in making proteins. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

3. I understand why some spider offspring have one type of protein, and others have two types of proteins for silk flexibility. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding (continued)

4. I understand how sexual reproduction results in variation in the spider offspring's traits. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

5. What do you still wonder about why traits vary?

_____

_____

_____

Name: _____ Date: _____

Chapter 3: Investigating Spider Inheritance
Chapter Overview

In this chapter, you will look at how the Darwin's bark spider offspring inherit genes. This will allow you to create a final explanation to send to Bay Medical Company, answering the question: *Why do traits for silk flexibility vary within this family of Darwin's bark spiders?*

Name: _____ Date: _____

Lesson 3.1: "Why Are Identical Twins Rare?"

Have you ever wondered why identical twins look exactly alike? In this lesson, you will read an article about identical twins, which will help you understand how organisms end up with the genes that determine their traits. Once you have read this article, you will be able to apply this understanding to the Darwin's bark spider, further understanding why there is variation between and among the spider parents and their offspring.

Unit Question

- Why do traits vary, and why do they vary even between parents and offspring and among siblings?

Chapter 3 Question

- Why do the Darwin's bark spider offspring have different gene combinations even though they have the same parents?

Vocabulary

- feature
- function
- gene
- gene version
- heterozygous
- homozygous
- inherit
- mutation
- protein molecule
- sexual reproduction
- structure
- trait
- variation

Digital Tools

- *Traits and Reproduction* Simulation

Name: _____ Date: _____

Warm-Up

The last time you saw the sisters pictured above, you considered how different protein molecules in their cells could lead to different traits. Now, you know that genes provide instructions for proteins that lead to traits. How could these sisters have ended up with different genes, leading to their different proteins and traits? Explain your ideas below.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Discussing Spider Silk Claims

With your partner, review the below claims about the spider family, discussing which claim or claims you find most convincing. Is there any information you still need to support or refute these claims?

Question: *Why do traits for silk flexibility vary within this family of Darwin's bark spiders?*

Claim 1: The offspring have **mutations** that affect their traits.

Claim 2: The offspring's traits depend on **which parent the offspring received more copies of genes from.**

Claim 3: The offspring received **different combinations of gene versions from their parents.**

Name: _____ Date: _____

Reading "Why Are Identical Twins Rare?"

1. Read and annotate the article "Why Are Identical Twins Rare?"
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Homework: Observing Inheritance in Darwin's Bark Spiders

Launch the Sim. Then, follow the steps below.

1. Select a female spider. Drag her on top of a male spider so that the spiders reproduce.
2. Press CREATE REPRODUCTIVE CELLS.
3. Once the cells have been produced, press RANDOMLY FERTILIZE to observe fertilization.
4. Compare the offspring with each other and with their parents. Pay careful attention to traits and combinations of gene versions. How are family members similar? How are they different?
5. Pick one feature to observe closely (except for body size) and answer the questions below.

I mated the female spider named _____ with the male spider named _____. I focused on the feature of _____.

How did the offspring's traits compare to their parents' traits?

_____

_____

_____

How did the offspring's gene versions compare to their parents' gene versions?

_____

_____

_____

Name: _____ Date: _____

Homework: Reading "Invasion of the Periodical Cicada"

You have learned a lot about how organisms pass on their genes through reproduction. Read and annotate the "Invasion of the Periodical Cicada" article to learn more about a unique organism called the cicada and how it increases its chances of reproducing successfully. Then, answer the questions below.

What are two reasons why arriving above ground all at once increases the cicadas' chances of surviving and reproducing?

_____

_____

_____

Why do scientists think it is helpful to the periodical cicadas to emerge every 13 to 17 years?

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 3.2: Gathering Evidence About Inheritance

Have you ever heard someone say: "You look like your mother" or "You look like your father"? How is it possible for someone to look more like one of their parents? Did this person inherit more genes from one parent over the other? Today, you will return to the Sim to answer the Investigation Question: *How do organisms get their genes?* You will gather evidence to either support or refute claim 2 of the Darwin's bark spider claims.

Unit Question

- Why do traits vary, and why do they vary even between parents and offspring and among siblings?

Chapter 3 Question

- Why do the Darwin's bark spider offspring have different gene combinations even though they have the same parents?

Vocabulary

- claim
- evidence
- feature
- gene
- gene version
- heterozygous
- homozygous
- inherit
- protein molecule
- sexual reproduction
- trait
- variation

Digital Tools

- *Traits and Reproduction* Simulation

Name: _____ Date: _____

Warm-Up

In this unit, you have been investigating the following question: *Why do traits for silk flexibility vary within this family of Darwin's bark spiders?*

Review claim 2, which is listed below. This claim provides one possible response to this question.

Claim 2: The offspring's traits depend on **which parent the offspring inherited more copies of genes from.**

Do you agree or disagree with this claim? (circle one)

a. **agree**

b. **disagree**

Explain why you either agree or disagree with the claim. Use what you have learned about genes and inheritance to explain your thinking.

_____

_____

_____

_____

_____

_____

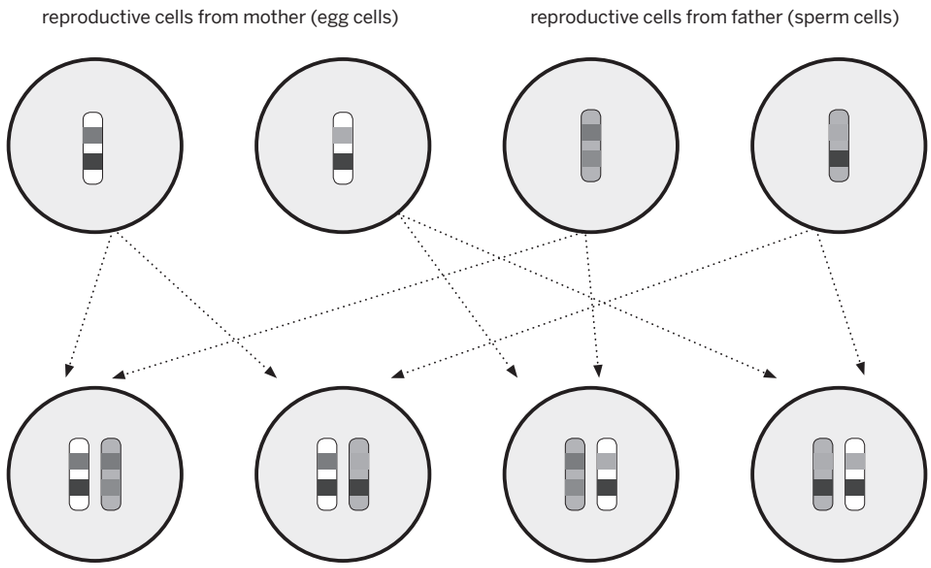
Name: _____ Date: _____

Second Read of "Why Are Identical Twins Rare?

You are investigating the question: *How do organisms get their genes?*

- Read and annotate the second two paragraphs of the "How We Get Our Genes" section of the "Why Are Identical Twins Rare?" article. Identify evidence that helps you answer the above question.
- Review the Sexual Reproduction diagram from the article (included below). Annotate the image.

Sexual Reproduction
Possible Reproductive Cell Combinations



cells of different possible offspring, each with a different combination of genes

Name: _____ Date: _____

Gathering Evidence from the Sim

Part 1: Gathering Evidence from the Sim: the Bristle Feature

Launch the Sim. As your teacher models this activity, make observations about Otis and Anne's offspring.

Otis

Feature	Trait	Gene versions
bristle	sparse	R1R2

Anne

Feature	Trait	Gene versions
bristle	dense	R1R1

Write your observations of the offspring below.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Gathering Evidence from the Sim (continued)

Part 2: Gathering Evidence from the Sim: the Body Color Feature

Launch the Sim and follow the steps below.

1. Press BODY COLOR to observe Otis and Anne's traits and gene versions for this feature. Record your observations in the first table.
2. Mate Otis with Anne by moving Anne over Otis until a dotted circle appears.
3. Press CREATE REPRODUCTIVE CELLS. Once the reproductive cells have been created, press RANDOMLY FERTILIZE. Observe as the egg and sperm cells come together to create new offspring.
4. Examine the traits and combinations of gene versions for each offspring. Then, record your observations in the second table below.

Parents

Parents	Gene versions	Trait
Otis		
Anne		

Offspring

	Gene version from Otis	Gene version from Anne	Gene versions	Body color trait
Offspring 1				
Offspring 2				
Offspring 3				
Offspring 4				

Name: _____ Date: _____

Homework: Reading "Why the Corpse Flower Smells So Bad"

You have been learning about how spiders pass on their traits through reproduction, but what about plants? Read and annotate the "Why the Corpse Flower Smells So Bad" article to learn more about a unique organism called the corpse flower. Then, answer the questions below.

Why does the corpse flower smell so bad?

_____

_____

_____

Why does the corpse flower need to attract insects to reproduce?

_____

_____

_____

What is another plant adaptation that helps a plant reproduce?

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 3.3: Analyzing Variation and Reproduction

In today's lesson, you will investigate a new question: *How does sexual reproduction result in variation among offspring?* To answer this question, you will use the Sim to make and test predictions about the gene versions offspring will inherit given a certain set of parents. Next, you will create a model that shows your ideas about how offspring can inherit different gene combinations. Completing these activities will bring you closer to answering the question: *Why do traits for silk flexibility vary within this family of Darwin's bark spiders?*

Unit Question

- Why do traits vary, and why do they vary even between parents and offspring and among siblings?

Chapter 3 Question

- Why do the Darwin's bark spider offspring have different gene combinations even though they have the same parents?

Key Concepts

- Organisms inherit their genes through sexual reproduction.
- Each parent randomly passes on one of its two copies of each gene to its offspring. Each offspring, therefore, receives two copies of each gene, one from each parent.

Vocabulary

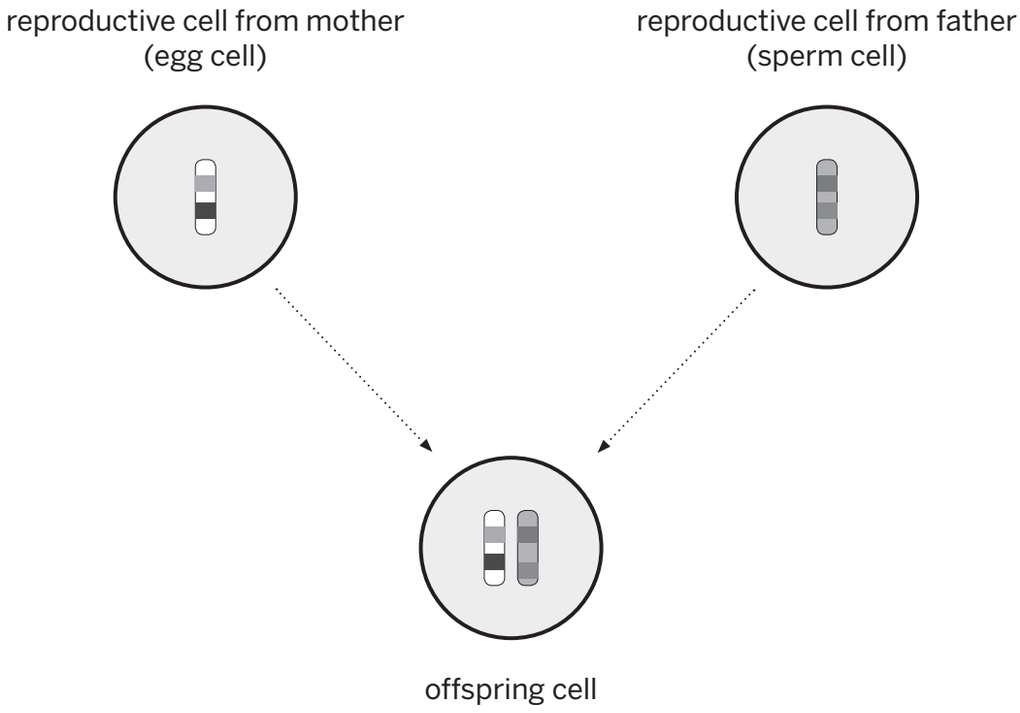
- feature
- gene
- gene version
- heterozygous
- homozygous
- inherit
- protein molecule
- sexual reproduction
- trait
- variation

Digital Tools

- *Traits and Reproduction* Simulation

Name: _____ Date: _____

Warm-Up



Word Bank

genes	inherit	offspring	parent

Use the diagram to explain how the offspring receives two copies of each gene. Refer to the word bank above when writing your response.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Testing Predictions About Inheritance

Part 1: Making and Testing Predictions About Inheritance: Silk Stickiness

Launch the Sim. Follow your teacher's instructions, recording information about Greg and Anne's gene versions and the possible combinations of gene versions their offspring might inherit.

- Greg's gene versions for silk stickiness are: _____
- Greg's trait for silk stickiness is: _____
- Anne's gene versions for silk stickiness are: _____
- Anne's trait for silk stickiness is: _____

Make Predictions

Use the information about Greg and Anne's gene versions to make predictions about all the possible gene combinations the offspring could inherit for the feature of silk stickiness. Be prepared to share your predictions with the class.

Silk Stickiness Inheritance Predictions

Possible gene combination	Gene version from Greg	Gene version from Anne	Offspring gene versions
Gene combination A			
Gene combination B			
Gene combination C			
Gene combination D			

Name: _____ Date: _____

Testing Predictions About Inheritance (continued)

Part 2: Making and Testing Predictions About Inheritance: Body Color

Launch the Sim. Then, follow the instructions below.

Examine Otis and Ruby's traits for body color. Record their gene versions and traits below.

- Otis's gene versions for body color are:_____
- Otis's trait for body color is: _____
- Ruby's gene versions for body color are: _____
- Ruby's trait for body color is: _____

Make Predictions

Use the information about Otis and Ruby's gene versions to make predictions about all the possible gene combinations the offspring could inherit for the feature of body color.

Body Color Inheritance Predictions

Possible gene combination	Gene version from Otis	Gene version from Ruby	Offspring gene versions
Gene combination A			
Gene combination B			
Gene combination C			
Gene combination D			

Name: _____ Date: _____

Testing Predictions About Inheritance (continued)

Test Predictions

Mate Otis and Ruby at least two times. Each time, record the offspring's gene versions and body color in the table below.

Body Color Inheritance Results: Test 1

	Combination of gene versions	Trait
Offspring 1		
Offspring 2		
Offspring 3		
Offspring 4		

Body Color Inheritance Results: Test 2

	Combination of gene versions	Trait
Offspring 1		
Offspring 2		
Offspring 3		
Offspring 4		

Name: _____ Date: _____

Modeling Venom Inheritance

You have been investigating the question: *How does sexual reproduction result in variation among offspring?* Use the Modeling Tool to show your current thinking about this question. Follow the instructions below.

Goal: Using venom as an example, show how the gene versions of siblings can be different from each other and from their parents.

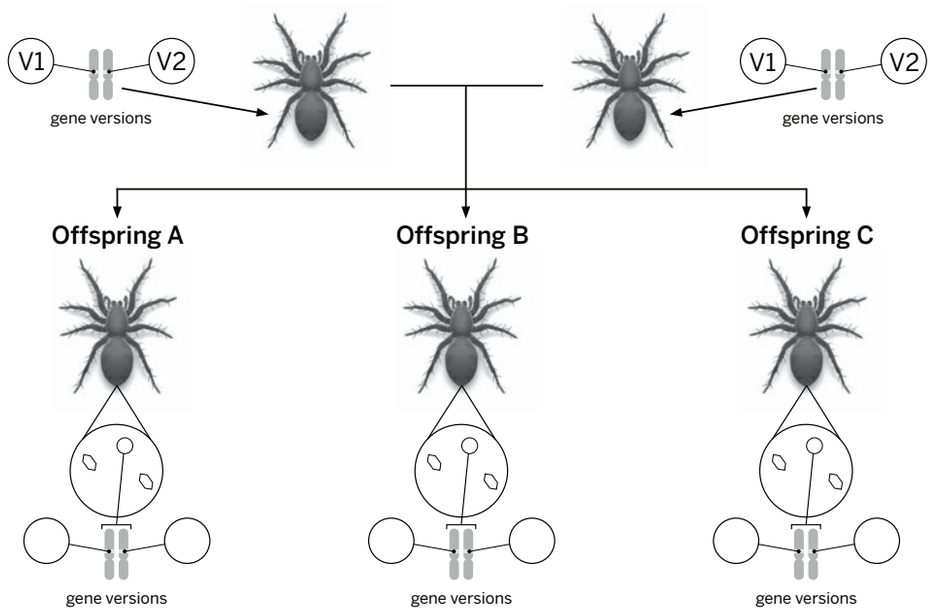
Do:

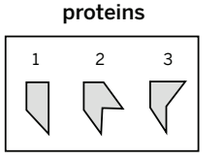
- Create a model that shows how the offspring could have different combinations of gene versions.
- Also draw and label the proteins each spider likely has in their cells.
- Add annotations to explain how each spider offspring received those gene versions and proteins.

