10 Animal Behavior

INVESTIGATION

2 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

Students analyze and interpret data to create arguments that explain behavioral and other traits in animals that at first glance seem to be either neutral or perhaps even harmful. By looking for patterns in the data, students develop arguments about how these traits cause the individual to have higher reproductive success than those with different traits. The activity provides an opportunity to assess student work related to Performance Expectation MS-LS1-4, focusing on animal traits. In the next activity, students will focus on plant traits.

NGSS CORRELATIONS

Performance Expectations

MS-LS1-4: Use argument based on empirical evidence and scientific reasoning to support and explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.

Disciplinary Core Ideas

MS-LS1.B Growth and Development of Organisms: Animals engage in characteristic behaviors that increase the odds of reproduction.

MS-LS4.C Adaptation: Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.

Science and Engineering Practices

Engaging in Argument from Evidence: Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

Analyzing and Interpreting Data: Analyze and interpret data to provide evidence for phenomena.

Crosscutting Concepts

Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural systems.

Patterns: Patterns can be used to identify cause and effect relationships.

Common Core State Standards—Mathematics

6.SP.A.2: Understand that a set of data collected to answer a statistical question has a distribution that can be described by its center, spread, and overall shape.

6.SP.B.4: Display numerical data in plots on a number line, including dot plots, histograms, and box plots.

Common Core State Standards—ELA/Literacy

RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

WHST.6-8.1: Write arguments focused on discipline-specific content.

WHAT STUDENTS DO

Students read one of four real-life case studies on a behavioral or physical trait in an animal. They examine and interpret graphs portraying data that relate directly or indirectly to the animals' reproductive success. Student groups must present and defend their arguments based on evidence to the rest of the class. In the Analysis, students consider which of the animal traits they examined are likely to be influenced primarily by genetics, the environment, or a combination of both.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*
  - 1 Scoring Guide: ENGAGING IN ARGUMENT FROM EVIDENCE (ARG)
  - 1 Visual Aid 10.1, "Reading and Interpreting Graphs"
  - Access to flamingos video
- *For each student*
  - 1 Scoring Guide: ENGAGING IN ARGUMENT FROM EVIDENCE (ARG) (optional)
  - 1 Literacy Student Sheet 4b, "Writing Frame—Engaging in Argument" (optional)

Preview the video before showing it to your students. For a link to the video, see the teacher page of the *SEPUP Third Edition Reproduction* website at *www.sepuplhs.org/middle/third-edition*.

TEACHING SUMMARY

GET STARTED

1. Students begin exploring traits in animals that at first seem useless or even harmful.
    a. Show the short video of flamingos without sound, and ask students to suggest explanations for the flamingos' behavior.
    b. Ask students how they could test their ideas.
    c. Consider showing the video again with the sound on.

DO THE ACTIVITY

2. Students work in groups to read one of four case studies to investigate a trait in an animal species and its effect on reproductive success.
    a. Let students know that they will work in their groups to analyze and interpret data about a trait to investigate that trait's effect on reproductive success.
    b. Discuss with students that reproductive success can be difficult to measure in nature, so sometimes researchers look at a trait that influences reproductive success that is easier to measure.
    c. (MATHEMATICS) Explain to students that they need to combine the information in the text with the graphical information.
    d. Assign groups to one of the four case studies.
    e. Explain your expectations for each group to present its investigation and argument to the rest of the class.
    f. Circulate throughout the room as groups read and evaluate their case studies.

BUILD UNDERSTANDING

3. Groups present their case studies to the rest of the class.
    a. Decide on the order for group presentations, and decide how groups that evaluated the same investigation will compare and contrast their arguments.

b. Have students summarize each investigation in their science notebooks after it has been presented.

4. (LITERACY, ARG ASSESSMENT) Students write an individual response to Analysis item 1.

5. Students address Analysis item 2.

   a. Instruct groups to read Analysis item 2 and decide which traits are affected by genes and which are effected by the environment.

   b. Have a class discussion to encourage some debate about genes versus the environment.