Tips:

- Try to use the following science words in your annotations: *proteins*, *traits*, *gene versions*, *heterozygous*, *homozygous*, and *sexual reproduction*.

Venom Inheritance Model





Name: _____ Date: _____

Homework: Revisiting the Anticipation Guide

Review your original response to this statement from the Anticipation Guide on page 6:

An offspring cannot have a trait if neither of its parents have it.

Do you agree or disagree with this statement now? What evidence supports your ideas about the statement?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Reading "Sea Anemones: Two Ways to Reproduce"

You have learned a lot about gene inheritance through sexual reproduction. Read and annotate the "Sea Anemones: Two Ways to Reproduce" article to learn more about a unique organism called the sea anemone. Then, answer the questions below.

How is asexual reproduction different from sexual reproduction?

_____

_____

_____

How does a sea anemone reproduce asexually?

_____

_____

_____

Why doesn't asexual reproduction result in variation among offspring and parents?

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 3.5: Revisiting Key Concepts

Bay Medical Company needs your help as they develop treatments for people with diseases caused by genetic disorders. They need more information about the genes and proteins that cause people to have these diseases. Working with a partner, you will use the Sim and a short reading in order to help Bay Medical with this research. This investigation will also help you review key concepts and understand more about how traits can vary within a family.

Unit Question

- Why do traits vary, and why do they vary even between parents and offspring and among siblings?

Chapter 3 Question

- Why do the Darwin's bark spider offspring have different gene combinations even though they have the same parents?

Key Concepts

- The function of a protein molecule depends on its structure and how it interacts with other protein molecules.
- Differences in the structure of protein molecules affect how they connect to other protein molecules. This can result in different traits.
- The structure of molecules determines how they function at a molecular scale, which determines the properties of the object they make up.
- Organisms can have different proteins in their cells for a particular feature.
- Genes are instructions for proteins.
- Each gene version provides a unique instruction to make a specific protein molecule in an organism's cells.
- An organism has two copies of a gene for each feature.
- The two copies of a gene for each feature can be the same version (homozygous) and provide instructions for only one type of protein.
- The two copies of a gene for each feature can be different versions (heterozygous) and provide instructions for two types of proteins.
- Organisms inherit their genes through sexual reproduction.
- Each parent randomly passes on one of its two copies of each gene to its offspring. Each offspring, therefore, receives two copies of each gene, one from each parent.
- Through sexual reproduction, each offspring can inherit a different combination of gene versions. Therefore, siblings can have different traits from each other and even from their parents.

Name: _____ Date: _____

Lesson 3.5: Revisiting Key Concepts (continued)

Vocabulary

- feature
- function
- gene
- gene version
- heterozygous
- homozygous
- inherit
- protein molecule
- sexual reproduction
- structure
- trait
- variation

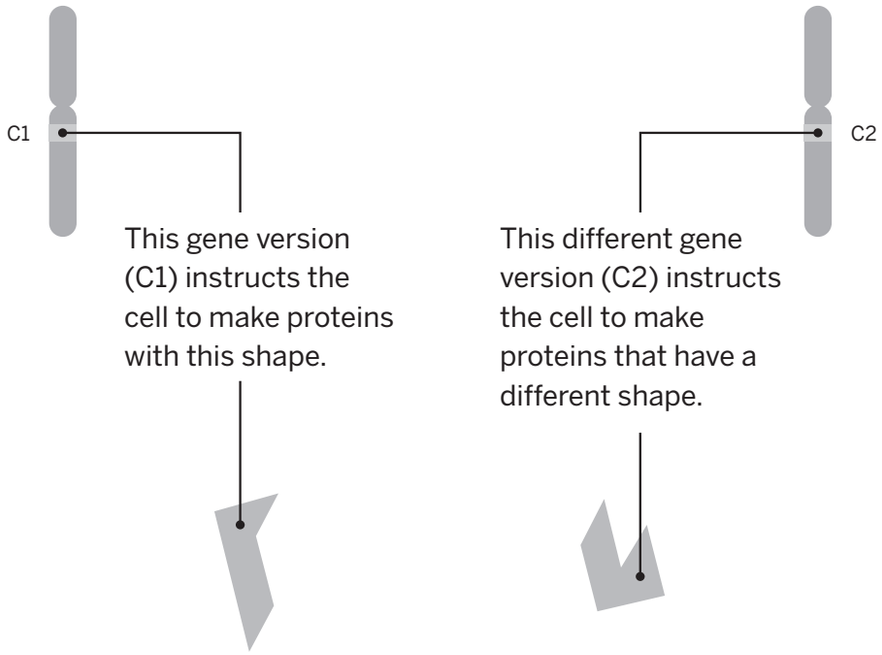
Digital Tools

- *Traits and Reproduction* Simulation

Name: _____ Date: _____

Blue Group: Warm-Up

1. Carefully look at the diagrams on this page and the next. Read the labels and captions.
2. Make at least two annotations for each diagram. Then, answer the question.

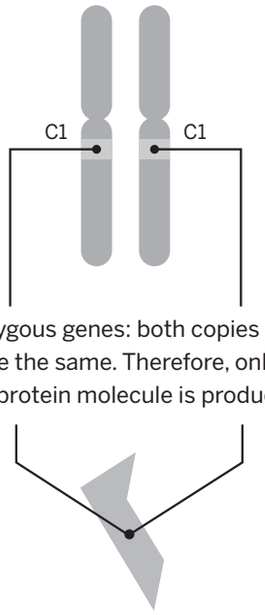


A gene is an instruction for making a specific kind of protein molecule. Different versions of genes instruct cells to create different protein molecules.

Name: _____ Date: _____

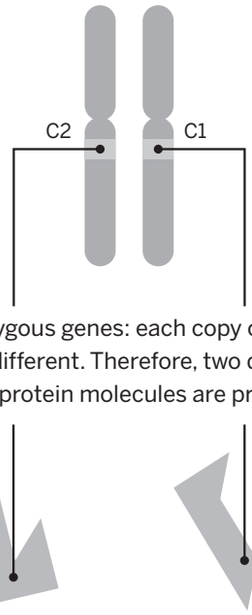
Blue Group: Warm-Up (continued)

Organism A



Homozygous genes: both copies of the gene are the same. Therefore, only one kind of protein molecule is produced.

Organism B



Heterozygous genes: each copy of the gene is different. Therefore, two different kinds of protein molecules are produced.

Every organism has two copies of each gene. If the copies are the same, then the genes are homozygous. If the copies are different, then the genes are heterozygous.

How do these diagrams explain why two organisms can have different proteins for a feature?

_____

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_____

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_____

Name: _____ Date: _____

Blue Group: Sim Activity

Examining Genes and Proteins for a Feature

Launch the Sim to investigate Greg's traits, proteins, and genes.

1. Select Greg.
2. Choose stripe color and examine Greg's trait, proteins, and genes for this feature.
3. Record your observations in the table below.

Trait for stripe color	Gene versions	Protein(s) (1, 2, or 3)

Add the proteins shown in the left column below, one protein at a time. Observe any changes to Greg's trait and genes for stripe color. Record your observations in the data table.

Proteins to add	Trait for stripe color	Did the gene versions change?
Protein 2		
Protein 3		

Answer the questions below.

Once you added the proteins, what happened after a period of time elapsed?

_____

_____

_____

Working in the Sim, change Greg's genes so that his stripe color is purple. What gene versions result in the purple stripe color?

_____

_____

_____

Name: _____ Date: _____

Blue Group: Sim Activity (continued)

Working in the Sim, this time change Greg's genes so that his stripe color is black. What gene versions result in the black stripe color?

_____

_____

_____

What differences did you notice in the Sim when you added proteins compared to when you changed Greg's gene versions?

_____

_____

_____

People with hemophilia need to have clotting factor proteins injected into their cells throughout their lifetime. Based on what you observed when you added proteins to change Greg's stripe color, why do you think people with hemophilia constantly need to receive injections of the protein?

_____

_____

_____

Name: _____ Date: _____

Blue Group: Reading About Diseases

Genes and Proteins in Hemophilia

Genetic researchers at Bay Medical Company are working to improve treatments for hemophilia. Currently, they are investigating the possibilities of gene therapy, which involves changing a person's genes so that person no longer has hemophilia. In order to help Bay Medical Company with their research, read the passage below and then answer the question.

Genes are instructions for proteins. Your traits are determined by the kinds of proteins your body makes. For example, when you get a cut, clotting factor proteins connect to form scabs. People with hemophilia do not have a version of the gene with the right instructions for making clotting factor VIII protein. Without the right instructions, their cells can't make the proteins needed to form scabs. Healthy people have at least one copy of the gene that provides the right instructions for making all of the clotting factor proteins.

If genetic researchers found a way to change a person's genes, would they be able to cure hemophilia? Why or why not?

_____

_____

_____

_____

_____

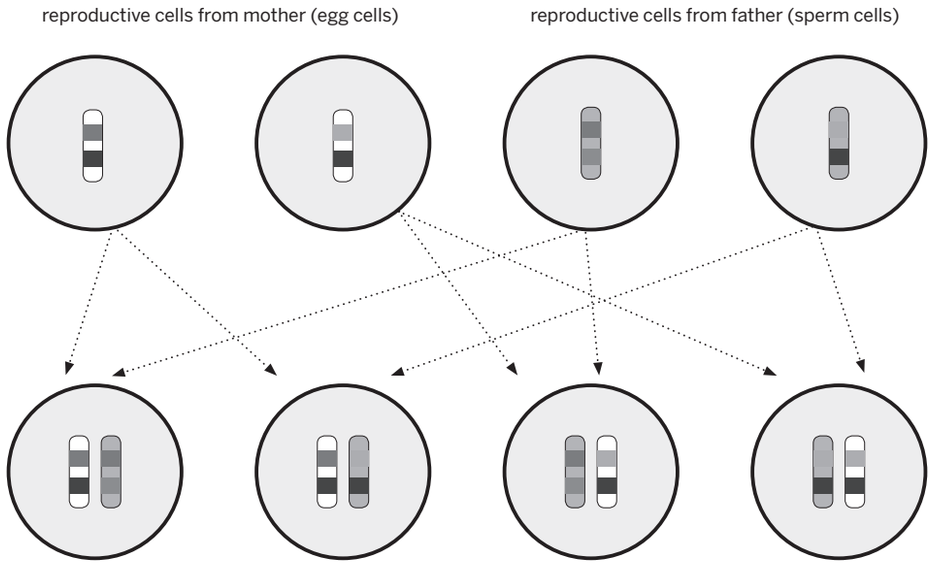
_____

Name: _____ Date: _____

Green Group: Warm-Up

1. Carefully look at the diagram. Read the labels and captions.
2. Make at least two annotations on the diagram. Then, answer the question below.

Sexual Reproduction
Possible Reproductive Cell Combinations



cells of different possible offspring, each with a different combination of genes

How does this diagram help you understand why siblings can have different combinations of gene versions?

_____

_____

_____

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_____

Name: _____ Date: _____

Green Group: Sim Activity

Predicting Offspring

Launch the Sim to investigate Otis and Zora's offspring.

1. Select the venom feature.
2. In the table below, record Otis and Zora's traits and gene versions for this feature.

Spider	Trait	Gene versions
Otis		
Zora		

Venom Genes and Traits Key

Genes	Trait
V1V1	kills
V2V2	stuns
V3V3	no venom
V1V2	kills
V1V3	kills
V2V3	stuns

List all possible combinations of gene versions and traits for Otis and Zora's offspring.

Possible combinations	Predicted trait

Name: _____ Date: _____

Green Group: Sim Activity (continued)

Mate Otis and Zora, recording the gene versions and traits of their offspring in the data table below.

	Offspring genes	Offspring trait
Spider 1		
Spider 2		
Spider 3		
Spider 4		

Answer the questions below.

Explain why there is variation in the traits of Otis and Zora's offspring for the venom feature. Try to use the following words in your explanation: gene, *heterozygous*, *homozygous*, *protein*, *sexual reproduction*, *trait*, and *variation*.

_____

_____

_____

_____

_____

_____

People with a genetic disease such as hemophilia or cystic fibrosis often want to know how likely it is for their children to have the same disease. Based on what you observed in the Sim, if one family member has a disease, will all members of that family have the disease? Why or why not?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Green Group: Reading About Diseases

Genes and Cystic Fibrosis

Genetic researchers at Bay Medical are working to improve treatments for cystic fibrosis, a disease that is caused by a genetic problem. Currently, the researchers are investigating how to predict which parents are at risk of having children with cystic fibrosis. In order to help Bay Medical Company with their research, read the passage below and then answer the question.

Cystic fibrosis is a disease that affects the lungs. It is caused by a problem with the CF gene, which instructs for a protein that helps keep the lungs clear. Each person has two copies of the CF gene. As long as at least one copy is working, a person's body can make the proteins they need. Some people have a faulty copy of the CF gene, however, which instructs for a nonfunctional protein. For a person to have cystic fibrosis, both copies of the CF gene must instruct for a nonfunctional protein. A person who has one faulty CF gene and one normal CF gene is called a CF carrier because he does not have the disease but can pass on the faulty gene to his child. If both parents are carriers, their offspring has a one in four chance of getting a faulty copy of the CF gene from each parent and having the cystic fibrosis disease. If only one parent is a carrier, the offspring will not have cystic fibrosis because she will receive a normal copy of the gene from the other parent.

George has one copy of the CF gene that instructs for a nonfunctional protein and one normal copy of the CF gene. Sylvia has two normal copies of the CF gene. Which of the following could be true about their children?

a. Their children could have two normal copies of the CF gene.
b. Their children could have one normal copy of the CF gene and one copy that instructs for a nonfunctional protein.
c. Their children could have two copies of the CF gene that instruct for a nonfunctional protein.

Could any of their children have cystic fibrosis? (check one)

☐ yes

☐ no

Name: _____ Date: _____

Green Group: Reading About Diseases (continued)

Explain why you answered either yes or no on the previous page. Use what you have learned about genes and inheritance to support your answer.

_____

_____

_____

_____

_____

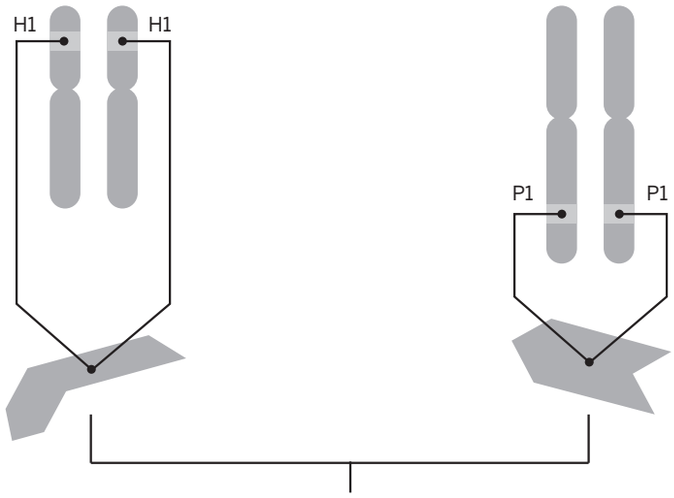
_____

Name: _____ Date: _____

Purple Group: Warm-Up

1. Carefully look at the diagrams on this page and the next. Read the labels and captions.
2. Make at least two annotations on each diagram. Then, answer the question.

One organism with two sets of genes



Both of these protein molecules affect hair texture.

Most traits are created through the interactions of many different kinds of protein molecules. For example, hair texture is affected by two types of proteins. The proteins that affect hair texture include those that actually make up hair as well as those that affect the shape of the pore (the hole where each strand of hair grows from). Each separate gene is an instruction for making a specific kind of protein molecule.

Name: _____ Date: _____

Purple Group: Warm-Up (continued)

Female Parent Genes:

H2H1 and P1P1

Male Parent Genes:

H2H3 and P1P2

Possible Gene Combinations for Offspring:

H2H2 and P1P1	H1H2 and P1P1
H2H2 and P1P2	H1H2 and P1P2
H2H3 and P1P1	H1H3 and P1P1
H2H3 and P1P2	H1H3 and P1P2

When a trait is affected by many genes, the number of possible gene combinations for offspring significantly increases.

Sometimes a trait is not determined by just one gene. The diagrams above show that multiple genes can affect a trait. What does it mean when multiple genes determine a trait? List your ideas below.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Purple Group: Sim Activity

Examining Traits Controlled by Multiple Genes

Launch the Sim to explore spiders' various traits for size. Many traits are controlled by more than one gene. In this activity, you will investigate different traits for size, learning more about how this works.

1. Select Greg.
2. Choose size, and observe Greg's trait for this feature.
3. Attempt to change Greg's genes so that he has the trait for medium body size. Then, attempt to do this for the trait for large body size.

Answer the questions below.

What do you notice about the genes and proteins that determine the trait for size?

_____

_____

_____

_____

_____

_____

Observe Otis and Ruby's traits and genes for size. What size do you think their offspring will be?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Purple Group: Sim Activity (continued)

Mate Ruby and Otis. Were their offspring all the same size? What do you notice about the body size gene combinations of the offspring?

_____

_____

_____

_____

_____

_____

We have 13 different clotting factor proteins in our blood. Do you think hemophilia is controlled by one or multiple genes?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Purple Group: Reading About Diseases

Diseases Caused By Multiple Genes

Genetic researchers at Bay Medical Company are working to improve treatments for many different diseases. Currently, they are investigating the possibilities of gene therapy, which involves changing a person's genes so that person no longer has a disease. But gene therapy may be more difficult, or impossible, in cases where a disease is caused by multiple genes. In order to help Bay Medical Company with their research, read the passage below and then answer the question.

Some diseases, such as hemophilia and cystic fibrosis, are caused by a single gene. However, many diseases are controlled by more than one gene. For example, multiple sclerosis, heart disease, and diabetes are all examples of diseases that are affected by a person's genes, but there is no single gene that determines whether or not a person will have these diseases. In many cases, one's environment can also affect whether or not that person will get these diseases. If a disease is caused by multiple genes, not just one, then there are many different combinations of gene versions that offspring can inherit from their parents. The causes of these diseases are more complicated, so it is much harder for doctors or geneticists to predict whether or not a person will have these diseases.

If a disease is controlled by more than one gene, will there be fewer, greater, or the same number of possible gene versions that offspring can inherit from their parents? Explain your answer below.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Sharing Information About Genetic Diseases

Refer to the questions below as you participate in the class discussion.

- How do genes determine whether or not someone has hemophilia, cystic fibrosis, or other genetic diseases?
- How is it possible for one sibling in a family to have hemophilia, cystic fibrosis, or other genetic diseases while another sibling does not?

Name: _____ Date: _____

Homework: Active Reading

Below is the description of the homework article. Read and annotate the article, and then answer the questions below.

"Cloning Mammoths: A Mammoth Task"

Mammoths have been extinct for thousands of years, but some scientists are hoping to bring them back through cloning. Could cloning mammoths really work? How would scientists make that happen?

Where are genes located in a cell?

_____

_____

_____

_____

_____

How does a new mammoth egg cell get chromosomes from each of the parents?

_____

_____

_____

_____

_____

How could scientists make a mammoth without using any reproductive cells?

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Active Reading (continued)

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 3.6: Reproduction in Darwin's Bark Spiders

Dr. Sattari and the researchers at Bay Medical Company have determined the gene versions of the Darwin's bark spiders' parents. Today, you will use this new evidence to arrive at a conclusion about why the spiders' traits for silk flexibility vary. You will use the Sim to make a recommendation about which spiders the researchers should breed to get offspring with the trait for medium silk flexibility.

Unit Question

- Why do traits vary, and why do they vary even between parents and offspring and among siblings?

Chapter 3 Question

- Why do the Darwin's bark spider offspring have different gene combinations even though they have the same parents?

Key Concepts

- Organisms inherit their genes through sexual reproduction.
- Each parent randomly passes on one of its two copies of each gene to its offspring. Each offspring, therefore, receives two copies of each gene, one from each parent.
- Through sexual reproduction, each offspring can inherit a different combination of gene versions. Therefore, siblings can have different traits from each other and even from their parents.

Vocabulary

- feature
- function
- gene
- gene version
- heterozygous
- homozygous
- inherit
- mutation
- protein molecule
- sexual reproduction
- structure
- trait
- variation

Digital Tools

- *Traits and Reproduction* Simulation

Name: _____ Date: _____

Warm-Up

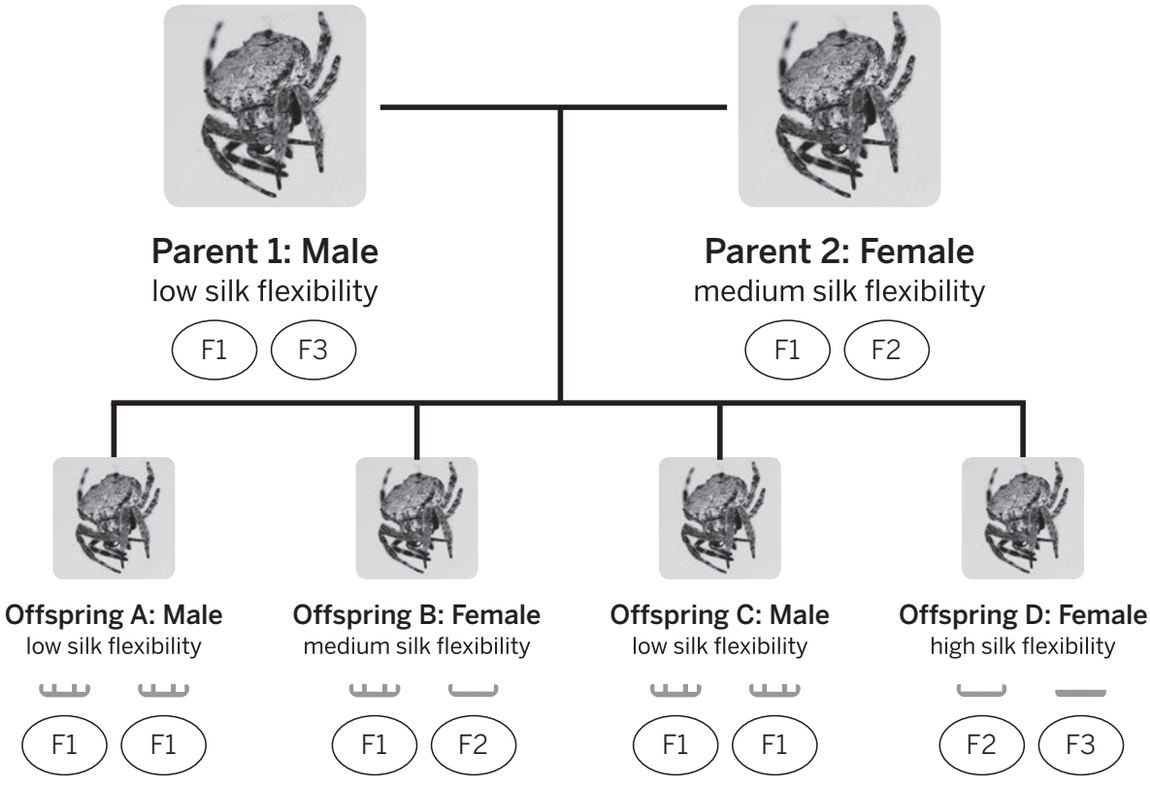
To: Student Researchers
From: Dr. Ada Sattari, Lead Scientist at Bay Medical Company
Subject: Gene Versions

BAY MEDICAL COMPANY

Our scientists have identified the gene versions for silk flexibility in the parents of the Darwin's bark spiders. We have submitted a diagram of the results for you to review. These genes are existing genes, common in this spider species.

We hope this information will help you with your research as you study why the spiders have different traits for silk flexibility.

Traits for Silk Flexibility in the Spider Family



Name: _____ Date: _____

Warm-Up (continued)

Do you think the new evidence supports or refutes **Claim 1:** The offspring have mutations that affect their traits?

_____

_____

_____

_____

_____

_____

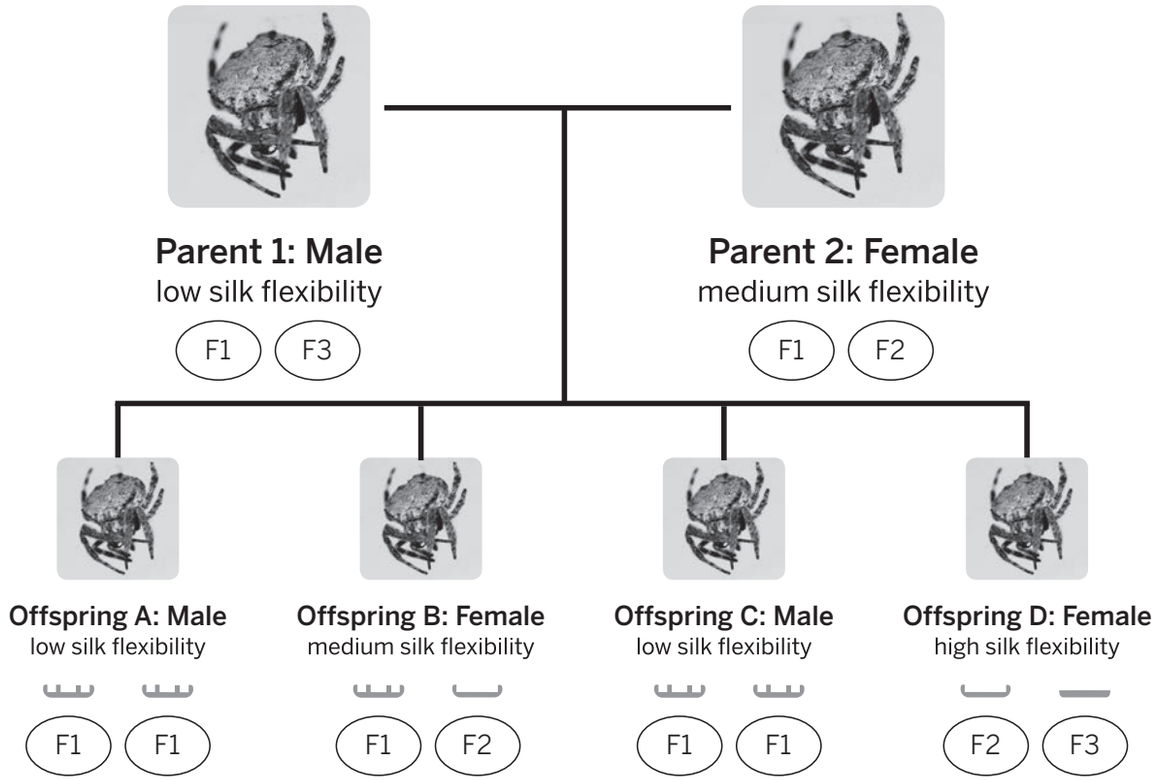
Name: _____ Date: _____

Reasoning About Spider Traits

Dr. Sattari hopes you will share your research about why the Darwin's bark spiders have varying traits for silk flexibility. Follow the steps below, using the new evidence about the parents' gene versions to support or refute the remaining claims.

1. Review the diagram carefully, paying special attention to the spiders' combinations of gene versions.
2. Read the evidence included in the first column of the Reasoning Tool.
3. In the last column, list which claim you think the evidence supports or refutes.
4. In the middle column, explain why the evidence matters or how it supports or refutes the claim you selected.

Traits for Silk Flexibility in the Spider Family



Name: _____ Date: _____

Reasoning About Spider Traits (continued)

Reasoning Tool

Why do traits for silk flexibility vary within this family of Darwin's bark spiders?

Claim 1: The offspring have mutations that affect their traits.

Claim 3: Offspring inherit different combinations of gene versions from their parents.

Evidence	**This evidence matters because. . .** (How does this support or refute the claim?)	**Therefore, . . .** (claim)
None of the spider offspring have a new gene version (a gene version not found in either parent).		
The male parent has F1F3 gene versions while the female parent has F1F2 gene versions. Offspring D has F2F3 gene versions and has the trait for high silk flexibility. This is a trait that neither parent has.		

Name: _____ Date: _____

Writing About Variation in the Spider Offspring

Write a short argument to Dr. Sattari and the genetic researchers at Bay Medical Company supporting **Claim 3:** Offspring inherit different combinations of gene versions from their parents.

Before writing, you may wish to review your completed Reasoning Tool on page 106. Remember to include reasoning, explaining why your evidence matters.

Dear Dr. Sattari,

We have concluded that the spiders have different traits for silk flexibility because the offspring inherited different combinations of gene versions from their parents.

The evidence supports this claim because . . .

Name: _____ Date: _____

Breeding Spiders

Mission: Help Bay Medical Company Decide Which Spiders to Breed

Launch the Sim, and then determine which parents researchers should breed in order to produce offspring with the trait for medium silk flexibility. Record your results in the tables below. Then, share your recommendation with Bay Medical Company.

Note: You may need to run multiple tests with the same or different parents.

Test 1

	Gene versions for silk flexibility	Trait for silk flexibility
Parent 1		
Parent 2		

What percentage of the offspring had the trait for medium silk flexibility? (circle one)

a. 0%
b. 25%
c. 50%
d. 75%
e. 100%

Test 2

	Gene versions for silk flexibility	Trait for silk flexibility
Parent 1		
Parent 2		

What percentage of the offspring had the trait for medium silk flexibility? (circle one)

a. 0%
b. 25%
c. 50%
d. 75%
e. 100%

Name: _____ Date: _____

Breeding Spiders (continued)

Test 3

	Gene versions for silk flexibility	Trait for silk flexibility
Parent 1		
Parent 2		

What percentage of the offspring had the trait for medium silk flexibility? (circle one)

a. 0%
b. 25%
c. 50%
d. 75%
e. 100%

Bay Medical Company should breed spiders with the following gene versions in order to produce the greatest number of offspring with the trait for medium silk flexibility.

Parent 1: _____

Parent 2: _____

Name: _____ Date: _____

Homework: Reading "Can Genes Affect Running Ability?"

Read the "Can Genes Affect Running Ability?" article, annotating as you read. When you have finished, review your annotations and answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

Scientists investigate in order to figure things out. Are you getting closer to figuring out why the spider family's traits vary?

1. I understand why spiders with different proteins in their cells will have different traits. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

2. I understand the role that genes play in making proteins. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

3. I understand why some spider offspring have one type of protein, and others have two types of proteins for silk flexibility. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding (continued)

4. I understand how sexual reproduction results in variation in the spider offspring's traits. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

5. What do you still wonder about why traits vary?

_____

_____

_____

Name: _____ Date: _____

Chapter 4: Explaining Variation in Running Ability
Chapter Overview

You will now apply your understanding of genes, proteins, traits, and inheritance to a mysterious case about human traits for running ability. Through an analysis of evidence, you will explain why one member of a family is an elite distance runner when no one else in her family has this trait.

Name: _____ Date: _____

Lesson 4.1: Analyzing Evidence

In response to your recommendations, Bay Medical Company is making progress with their research on the medical uses of Darwin's bark spider silk. Now the genetic researchers at Bay Medical Company need your help with a new project. They are investigating the ACTN3 protein and its effect on running ability. To learn more about ACTN3, the researchers are studying a family of runners. They want to know why the daughter, Jackie, is an elite long-distance runner when no one else in her family has this trait. Today, you will work with your partner to analyze evidence and discuss how it might support or refute claims about how Jackie ended up with a trait that no one else in her family has.

Unit Question

- Why do traits vary, and why do they vary even between parents and offspring and among siblings?

Chapter 4 Question

- Why is Jackie an elite distance runner when no one else in her family has that trait?

Key Concepts

- The function of a protein molecule depends on its structure and how it interacts with other protein molecules.
- Differences in the structure of protein molecules affect how they connect to other protein molecules. This can result in different traits.
- The structure of molecules determines how they function at a molecular scale, which determines the properties of the object they make up.
- Organisms can have different proteins in their cells for a particular feature.
- Genes are instructions for proteins.
- Each gene version provides a unique instruction to make a specific protein molecule in an organism's cells.
- An organism has two copies of a gene for each feature.
- The two copies of a gene for each feature can be the same version (homozygous) and provide instructions for only one type of protein.
- The two copies of a gene for each feature can be different versions (heterozygous) and provide instructions for two types of proteins.
- Organisms inherit their genes through sexual reproduction.
- Each parent randomly passes on one of its two copies of each gene to its offspring. Each offspring, therefore, receives two copies of each gene, one from each parent.
- Through sexual reproduction, each offspring can inherit a different combination of gene versions. Therefore, siblings can have different traits from each other and even from their parents.

Name: _____ Date: _____

Lesson 4.1: Analyzing Evidence (continued)

Vocabulary

- claim
- evidence
- feature
- function
- gene
- gene version
- heterozygous
- homozygous
- inherit
- mutation
- protein molecule
- sexual reproduction
- structure
- trait
- variation

Digital Tools

- *Traits and Reproduction* Simulation

Name: _____ Date: _____

Warm-Up

Revisiting the Anticipation Guide

Review your original response to this statement from the Anticipation Guide on page 6:

All traits are determined by the experiences an organism has or the environment it lives in. For example, you will have the trait of being a strong swimmer if you swim a lot and live in or near the water.

Do you agree or disagree with this statement now? What evidence supports your ideas about the statement?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Science Seminar Claims

Chapter 4 Question

- Why is Jackie an elite distance runner when no one else in her family has that trait?

Claim 1: Jackie's trait is due to her **training**.

Claim 2: Jackie has a different **combination of gene versions**. Jackie's trait can be explained by the combination of gene versions she inherited from her parents.

Claim 3: Jackie has a **mutation** in her gene for the ACTN3 protein. This mutation instructs for a protein that results in the long-distance running trait instead of the sprinting trait.

Based on your initial thinking, which claim do you think explains why Jackie is an elite distance runner when no one else in her family has that trait? (check one)

- ☐ Claim 1
- ☐ Claim 2
- ☐ Claim 3

Name: _____ Date: _____

Analyzing Evidence

Annotating and Discussing the Evidence

Read and annotate the Science Seminar Evidence Cards. Use the questions below to guide you as you analyze each card.

- What questions do you have about the information on the card?
- How is the evidence connected to what you have been learning about proteins, traits, and genes?
- How might the evidence help you answer the question about Jackie's trait for running ability?

When you are finished annotating the cards, share your annotations with your partner. Use the suggestions below to guide your discussion.

- Discuss the annotations and questions you had about the Science Seminar Evidence Cards. If possible, answer each other's questions.
- Are there any two pieces of evidence that you think could work together? How do you think these two cards are connected to each other?

Name: _____ Date: _____

Sorting Evidence

1. With a partner, discuss whether or not each piece of evidence supports or refutes a claim. Use the sentence starters below to help you discuss these claims with your partner.
2. Add new annotations to each evidence card:
   - If the evidence supports a claim, write "Supports Claim __ (1, 2, or 3)" on the card.
   - If the evidence refutes a claim, write "Refutes Claim __ (1, 2, or 3)" on the card.
   - If the evidence connects one evidence card with another, write "Connects with Evidence Card __ (A–F)" on the card.
3. Sort the evidence by placing the cards under the claim they support.

Sentence Starters

I think this evidence supports this claim because . . .

I don't think this evidence supports this claim because . . .

I agree because . . .

I disagree because . . .

Why do you think that?

Name: _____ Date: _____

Homework: Observing Mutations in the Sim

Launch the Sim to create mutant spider offspring.

The genetic researchers at Bay Medical Company want to know whether or not they can create new silk traits in spiders by mutating genes. Dr. Sattari wants you to see how often a gene mutation leads to a new spider trait. Follow the steps below to conduct your research.

1. Mate two spiders. Then, press CREATE REPRODUCTIVE CELLS.
2. Press MUTATE. Notice a few features in the Feature menu bar will now have a pink dot. This dot indicates that there has been a mutation to the gene for this feature.
3. Select the features with pink dots, observing the mutations.
4. Press RANDOMLY FERTILIZE. Notice if any offspring inherited a mutation. If so, did this mutation result in a new trait?
5. Answer the questions below.

Did any of the gene mutations result in a new trait? (check one)

- ☐ yes
- ☐ not yet

Do you think a mutation (created during reproduction) in one gene is likely to result in a new trait in an offspring? Why or why not?

_____

_____

_____

Now mate at least one offspring with a mutation with another spider. (**Note:** If you get all male or all female offspring, press BACK to mate the spiders again.) Press RANDOMLY FERTILIZE.

Was the mutation passed on to the offspring? Why or why not?

_____

_____

_____

Name: _____ Date: _____

Homework: Reading "Growing Giant Pumpkins"

You have learned a lot about how genes instruct for proteins, which determine an organism's traits. To learn about other ways that traits can be affected, read and annotate the article "Growing Giant Pumpkins" and answer the questions below.

What kind of seeds should farmers plant in order to grow giant pumpkins, and why is this important?

_____

_____

_____

_____

What are the important things farmers should do to take care of the pumpkin plant in order to grow a giant pumpkin?

_____

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 4.2: Science Seminar

Why is Jackie an elite distance runner when no one else in her family has that trait? In today's Science Seminar, you and your classmates will discuss this question, using all the evidence to arrive at the best explanation you can for why Jackie has this trait. By the end of the lesson, you will be ready to write a convincing scientific argument for the researchers at Bay Medical Company.

Unit Question

- Why do traits vary, and why do they vary even between parents and offspring and among siblings?

Chapter 4 Question

- Why is Jackie an elite distance runner when no one else in her family has that trait?

Key Concepts

- The function of a protein molecule depends on its structure and how it interacts with other protein molecules.
- Differences in the structure of protein molecules affect how they connect to other protein molecules. This can result in different traits.
- The structure of molecules determines how they function at a molecular scale, which determines the properties of the object they make up.
- Organisms can have different proteins in their cells for a particular feature.
- Genes are instructions for proteins.
- Each gene version provides a unique instruction to make a specific protein molecule in an organism's cells.
- An organism has two copies of a gene for each feature.
- The two copies of a gene for each feature can be the same version (homozygous) and provide instructions for only one type of protein.
- The two copies of a gene for each feature can be different versions (heterozygous) and provide instructions for two types of proteins.
- Organisms inherit their genes through sexual reproduction.
- Each parent randomly passes on one of its two copies of each gene to its offspring. Each offspring, therefore, receives two copies of each gene, one from each parent.
- Through sexual reproduction, each offspring can inherit a different combination of gene versions. Therefore, siblings can have different traits from each other and even from their parents.

Name: _____ Date: _____

Lesson 4.2: Science Seminar (continued)

Vocabulary

- claim
- evidence
- feature
- function
- gene
- gene version
- heterozygous
- homozygous
- inherit
- mutation
- offspring
- protein molecule
- sexual reproduction
- structure
- trait
- variation

Name: _____ Date: _____

Warm-Up

Science Seminar Claims

Claim 1: Jackie's trait is due to her **training.**

Claim 2: Jackie has a different **combination of gene versions.** Jackie's trait can be explained by the combination of gene versions she inherited from her parents.

Claim 3: Jackie has a **mutation** in her gene for the ACTN3 protein. This mutation instructs for a protein that results in the long-distance running trait instead of the sprinting trait.

Which claim do you now think is most convincing? (check one)

- ☐ Claim 1
- ☐ Claim 2
- ☐ Claim 3

Draw a star on the Science Seminar Evidence Card that you feel best supports your claim. Why did you choose this piece of evidence?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Science Seminar Observations

Write a check mark in the right-hand column every time you hear one of your peers say or do something listed in the left-hand column. If you hear an interesting idea, write it in the last row of the table.

Observations during the seminar	**Check marks**
I heard a student use evidence to support a claim.	
I heard a student respectfully disagree with someone else's thinking.	
I heard a student explain how her evidence is connected to her claim.	
I heard a student evaluate the quality of evidence.	
I heard an idea that makes me better understand one of the claims. That idea is:	

Name: _____ Date: _____

Homework: Reflecting on the Science Seminar

Now that the Science Seminar is over, review the claims again. After participating in the discussion, you may have changed your mind about which claim you think is best. Answer the questions below to reflect your current thinking.

Science Seminar Question: Why is Jackie an elite distance runner when no one else in her family has that trait?

Science Seminar Claims

Claim 1: Jackie's trait is due to her **training.**

Claim 2: Jackie has a different **combination of gene versions.** Jackie's trait can be explained by the combination of gene versions she inherited from her parents.

Claim 3: Jackie has a **mutation** in her gene for the ACTN3 protein. This mutation instructs for a protein that results in the long-distance running trait instead of the sprinting trait.

Which claim do you now think is most convincing? (check one)

- ☐ Claim 1
- ☐ Claim 2
- ☐ Claim 3

What evidence best supports your claim? If you have your Science Seminar Evidence Cards with you, review them before answering the question.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 4.3: Writing a Scientific Argument

Why is Jackie an elite distance runner when no one else in her family has that trait? You have already carefully considered the claims and available evidence regarding the Smith family. You have discussed these claims and the evidence with your fellow classmates. Now, it is time to write your argument. Today, you will review the evidence, using the Reasoning Tool to organize your thinking. You will then write an argument about why Jackie has this trait when no one else in her family does. You will consider if Jackie's trait is due to: her training, the combination of gene versions she inherited, or a mutation. Do your best to make your argument as convincing as possible.

Unit Question

- Why do traits vary, and why do they vary even between parents and offspring and among siblings?

Chapter 4 Question

- Why is Jackie an elite distance runner when no one else in her family has that trait?

Key Concepts

- The function of a protein molecule depends on its structure and how it interacts with other protein molecules.
- Differences in the structure of protein molecules affect how they connect to other protein molecules. This can result in different traits.
- The structure of molecules determines how they function at a molecular scale, which determines the properties of the object they make up.
- Organisms can have different proteins in their cells for a particular feature.
- Genes are instructions for proteins.
- Each gene version provides a unique instruction to make a specific protein molecule in an organism's cells.
- An organism has two copies of a gene for each feature.
- The two copies of a gene for each feature can be the same version (homozygous) and provide instructions for only one type of protein.
- The two copies of a gene for each feature can be different versions (heterozygous) and provide instructions for two types of proteins.
- Organisms inherit their genes through sexual reproduction.
- Each parent randomly passes on one of its two copies of each gene to its offspring. Each offspring, therefore, receives two copies of each gene, one from each parent.
- Through sexual reproduction, each offspring can inherit a different combination of gene versions. Therefore, siblings can have different traits from each other and even from their parents.

Name: _____ Date: _____

Lesson 4.3: Writing a Scientific Argument (continued)

Vocabulary

- claim
- evidence
- feature
- function
- gene
- gene version
- heterozygous
- homozygous
- inherit
- mutation
- protein molecule
- refute
- sexual reproduction
- structure
- support
- trait
- variation

Name: _____ Date: _____

Warm-Up

Making a Convincing Argument

Sawako and Madeline are students who have been investigating the effects of drinking cola. Read and compare their arguments. Then, answer the questions below.

Sawako's Argument

Drinking cola is bad for your health. Cola contains a caramel coloring ingredient called 4-mel. Avoid drinking cola in order to stay healthy.

Madeline's Argument

Drinking cola is bad for your health. Cola contains 4-mel, which is a caramel coloring ingredient that has caused cancer in lab rats. Many things that are bad for rats are bad for other living things, such as humans. Therefore, drinking cola is harmful to the health of humans.

Which argument is more convincing? (circle one)

a. Sawako's argument
b. Madeline's argument

What makes one argument more convincing than the other?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Using the Reasoning Tool

Part 1: Reviewing the Evidence and Choosing a Claim

Review your evidence cards. Then, with your partner, discuss which claim you will support. Remember: It's okay to change your thinking.

Science Seminar Question: *Why is Jackie an elite distance runner when no one else in her family has that trait?*

Science Seminar Claims

Claim 1: Jackie's trait is due to her **training.**

Claim 2: Jackie has a different **combination of gene versions.** Jackie's trait can be explained by the combination of gene versions she inherited from her parents.

Claim 3: Jackie has a **mutation** in her gene for the ACTN3 protein. This mutation instructs for a protein that results in the long-distance running trait instead of the sprinting trait.

Part 2: Using the Reasoning Tool to Support Your Claim

Use the Science Seminar Reasoning Tool sheet to explain how the evidence supports your claim. Follow the instructions below.

1. Record the claim that you think is best supported by the evidence (in the **Therefore,** column). If you prefer, you can also write and record your own claim.
2. Tape the evidence cards that support your claim to the Reasoning Tool (in the **Evidence** column). You do not need to use all the cards, but you can use more than one to support your claim.
3. Use the middle column (**This matters because . . .**) to record how the evidence in the left column connects to the claim in the right column.

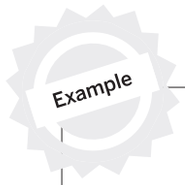
Name: _____ Date: _____

Preparing to Write

Plan how you will use your completed Reasoning Tool to write your argument. Use the example below to guide you.

Using the Reasoning Tool to Support Your Claim

- Circle your strongest piece of evidence.
- Draw an X over those pieces of evidence that you do not plan to use in your argument.
- Draw an arrow to connect two pieces of evidence if you think that they go together.



Evidence	**This matters because . . .** (How does this evidence support the claim?)	**Therefore, . . .** (claim)
Example Evidence Card A	Your ideas about how the evidence supports the claim	Your claim
Example Evidence Card B	Your ideas about how the evidence supports the claim	
Example Evidence Card C	Your ideas about how the evidence supports the claim	

Name: _____ Date: _____

Writing a Scientific Argument About Jackie's Trait for Running Ability

Scientific Argument Sentence Starters

Describing evidence:	**Explaining how the evidence supports the claim:**
The evidence that supports (or refutes) my claim is . . .	If ___, then . . .
My first piece of evidence is . . .	This is important because . . .
Another piece of evidence is . . .	Since . . .
Scientists found . . .	Based on the evidence, I conclude that . . .
	This claim is stronger (or weaker) because . . .

Write a scientific argument that addresses the question: *Why is Jackie an elite distance runner when no one else in her family has that trait?*

1. Review your completed Reasoning Tool. Be sure to include your strongest piece of evidence and make a connection between the pieces of evidence that go together.
2. State your claim, explaining how it leads to Jackie's trait for running ability. Then, use the evidence to support your claim.
3. Use the Scientific Argument Sentence Starters above to help you explain your thinking.
4. To make your argument more convincing, be sure to answer the following questions:
   - Which combinations of gene versions do you think Jackie's mom has? Explain your thinking.
   - Which combinations of gene versions do you think Jackie has? Explain your thinking.
   - How do Jackie's gene versions relate to her trait for running ability?

Name: _____ Date: _____

Writing a Scientific Argument About Jackie's Trait for Running Ability (continued)

Name: _____ Date: _____

Homework: Revising an Argument

Revising an Argument

1. Reread your scientific argument about Jackie's trait for running ability. If needed, finish writing your argument.
2. Then, look for ways you could make your argument clearer or more convincing. Consider reading your argument aloud or having another person read it.
3. Consider the following questions as you review your argument:
   - Does your argument clearly explain why Jackie has a trait that no one else in her family has?
   - Do you describe your supporting evidence?
   - Do you thoroughly explain how the evidence supports your claim?
4. Rewrite any sections of your argument that could be clearer or more convincing.

Name: _____ Date: _____

Homework: Revising an Argument (continued)

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

1. I understand that scientists use evidence to evaluate competing explanations. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

2. What are the most important things you have learned in this unit?

_____

_____

_____

_____

_____

_____

3. What questions do you still have?

_____

_____

_____

_____

_____

_____

Traits and Reproduction Glossary

allele: a specific form of a gene that provides instructions for making a particular protein molecule

alelo: una forma específica de un gen que proporciona instrucciones para hacer una molécula de proteína particular

chromosome: a long piece of DNA that contains many genes

cromosoma: un pedazo largo de ADN que contiene muchos genes

claim: a proposed answer to a question about the natural world

afirmación: una respuesta propuesta a una pregunta sobre el mundo natural

DNA: a type of molecule that genes and chromosomes are made of

ADN: un tipo de molécula de la que están hechos los genes y los cromosomas

evidence: information about the natural world that is used to support or go against (refute) a claim

evidencia: información sobre el mundo natural que se utiliza para respaldar o rechazar (refutar) una afirmación

feature: a characteristic that all members of a species have

atributo: una característica que tienen todos los individuos de una especie

fertilization: when a male and a female reproductive cell combine to create an offspring

fertilización: cuando una célula reproductiva masculina y una célula reproductiva femenina se combinan para crear descendencia

function: how something works

función: como trabaja algo

gene: an instruction for making a protein molecule

gen: una instrucción para formar una molécula de proteína

gene version: a specific form of a gene that provides instructions for making a particular protein molecule

versión de gen: una forma específica de un gen que proporciona instrucciones para hacer una molécula de proteína particular

heterozygous: having gene versions that are different

heterocigótico: que tiene versiones de genes que son diferentes

homozygous: having gene versions that are the same

homocigótico: que tiene versiones de genes que son iguales

inherit: to receive genes from a parent

heredar: recibir genes de uno de los padres

mutation: a random change to a gene that sometimes results in a new trait

mutación: un cambio aleatorio a un gen que a veces da como resultado un rasgo nuevo

nonfunctional protein: a protein molecule that does not perform its function, often because it does not connect to other molecules

proteína no funcional: una molécula de proteína que no desempeña su función, a menudo porque no conecta con otras moléculas

nucleus: the part of a cell where genes are found

núcleo: la parte de una célula donde se encuentran los genes

offspring: an organism produced as a result of reproduction

descendencia: un organismo producido como resultado de la reproducción

protein molecule: a type of large molecule that performs important functions inside organisms

molécula de proteína: un tipo de molécula grande que desempeña funciones importantes dentro de organismos

reasoning: the process of making clear how your evidence supports your claim

razonamiento: el proceso de aclarar cómo tu evidencia respalda tu afirmación

ribosomes: the parts of the cell that build protein molecules based on instructions from genes

ribosomas: las partes de la célula que construyen moléculas de proteína con base en las instrucciones de los genes

scientific argument: a claim supported by evidence

argumento científico: una afirmación respaldada por evidencia

sexual reproduction: the process in which two parents pass on their genes to create offspring

reproducción sexual: el proceso en el cual un padre y una madre transmiten sus genes para generar descendencia

structure: the way something is shaped or constructed
estructura: la manera en la cual algo está formado o construido

trait: a specific characteristic of an individual organism
rasgo: una característica específica de un organismo individual

variation: any difference in traits between individual organisms
variación: cualquier diferencia de rasgos entre organismos individuales

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Traits and Reproduction:

The Genetics of Spider Silk

Article Compilation

Table of Contents: Articles

Spider webs come in all shapes and sizes, but they are all made of spider silk.

Surprising Spider Silk

Chapter 1: Different Silks for Different Functions

Deep inside the body of a spider, specialized cells produce protein molecules that are much longer than ordinary protein molecules. These long protein molecules connect to form an amazing material: spider silk.

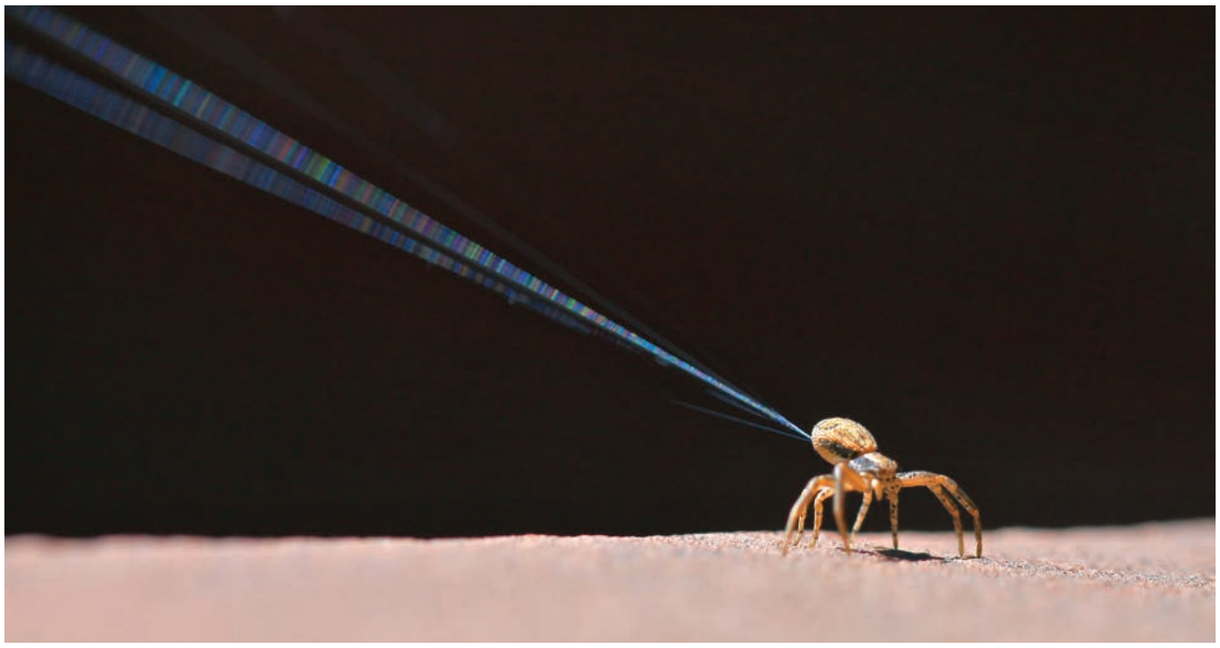
Spiders use their silk to build strong webs, to trap bugs, to save themselves from falling, to wrap their eggs safely, and even to glide through the air. How can one material—spider silk—be used for so many different functions? Different uses for spider silk are possible because not all spider silk is the same: there are many variations, or differences, in spider silk. This is because there are different features of spider silk, such as strength, stickiness, stretchiness, and color. For each of these features, there

Here is a close-up of a spider that makes golden colored spider silk.

are several possible traits. For example, for the feature of silk color, a spider might have the trait of making gray, white, or even golden-colored silk.

Spiders have different traits for each feature because of differences in the protein molecules that make up the silk. The cells of different spiders make different kinds of protein molecules, and these molecules combine to make different kinds of silk. This means that the kind of protein molecules a spider makes for a feature determine its trait for that feature. The spider pictured here makes specific protein molecules for the silk color feature. These protein molecules result in golden-colored spider silk.

To learn more about some amazing spider silks and the proteins that make them that way, read one or more of the chapters that follow.



Some spiders shoot silk into the air and use the silk as a sail for gliding.

Chapter 2: Spider Silk for Gliding Through the Air

A tiny spider climbs to the tip of a leaf. It stands up high on its legs, tilts its body upward, and shoots out several threads of fine, wispy silk. The wind catches the silk and it becomes a kind of sail, lifting the spider into the air. The spider glides away under its silk sail, traveling much faster than it could by crawling along the ground.

The weight of the spider silk is a feature. Some spiders have the trait for a kind of lightweight silk called gossamer silk. Gossamer silk is extremely light and fine because of the protein molecules it is made of. These proteins make gossamer silk perfect for gliding: the light silk catches the air, but doesn't weigh the spider down.

This photo shows strands of spider silk in mid-air. A spider may be hitching a ride! (It would be too small to see from this distance.)

This spider has surrounded itself with a circle of sticky white silk.

Chapter 3: Spider Silk for Spitting at Prey

A spitting spider prowls through the night, finding its way in the dark by feel. A small moth wanders into its path. The spider spits out a stream of sticky silk, waving it back and forth to cover its prey. The moth never had a chance!

Silk stickiness is a feature. The spitting spider has the trait for extremely sticky spider silk. This silk is so sticky because of the protein molecules that make it up. The silk also contains another kind of protein: venom. The venom paralyzes insects, making them unable to move. Once its prey is paralyzed, the spitting spider moves in to feast.

Chapter 4: Spider Silk for Living Underwater

Imagine an animal that needs air to breathe, but spends its whole life underwater. How could it possibly survive? Diving bell spiders manage to do it...with the help of spider silk. Diving bell spiders use their silk to build themselves tiny underwater homes.

To make its home, a diving bell spider weaves a waterproof net of silk and attaches it to an underwater plant. Then the spider gathers bubbles of air from the surface. It carries the bubbles down to the silk net, filling the net with air. When it is finished, the diving bell spider has a small air-filled chamber surrounded by a net of silk. Because of the protein molecules it is made of, the silk net holds air in and keeps water out.

Scientists have studied the air inside diving bell spiders' homes. They've discovered something surprising: oxygen gas dissolved in the surrounding water comes in through the silk walls, giving the spiders extra oxygen to breathe. The silk net keeps water out, but lets oxygen in. That's very special silk—and it's all thanks to the proteins that make it up.

Diving bell spiders breathe air from bubbles underwater.

Darwin's bark spiders build some of the world's largest webs.

Chapter 5: Spider Silk for Super-Sized Webs

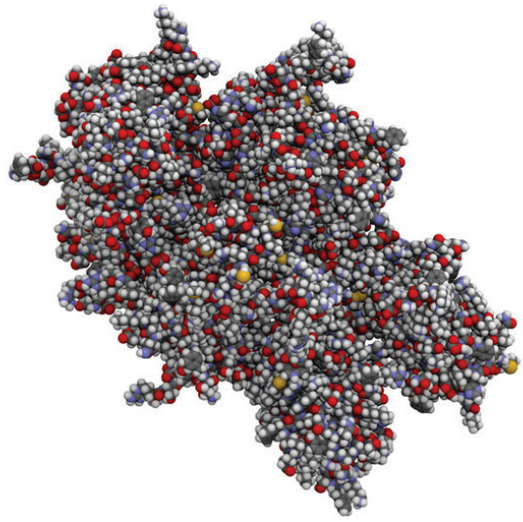
You are boating down a river in Madagascar. You look up and see a spider web stretching from one side of the riverbank, all the way across the river, to the bank on the other side. This huge web is the work of a Darwin's bark spider.

Darwin's bark spiders build some of the world's largest webs—as big as 82 feet across. To build such huge webs, Darwin's bark spiders need to produce very strong silk. The strength of spider silk is a feature. Darwin's bark spiders have the trait for extremely strong spider silk. Scientists only discovered these spiders recently, and they are studying the spiders' silk to find out what makes it so strong. Because spider silk is almost entirely made of protein molecules, it may be something about the protein molecules that makes Darwin's bark spider silk so strong.

Darwin's bark spiders are large spiders that produce very strong silk.

Clotting factor proteins work together to bind blood cells into a clot that stops the bleeding.

Hemophilia, Proteins, and Genes



There are thirteen different clotting factor proteins. This model represents a molecule of one of these proteins—the one most hemophilia patients are missing.

You fall off your bike and scrape your knee. Blood drips out, but soon a scab starts to form and the bleeding stops. Sounds simple, doesn't it? However, if you could zoom in to see what's happening on a molecular scale, it's not simple at all. Your blood includes thirteen different protein molecules called clotting factors. When you injure yourself, these clotting factor proteins all connect and work together to form a solid clot (also known as a scab). If you were missing even ONE of those thirteen proteins, the clot wouldn't form, and the dangerous bleeding would continue. This is exactly what happens in a disease called hemophilia (HEE-mo-FEEL-ya). People with hemophilia are missing one of the proteins needed for blood clotting.

Causes of Hemophilia

People with hemophilia are missing clotting factor proteins because of a problem with their genes. Different genes carry instructions for making different proteins. For every gene, there may be several possible versions. (Different versions of a gene can also be

called alleles.) An organism has two copies of each gene. Those gene copies can either be the same version (homozygous) or different versions (heterozygous). If the gene copies are homozygous, just one type of protein is produced, since both gene copies give the same instructions. If the gene copies are heterozygous, two types of protein are produced, since each gene copy gives a somewhat different instruction.

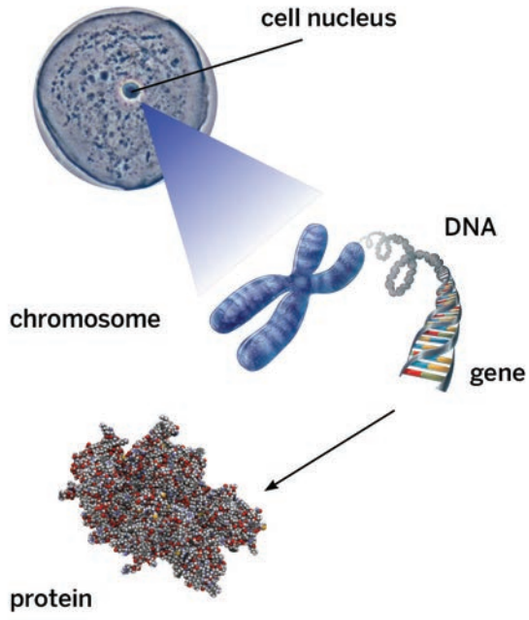
People with hemophilia have a version of the gene that doesn't have the right instructions for making clotting factor protein. Without the right instructions, their cells can't make that protein—or they make a protein that doesn't work. Without functional clotting factor protein, the proteins in their blood can't make the connections needed to form clots and build scabs. Healthy people have at least one copy of the gene version that provides the right instructions for making all of the clotting factor proteins.

Being able to form scabs may seem so basic that it's strange to think of it as a genetic trait like having brown eyes or having freckles. However, just like those other traits, the ability to form scabs is a trait that is determined by proteins. To have that trait, you need to have those proteins—and to make those proteins, you need to have the genes that give your cells the instructions for making them.

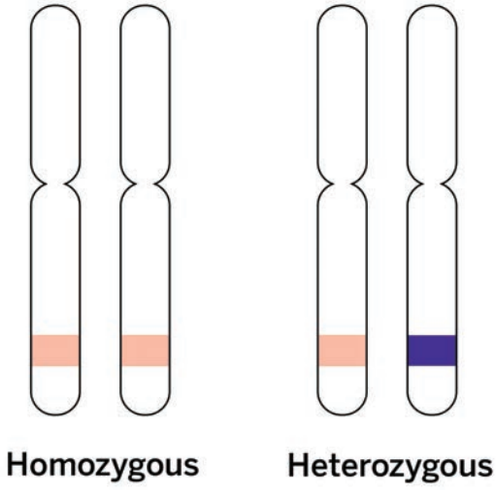
Treating Hemophilia with Proteins

Even though hemophilia is a serious disease, most hemophilia patients can live relatively normal lives if they get proper treatment. Hemophilia is caused by a missing protein, so doctors treat it by replacing that protein. Doctors inject clotting factor protein into a patient with hemophilia so the patient's blood clots the way it is supposed to. Injecting the protein into the body does not change

Genes and Proteins



Genes are located on chromosomes in the cell's nucleus. They provide instructions for building protein molecules. People with hemophilia can't make a clotting factor protein because of a change in one of their genes.



An organism with two gene copies that are the same is homozygous, while an organism with two gene copies that are different is heterozygous.

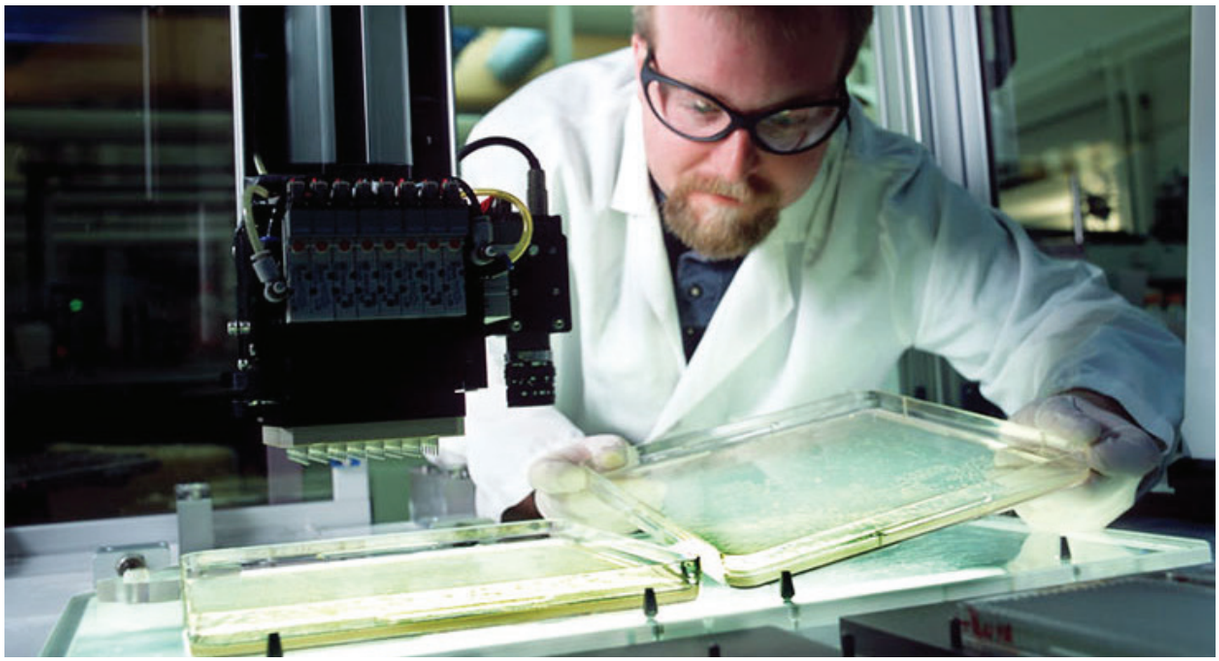
the proteins the body produces; instead, it supplies the protein the blood needs to clot properly. People with hemophilia need to have the missing protein injected into their bodies throughout their lifetimes because the injected protein will be used up. The patients then need to be injected again for their blood to continue to form clots properly.

For many years, the only way to get clotting factor protein was to separate the protein from donated blood. However, it takes a lot of blood to get just a little bit of clotting factor protein! Today, scientists can make lots of clotting factor protein by inserting human genes into hamster chromosomes. If you put the human gene for making clotting factor protein into the chromosomes in the nucleus of a hamster cell, the cell makes the protein. Even though it's a hamster cell, the cell makes clotting factor protein that's identical to clotting factor protein made in human cells. As long as the cell has the gene with instructions for making clotting factor protein, the cell will make the protein.

Gene Therapy for Hemophilia

Hemophilia can be treated using clotting factor protein, but it can't be cured...for now, at least. Scientists are researching possible cures for hemophilia: cures that would get the patient's own cells to produce clotting factor protein. For this kind of a cure, scientists would have to figure out how to fix a patient's faulty gene for making clotting factor protein. If the faulty gene were fixed, the patient's cells could start making clotting factor protein naturally. Working to fix or replace genes is called gene therapy. Hemophilia can't be cured with gene therapy yet, but scientists are working on it.

Scientists are making progress in treating hemophilia and other genetic diseases.



This scientist is working on the Human Genome Project, making a map of all the genes in the human body.

Exploring the Human Genome

The world is full of places to explore. For thousands of years, people have been visiting new places to learn about them—hacking their way through the jungle or climbing the world's tallest peaks. However, not all explorers spend their time learning about new places on the globe. Some scientists explore the human body. Scientists have learned a lot about how the body works, but there is still a lot to learn. Through the Human Genome Project and the Human Proteome Project, scientists all over the world are working to explore and map the genetic landscape of the human body.

The instructions to make and maintain a human are located on thousands of genes inside the nuclei of body cells. All of these instructions together are called the human genome, and as new technologies have developed, scientists have been able to learn more about how it works. Between 1990 and 2003, scientists all over the world worked together to make a map of the human genome. The goal of the Human Genome Project was to find out exactly where, and in what order, each gene of the human body is located. Understanding how many genes there are in the body and where each gene is located is the first step in being able to identify how genes interact—and also the first step in creating medical treatments that target specific genes. As a result of the Human Genome Project, scientists know that there are about 20,500 genes in the human genome.

All people's genes have a lot in common. For example, eye color is determined by multiple genes, and these genes are located in the same place on the same chromosome for all people. However, there's also variation in these genes—different people have different versions of these genes, which is why people have so many different eye colors. There's also lots of variation in other genes, including genes involved in diseases. Through cooperation between many scientists, the Human Genome Project laid the groundwork to create medicine

that is made specifically for each patient, depending on his or her genome.

Having a map of the human genome is a huge step toward understanding our genes and how they affect us. However, genes aren't the end of the story. Each gene instructs the body to produce a particular protein or proteins. The Human Proteome Project is a current collaboration between scientists that takes the work of the Human Genome Project a step further. The goal of the project is to discover which genes code for which proteins in the body. By examining different types of normal tissue from all over the body, scientists are identifying which proteins appear and which genes they come from.

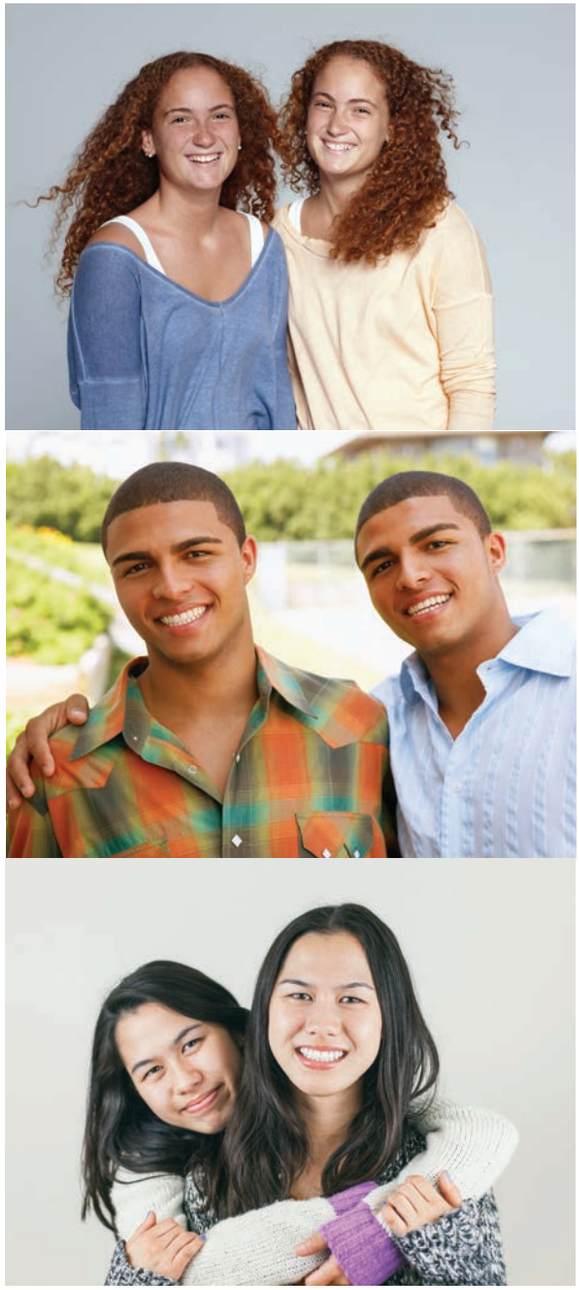
Together, the Human Genome Project and the Human Proteome Project will help us better understand how the body works and will change the way we treat disease. New technology has allowed scientists to see how chromosomes, genes, and proteins work together. Without biomedical research technologies, we would not be able to understand what happens inside the nuclei of body cells. What scientists learn from these projects may unlock many important discoveries for the future.

Why Are Identical Twins Rare?

Everyone is different. We can recognize one another's faces because every face is unique, with different combinations of traits like eye color, skin color, nose shape, and so on. All these differences are called variation. Where does variation come from? Genes instruct for proteins, which determine our traits. People have different traits because our protein molecules are different, and our proteins are different because our genes are different. Every human has a unique set of genes, different from anyone else's...at least, almost all of us do.

Imagine knowing someone who looks almost exactly like you—so much like you that people often mistake you for each other. You are the same height, your hair and eyes are the same colors...even the shape of your smile is the same. If you are an identical twin, you already know what that's like.

Identical means "exactly the same." Identical twins look so much alike because they have the same proteins, and they have the same proteins because their genes are the same. How can two different people end up with identical genes?



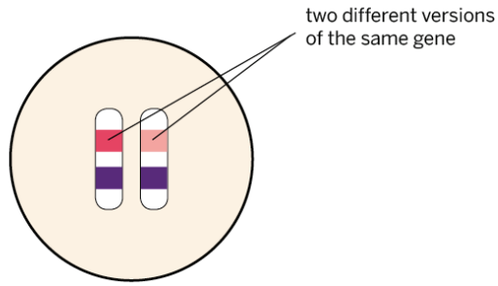
Identical twins are identical because their genes are the same.

How We Get Our Genes

We inherit our genes from our biological parents through the process of sexual reproduction. Each parent has a complete set of genes. These genes are organized on matching pairs of chromosomes. Each chromosome pair has two copies of each gene. However, the two copies of any particular gene can be the same version or different versions.

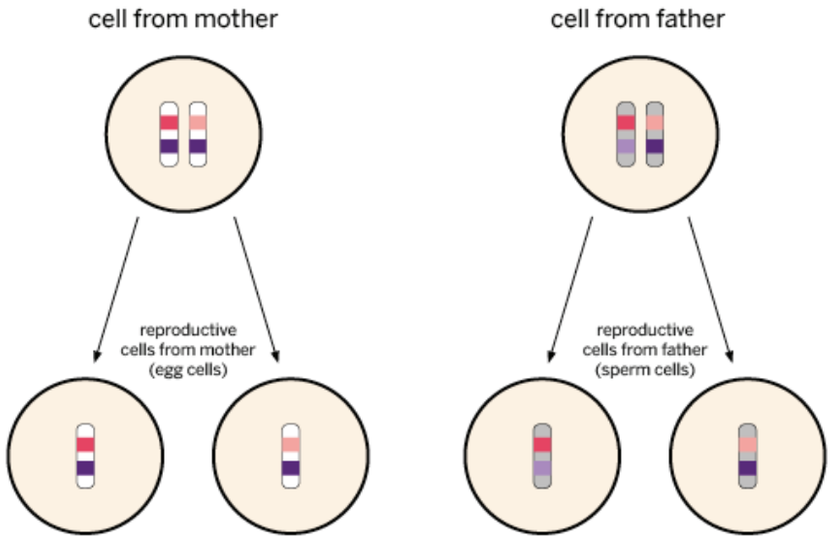
Sexual reproduction involves special reproductive cells from both parents. The mother's reproductive cells are called eggs, and the father's reproductive cells are called sperm. Unlike other cells that have two copies of every gene, egg cells and sperm cells only have one copy of each gene, which means the cell only contains one version of each gene. If a parent has two different versions of the gene, some reproductive cells will end up with one version, while other reproductive cells will end up with the other version. Each time these special cells are produced, the division of genes is different and random. Every sperm or egg cell is unique!

Chromosome Pair



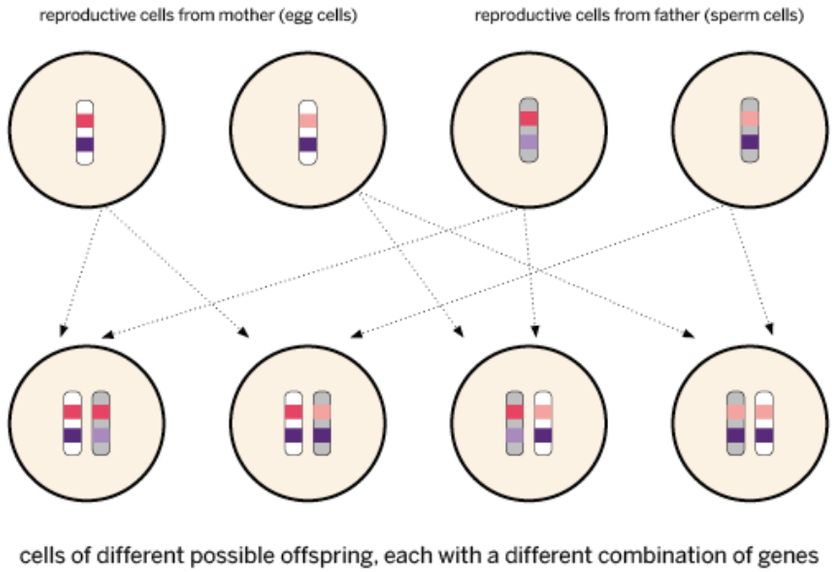
This is a simplified diagram. It shows a cell with just one pair of chromosomes. People don't really have one pair: we have 23 pairs! That's too many to show in this diagram.

Sexual Reproduction



While all other cells contain two gene copies, reproductive cells are different. They contain just one gene copy.

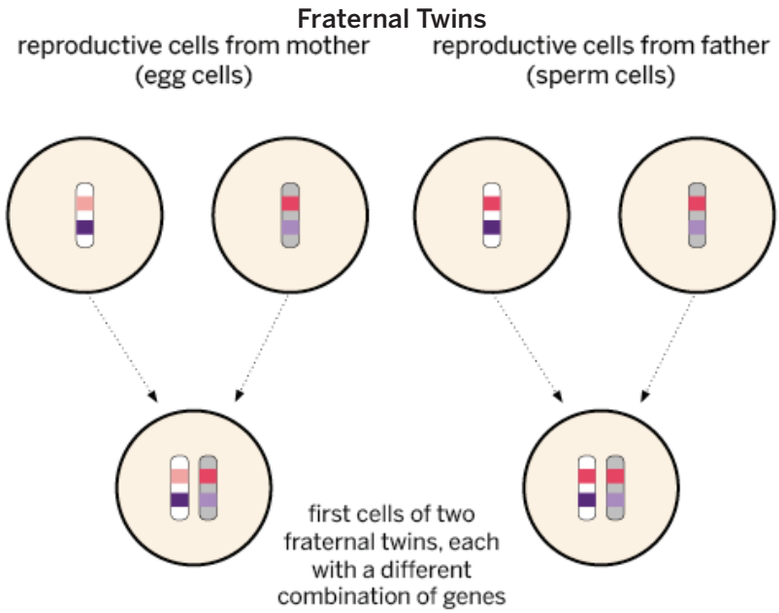
Sexual Reproduction
Possible Reproductive Cell Combinations



Reproductive cells can combine in lots of different ways. This diagram shows four possible combinations for just one chromosome. Remember, humans have 23 chromosomes! The possibilities are practically endless.

When the egg and sperm cells from two parents come together, fertilization occurs. Fertilization is when these cells combine to form the first cell of a new offspring. This new cell has two copies of each gene, one from each parent. Each parent randomly passes on only one copy of each gene, so there can be lots of possible combinations of genes passed on from two parents. The many possible combinations of genes are what give us variation.

All variation in humans comes from sexual reproduction. Identical twins DO vary from their parents; however, identical twins have the same gene versions as each other. How is this possible? To understand why, let's think about the difference between identical twins and fraternal twins.



Because fraternal twins inherit totally different combinations of genes from their parents, they can vary genetically.

Not All Twins Are Identical

Many sets of twins are fraternal twins. Unlike identical twins, fraternal twins have different traits. They may have different eye colors and different heights, and can even be different sexes. There can be lots of variation between fraternal twins.

The difference between fraternal twins and identical twins has to do with fertilization. In fraternal twins, fertilization happens twice. A sperm cell from the father combines with an egg cell from the mother to form the first cell of one twin. At around the same time, a different sperm cell from the father fertilizes another egg cell from the mother to form the first cell of the other twin. The cells of these two twins inherit completely different combinations of genes from the parents. Because they inherited different genes, the fraternal twins will have different proteins—which will interact to determine different traits. Because sexual reproduction happens twice, and each time one copy of each gene is randomly passed on to each of the offspring, fraternal twins have lots of opportunities for genetic variation.

Fraternal twins can be of the same sex or different sexes.

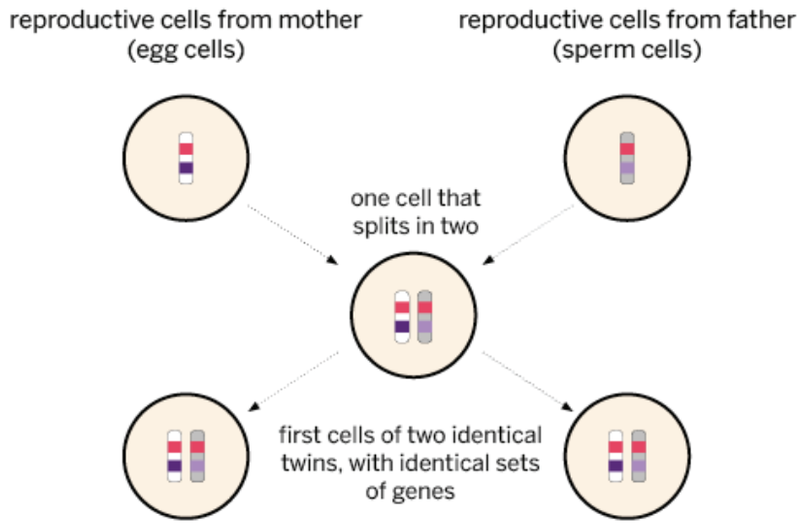
How Identical Twins Get Identical Genes

On the other hand, in identical twins, fertilization happens only once. A sperm cell from the father combines with an egg cell from the mother to form a cell. Then this single cell copies itself and splits, forming two identical cells—the first cells of two identical twins. The cells of these twins inherit the same combinations of gene versions, because they were produced from the same egg and sperm cells. Because they have the same genes, the identical twins will have identical genetic traits.

Of course, even identical twins will develop in different ways over their lives, becoming individual people with different talents and experiences. One twin may train to become a muscular body builder, while the other may sit at a computer writing all day. Just because they inherited the same genes, that doesn't mean they are the same person. Even identical twins aren't identical in every way.

Identical twins are the result of one fertilized egg splitting into two. Both twins have the same genes, which means they also have the same genetic traits.

Identical Twins



Identical twins happen when one fertilized egg splits into two cells. The two cells have exactly the same genes.

Periodical cicadas spend most of their lives underground.

Invasion of the Periodical Cicadas

It sounds like a scary movie: millions of insects spend years maturing underground, only to climb up to the surface and invade a town or city practically overnight. They have buzzing wings and orange eyes. They fly around and settle in the trees, singing a loud, rattling song. A few weeks later, they all die, leaving bug bodies all over the ground. Years later, their children appear and repeat the process.

It sounds like a movie, but it isn't—it really happens in certain parts of the United States. The invading insects are cicadas (si-KAY-dahs), flying insects known for the loud, rattling sound the males make when they try to attract females. Cicadas spend most of their lives underground, but they emerge by the millions at certain times and in certain places to find mates, reproduce, and die.

There are many species of cicada. Some have one-year life spans: they mature for one year, come above ground to reproduce, then die. Others are known as periodical cicadas—they live underground for many years before it's time to come above ground. They are called "periodical" because they appear above ground periodically, or on a predictable schedule. Periodical cicadas come up once every 13 or 17 years to mate. Because some of them live at least 17 years, they may be the longest-living insects on Earth!

Arriving above ground all at once is good for the cicada species for two reasons. When there are millions of cicadas all looking for mates at the same time and in the same place, the odds of successful reproduction are much better. This means there will be a new generation of cicadas that will arrive above ground in another 13 or 17 years, like their parents. Cicadas aren't the only species that meet up at certain places and

times to reproduce: lots of species increase their odds of finding a mate by reproducing this way.

At the same time, having many cicadas above ground at once is a way of protecting the whole species from predators. When they appear, some cicadas will be eaten—but there are so many cicadas around that predators can't possibly eat all of them. Most of the cicadas survive and reproduce successfully. This strategy is bad for the cicadas that do get eaten, but it's a good way to keep the whole species going.

Why do the periodical cicadas emerge every 13 or 17 years? According to scientists, this long, odd-numbered life cycle is a way of avoiding predators with shorter, more regular life cycles. The populations of some bird species rise and fall every few years, so there are certain years where there are more birds around. If periodical cicadas were to appear more often, their mating time would be more likely to match up with the years where their predator populations were strong, causing more cicadas to be eaten. However, 13- and 17-year cycles don't really match up with any other species' cycles. Showing up in years where their predators are less common means fewer cicadas are eaten, and the new generation of cicadas can rise by the millions in another 13 or 17 years.

Why the Corpse Flower Smells So Bad

Sending out a terrible smell may not seem like the best way to increase your chance of reproducing. However, it's a very successful adaptation for the plant *Amorphophallus titanum*, or corpse flower.

Rotting meat smells awful to humans, but that same odor smells like a good meal to insects that eat rotting meat, like flesh flies and carrion beetles. In order to attract these insects, the corpse flower releases a powerful smell of decay. In addition, the plant has structures that increase reproductive success. For example, the petal of its flower is a deep red that's similar to the color of meat, and at the peak of its reproduction process, it gets warm, like a piece of rotting meat would be. All of these adaptations help the corpse flower attract insects that feed on decaying meat. By tricking insects into landing on it, the flower increases its odds of reproducing successfully.

Why does the corpse flower need to attract insects to reproduce? Flowering plants can't reproduce on their own: they need the pollen produced by their flowers to be moved from one plant to another, and they need animals to do the moving. This process is called pollination. Most plants are pollinated by bees, butterflies, moths, or bats. To make pollination more likely, some plants put out smells that attract the type of animal most likely to pollinate them—a sweet smell to attract bees, for example. In the case of the corpse flower, a rotting-meat smell attracts flies and beetles to help with pollination. More insects mean more chances to reproduce.

When it blooms, the corpse flower can reach six feet tall.

Many plants have structures and behaviors that increase their odds of reproducing.. In fact, that's why flowers have scents and colors in the first place—to attract a variety of pollinators. Other plants have structures like seeds that catch the wind or stick to animals passing by, which helps them come into contact with new environments. These adaptations all arose from random mutations in the plants' genes. Even though they were random, these particular mutations happened to help individual organisms reproduce and pass their genes on, and so the genes became more common in the population. So smelling like rotting meat might not be a great strategy for humans—but for the corpse flower, it's just the right thing.

Sea anemones are animals that attach themselves to the sea floor.

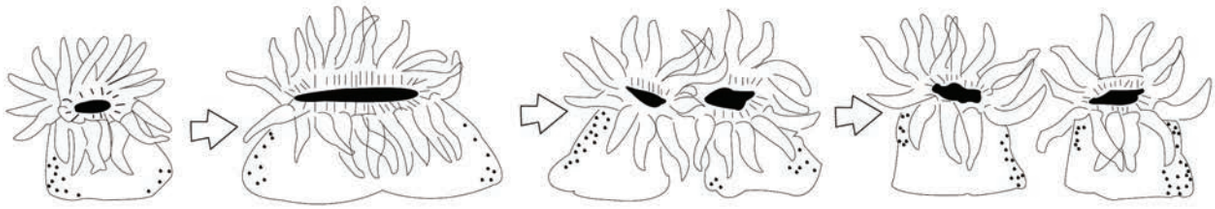
Sea Anemones: Two Ways to Reproduce

Can you split yourself in half to create a new you? You could if you were an aggregating sea anemone (ah-NEH-muh-nee). Sea anemones are animals that attach themselves to the sea floor. Most sea anemones have a thick stalk with finger-like parts at the top. They look a bit like plants growing out of the bottom of the ocean, but they are actually animals that eat tiny organisms they find floating in the water.

Splitting in half is a kind of asexual reproduction. Aggregating sea anemones can reproduce in two ways: through asexual reproduction and sexual reproduction. Either way, the end result is a new offspring sea anemone, so what difference does it make which way they reproduce?

Actually, it makes a big difference. When a sea anemone reproduces asexually, the offspring anemone is identical to the parent anemone, with exactly the same traits. However, when anemones reproduce sexually, the offspring are similar to their parents, but not exactly the same. Offspring produced through sexual reproduction will have variations from their parents—differences in their traits that could make a big difference to their survival.

To understand the difference between sexual reproduction and asexual reproduction, we need to get down to the level of cells. All living



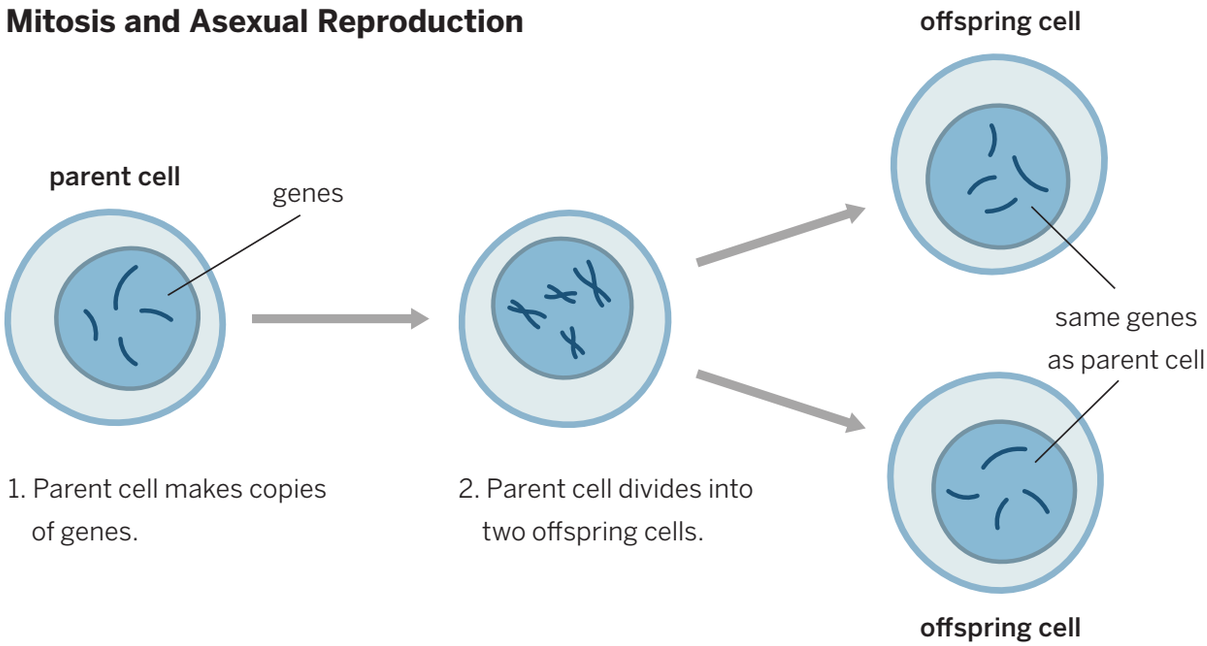
Aggregating sea anemones can reproduce asexually by splitting in half.

things are made of tiny cells—they are the basic building blocks of life, and they contain the genes that determine an organism's traits.

Asexual reproduction begins with a cell from the parent (you only need one parent for asexual reproduction!) dividing to become two cells. This kind of cell division is called mitosis (my-TOE-sis). Before it divides, the parent cell makes copies of the chromosomes that contain all its genes, so the new offspring cell contains a complete set of chromosomes (and genes) that are the same as the parent cell. This new offspring cell is what will develop to become the offspring organism. As the offspring organism grows, it will have the same traits as its parent organism because it has the same genes. Asexual reproduction is simple and convenient: the sea anemone doesn't even need to find a mate in order to reproduce.

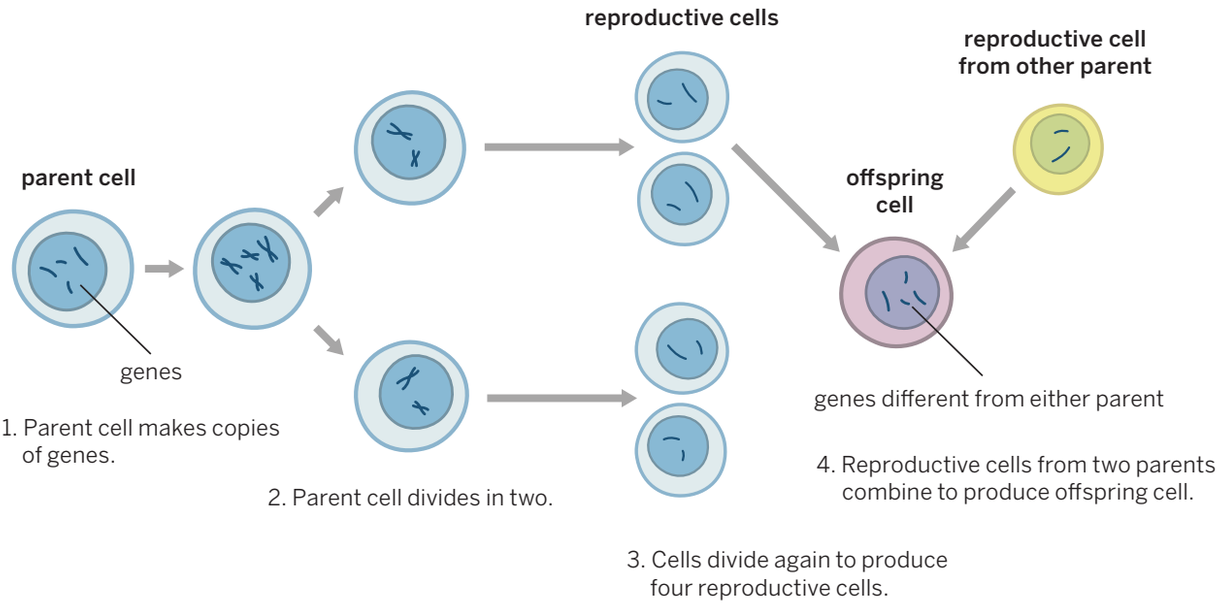
Sexual reproduction also begins with parent cells dividing, but the process is more complicated. For one thing, sexual reproduction requires two parent organisms instead of just one. In each parent organism, a cell copies its chromosomes and then divides in two—and then those two cells

Mitosis and Asexual Reproduction



Mitosis is one way that cells can divide in order to reproduce. Asexual reproduction involves mitosis.

Meiosis and Sexual Reproduction



Meiosis is another way that cells can divide in order to reproduce. Sexual reproduction involves meiosis.

divide in two again. This kind of cell division is called meiosis (my-OH-sis), and it results in four special reproductive cells from each parent. A reproductive cell only has half of the genetic information that an ordinary cell from the organism does.

After the reproductive cells have formed, there's still one more step to sexual reproduction. In a process called fertilization, two reproductive cells—one from each parent—come together to form a new offspring cell. This new offspring cell is what will develop to become the offspring organism. That new offspring has a full set of genes: half the genes came from one parent, and the other half came from the other parent.

Because the offspring gets half its genes from one parent and half from the other, the new offspring cell has a unique combination of genes, different from either one of its parents. This new offspring cell is what will develop to become the offspring organism. With a new combination of genes, the offspring will also have a new combination of traits. As it grows, the offspring organism will be similar to its parents, but it won't be exactly the same as either one of its parents.

Sexual reproduction helps produce variation in the traits of the organisms in a population, and variation is important because different traits may be helpful to survival in different conditions. That's why many organisms that can reproduce asexually (like aggregating sea anemones) also reproduce sexually.

Cloning Mammoths: A Mammoth Task

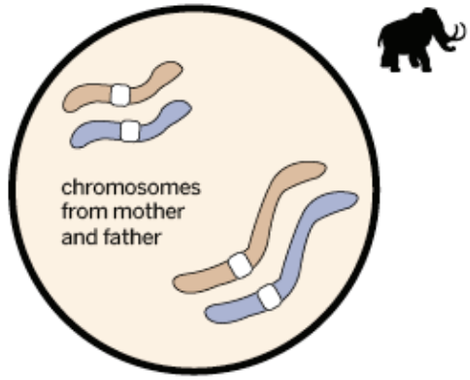
Imagine a huge, elephant-like creature covered in hair: a woolly mammoth. Mammoths died out thousands of years ago, but some mammoth bodies have stayed well-preserved in the frozen ground ever since. Scientists have been able to study mammoth DNA, and some are even considering the possibility of cloning a mammoth—using DNA from an ancient mammoth to make a new, living mammoth. Cloning a mammoth might give scientists new evidence about what these ancient animals were like and why they went extinct. Could it work?

This illustration shows a woolly mammoth, an animal that lived on Earth thousands of years ago. There are no woolly mammoths living on Earth today, but some scientists would like to try cloning them to bring them back.

Ingredients for a Mammoth

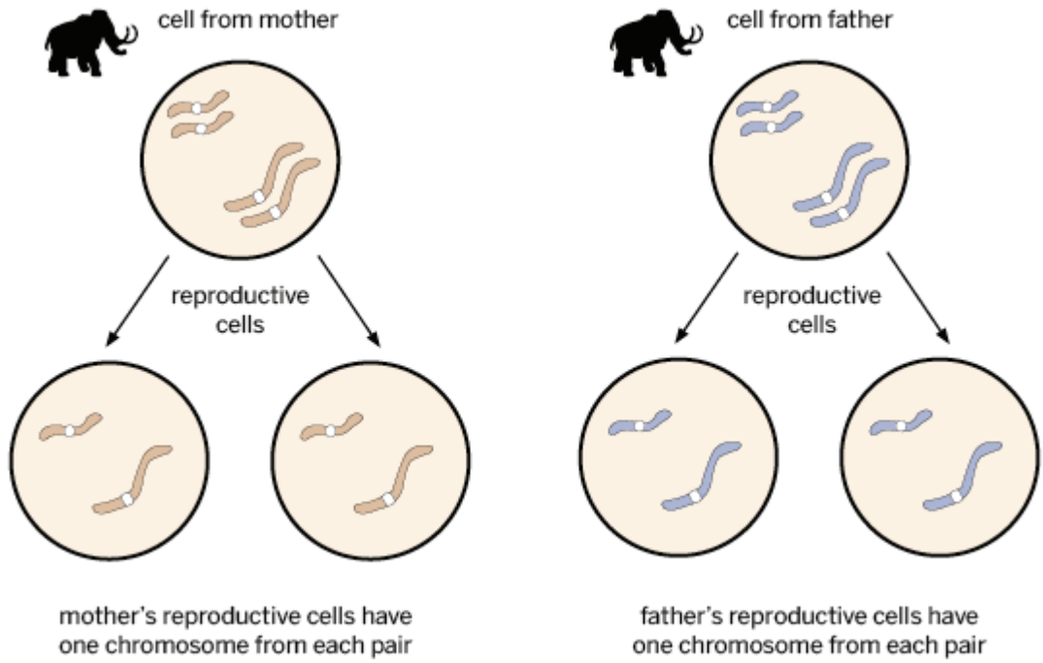
How do you make a mammoth? When mammoths were alive on Earth, every new baby mammoth was the offspring of a mother and a father mammoth. Each parent contributed half of the offspring's genetic material. The baby mammoth would get one set of chromosomes (which contain genes) from its mother and another set of chromosomes from its father. In Diagram 1, the chromosomes from the father are shown in blue and the chromosomes from the mother are shown in orange.

Diagram 1: Mammoth Cell



A baby mammoth's cells would get one set of chromosomes from its mother and one set of chromosomes from its father.

Diagram 2: Making Reproductive Cells



Reproductive cells have one chromosome from each of the organism's chromosome pairs.

Sexual Reproduction

Mother and father mammoths produced offspring through a process called sexual reproduction, just as many organisms do today. Sexual reproduction begins when both parents create reproductive cells. These reproductive cells are different from other cells in the body because they do not have chromosome pairs. Instead, reproductive cells have only one chromosome from each pair: half the genetic material of a normal cell.

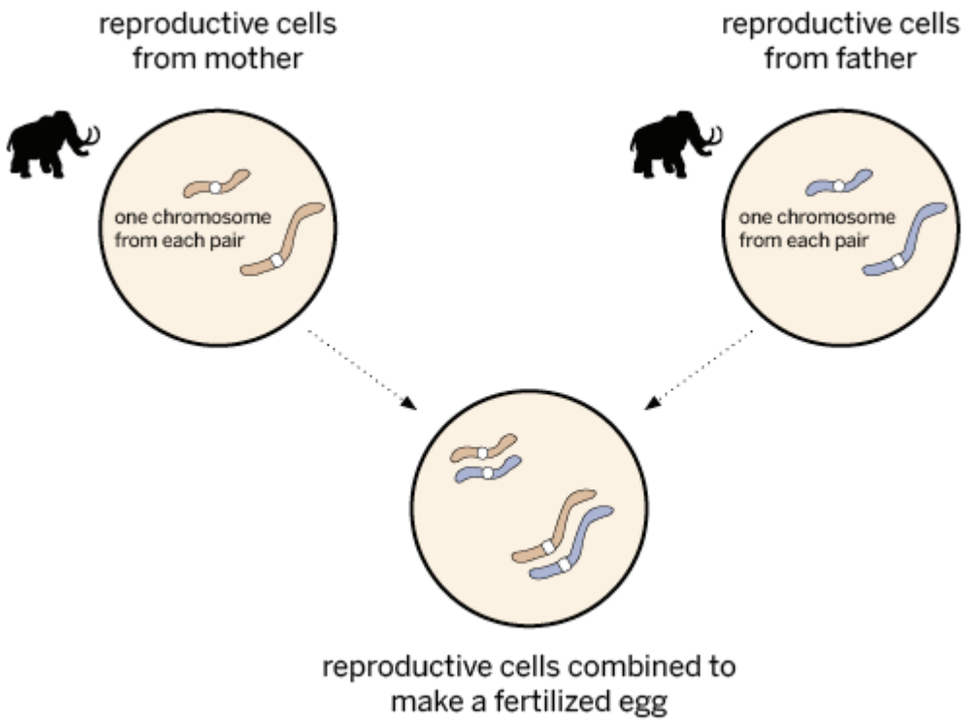
When a reproductive cell from a female mammoth and a reproductive cell from a male mammoth come together, they form a larger cell—the first cell of a new organism. Single chromosomes from each of the parents' reproductive cells match up to form pairs. Each pair contains one chromosome from the mother and one chromosome from the father. This new cell is what develops into a baby mammoth.

How Cloning Is Different

Here's the problem: there aren't any living mammoths left to be mothers and fathers of new mammoth offspring. That's where cloning comes in! The idea of cloning is to make a new mammoth but skip all those steps of making reproductive cells and combining them. When scientists create a clone, they do not need chromosomes from both a mother and a father, like those found in eggs and sperm—they only need chromosomes from one body cell of one parent organism. The body cell will already contain a full set of genes.

To clone a mammoth, scientists would have to find a cell with a perfectly preserved nucleus from the body of a dead mammoth. The nucleus is a structure inside the cell where the DNA and genes are found. The nucleus from the mammoth's cell needs to be put into an egg cell of a similar organism. In the case of mammoth

Diagram 3: Reproductive Cells Come Together



During reproduction, a reproductive cell from the mother and a reproductive cell from the father come together to make a fertilized egg. The fertilized egg gets chromosomes from both parents.

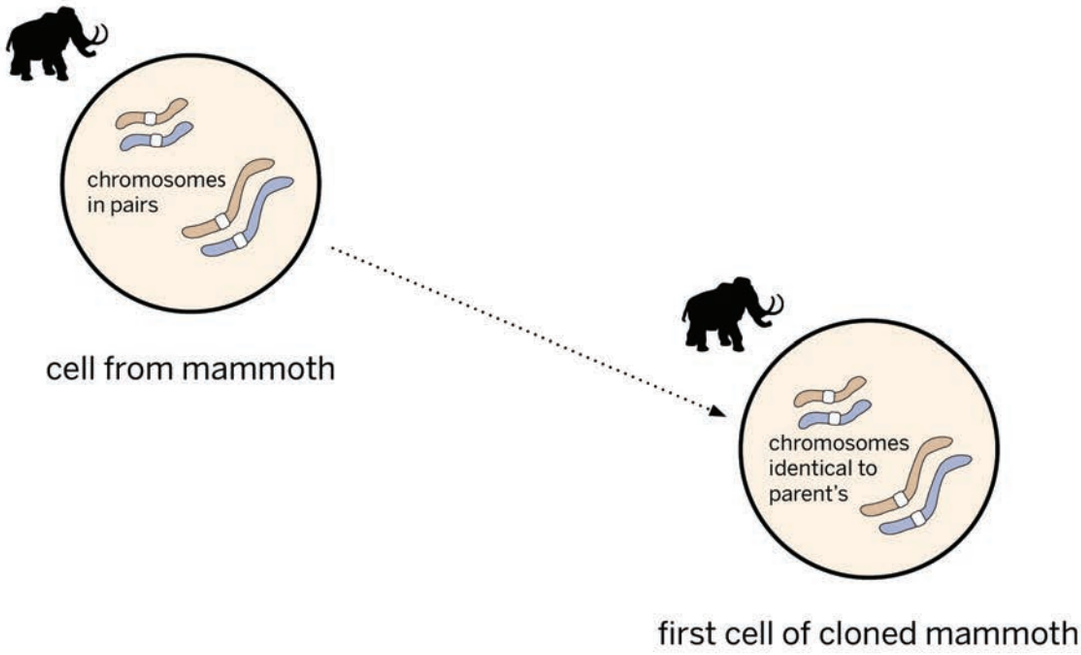
cloning, it would probably be an egg cell from an elephant. The scientists would remove the nucleus from the elephant's egg cell and replace it with the nucleus from the mammoth's cell. With the nucleus inside, the egg cell develops into a new mammoth with the same genes as the dead mammoth! In cloning, there is only one parent, and the cloned offspring has DNA identical to its parent's DNA.

Challenges of Cloning

Cloning is difficult, but scientists have managed to clone some living animals using this method. The first animal cloned in this way was a sheep named Dolly, and scientists have also been able to clone mice and several other animals since then. Cloning a mammoth would be an even bigger challenge than cloning a living animal. For one thing, finding a perfectly preserved mammoth nucleus would be extremely difficult. The last mammoth died thousands of years ago, and DNA becomes damaged after an animal dies.

In addition, a baby mammoth can't just develop in a lab–it needs to develop inside a mother's body. There aren't any mother mammoths around, but elephants are closely related to mammoths. Scientists would need to put an elephant egg cell with mammoth DNA inside it into a female elephant to develop. Elephants are pregnant for almost two years before they give birth, so scientists would have to wait at least that long for the cloned mammoth to be born. Only then would they find out whether they had successfully cloned a mammoth.

Diagram 4: Cloning



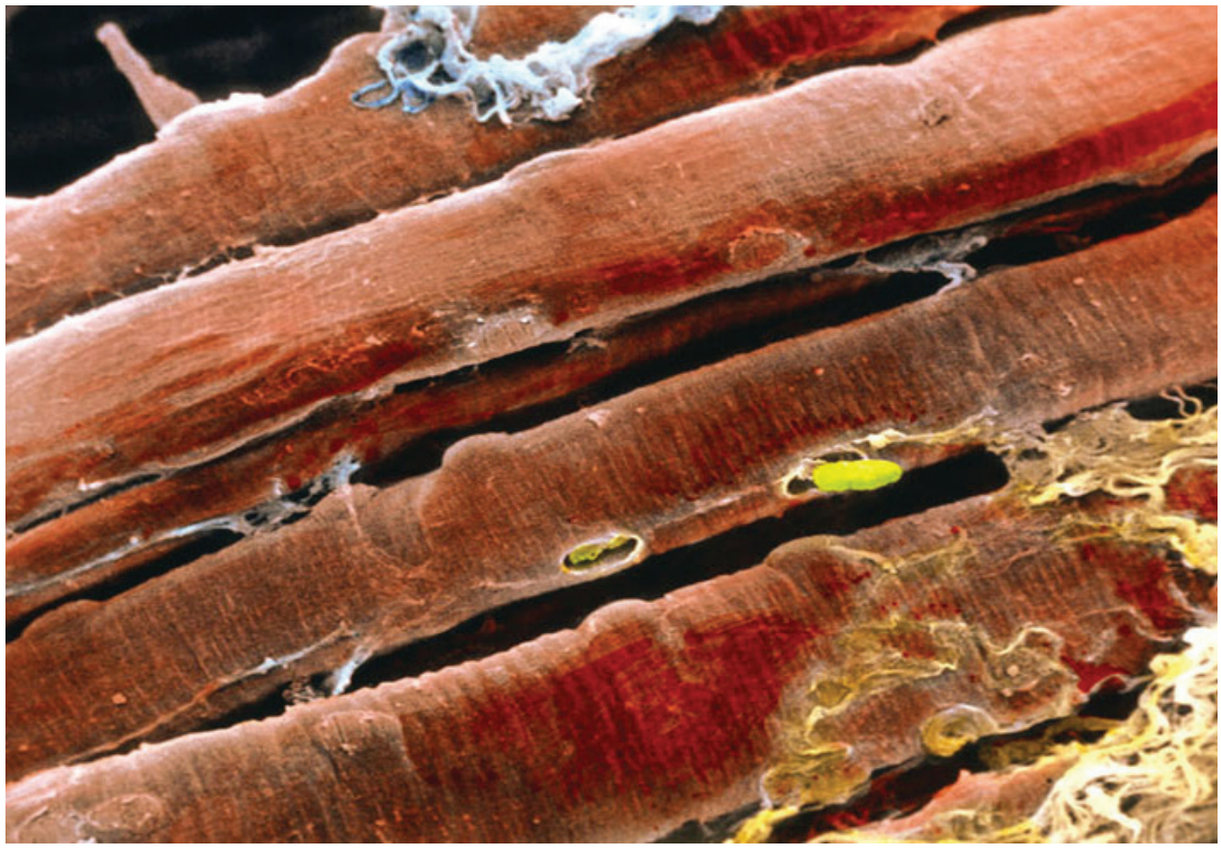
If a mammoth were cloned, its cells would be exactly the same as the cells of the mammoth it was cloned from.

Arguments for and Against Cloning

Many people argue that cloning is dangerous and wrong. Cloning is difficult, and it usually takes many failed attempts to produce one living clone. Some fear that cloned animals could have genetic problems that no one could predict. They also worry about what might happen if cloned animals escaped and reproduced with other animals. This could have unintended negative effects on wild populations and the whole ecosystem.

On the other hand, many argue that cloning can lead to medical advances. For instance, scientists have cloned some goats that were genetically modified to produce a human protein. This protein prevents blood clots and is important medicine for people who cannot make the protein themselves. Cloning helps scientists produce more goats that make this protein.

Most people feel uncomfortable with the idea of making a human clone. In fact, the United Nations has recommended the banning of human cloning. No one has succeeded in making a human clone, and very few scientists want to try. What are your thoughts on cloning?



The proteins that make up muscles are arranged in long, thin bundles. They stretch and contract to make the body move.

Can Genes Affect Running Ability?

The Human Muscle lab at Bay Medical Company has been studying the Alpha-actinin-3 protein (ACTN3 for short) found in the muscle cells of some people. They believe this protein molecule may affect the trait of running ability. Researchers think that the ACTN3 protein molecules help muscles move quickly. The experiments in their lab suggest that people with high amounts of ACTN3 protein are more likely to be sprinters (people who can run short distances very quickly).

During their research, they came across the case of the Smith family.

Jackie Smith is 16 years old. She is a champion long-distance runner. She is training for the Olympics.

Jackie's 20-year-old brother, Lincoln, is also a runner. He is a sprinter. He earned a college scholarship for sprinting and hopes to win a college race.

Jackie and Lincoln's mother was a sprinter in high school and college. She competed in many races.

Jackie and Lincoln's father has never been a serious runner.

It is unusual to find a family that has three competitive runners. It's especially puzzling that Jackie is a long-distance runner, unlike her brother and mother, who are sprinters. The lab contacted the family, but only Jackie, Lincoln, and their father agreed to participate in the Human Muscle lab's study. Jackie and Lincoln's mother decided not to participate in this research study, so information about her is not available.

Currently, researchers are working to understand why Jackie is a champion distance runner when no one else in her family has this trait.

People around the world compete to grow the largest pumpkins.

Growing Giant Pumpkins

Can you imagine a jack-o-lantern as big as a car? It might have glowing eyes as big as headlights and a grin as big as a bumper. A jack-o-lantern of that size has to come from a very large pumpkin! Some farmers do grow these giant pumpkins, competing to see who can grow the biggest and heaviest pumpkin. Growing giant pumpkins takes knowledge and skill, but farmers can use both genetic and environmental factors to make their pumpkins as big as possible. Planting the seeds with the best genetics for large pumpkins is as crucial as providing the best environmental conditions for pumpkins. Both factors strongly influence the growth of giant pumpkins.

Not every pumpkin is capable of growing to a monster size. Each pumpkin's genes determine how big it can get, and different types of pumpkins have genes that instruct them to grow in different ways. Some pumpkins' genes instruct them to stay small.

These small pumpkins are good for decorating. Others are medium-sized and good for making pies. One way farmers can grow the biggest pumpkins is by planting seeds from types of pumpkins that grow very large. Every world-

champion giant pumpkin grown since 1979 has come from the same type of seed, a variety called Atlantic Giant. Atlantic Giants can grow to weigh over 1,000 pounds!

Using Atlantic Giant seeds won't automatically allow you to grow a world-championship pumpkin, however. A giant pumpkin needs support from its environment to grow really huge. Farmers who grow giant pumpkins begin by making sure the soil has plenty of nutrients the pumpkin plant can use. They add plenty of fertilizer. They plant the pumpkin plants in sunny places so the plants' cells can perform lots of photosynthesis, and they make sure the plants get plenty of water. Another way farmers can encourage their pumpkins to grow is by making sure each plant only has one pumpkin—they cut off every vine except the one with the biggest, strongest pumpkin, and remove any other pumpkins that begin to grow on that vine. That way, all of the plant's energy and resources go toward just one pumpkin. A healthy Atlantic Giant pumpkin grown this way can gain 40 to 50 pounds every day. That's a lot of pie!

Farmers who grow giant pumpkins only allow one pumpkin on each vine to grow to maturity. This way all the plant's energy goes to that one pumpkin.

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The Genetics of Spider Silk

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