6. Students write a response to Analysis item 3 on Group Size in Meerkats.

   a. Instruct students to write a response to Analysis item 3.

   b. Let student know they should use the same process for developing their argument that they used for their first investigation.

   c. Facilitate a whole-class discussion in which groups share their arguments and challenge the arguments of others.

TEACHING STEPS

GET STARTED

1. Students begin exploring traits in animals that at first seem useless or even harmful.

   a. Show the short video of flamingos without sound, and ask students to suggest explanations for the flamingos' behavior.

      This video (3:22) shows a group of flamingos engaging in a collective mating display. Students responses may include that they are feeding, looking for food, or dancing, but accept all responses.

   b. Ask students how they could test their ideas.

      For example, to test the idea that flamingos dance to attract a mate, researchers could identify individual flamingos and keep track of how well they dance and how quickly they attract a mate. This would require researchers that have some way to determine the quality of the dance.

   c. Consider showing the video again with the sound on.

      The music and narration for this video adds a dramatic flair and makes clear that this is a mating dance.

DO THE ACTIVITY

2. Students work in groups to read one of four case studies to investigate a trait in an animal species and its effect on reproductive success.

   a. Let students know that they will work in their groups to analyze and interpret data about a trait to investigate that trait's effect on reproductive success.

   b. Discuss with students that reproductive success can be difficult to measure in nature, so sometimes researchers look at a trait that influences reproductive success that is easier to measure.

      Scientists are often interested in lifetime reproductive success, but because of the challenges of studying organisms in their natural settings, researchers are sometimes able to look at reproductive success for only one breeding cycle.

   c. (MATHEMATICS) Explain to students that they need to combine the information in the text with the graphical information.

      If your students need help with reading and interpreting graphs like the ones in the case studies, use Visual Aid 10.1, "Reading and Interpreting Graphs." This graph presents the percentage of students reporting bullying in middle and high school. Having students separate what they observe in a graph from their interpretation is a scaffolding tool that helps students correctly analyze graphical data.

      First, have students identify what they observe in the graph. For example, students might observe that there are green bars and purple bars; the green bars are from 2003 and the purple bars are from 1999; the x axis is divided into grades, from 6th grade to 12th grade; the y axis shows percentage of students bullied, from 0 to 15; the green bars are higher than the purple bars for each grade.

      Then have students interpret the graph. This graph indicates that the reported rate of bullying increased at all grades from 1999 to 2003 and that the reported rate of bullying is highest at the start of middle school and decreases every year through the end of high school.

This graph might mean that bullying has increased between 1999 and 2003 or that students are more likely to report bullying in 2003 than in 1999.

d. Assign groups to one of the four investigations.

The investigations are similar in their level of complexity, but they can be ranked roughly as follows, from most complex to least complex: Egg Color, Long-tailed Widowbirds, Meerkats, Deer Antlers. Assigning groups to cases based on complexity can be a way to differentiate so that the groups with lesser familiarity with interpreting graphs can be assigned to a slightly simpler case.

e. Explain your expectations for each group to present its investigation and argument to the rest of the class.

Each presentation should take 3–5 minutes plus 1–2 minutes for questions. The presentation should include a brief description of the investigation to provide the context for the investigation. Encourage other students to ask questions so that groups are challenged to defend their arguments, which should cite evidence from the text. Decide if you will require each student in the presenting group to speak at least once.

f. Circulate throughout the room as groups read and evaluate their case studies.

BUILD UNDERSTANDING

3. Groups present their case studies to the rest of the class.

a. Decide on the order for group presentations, and decide how groups that evaluated the same investigation will compare and contrast their arguments.

To help ensure that all students understand the context for each investigation, you may decide to do one of the following before each presentation: have students read that investigation to themselves, have a student read the investigation aloud, or read the investigation aloud yourself.

If two groups evaluated the same investigation, consider having one group present first and then having the second group add to or disagree with the first group's argument based on the evidence provided in the text or graph. Explain to groups that it is not necessary to repeat the same argument if they agree. This will encourage them to listen to each other's presentations and will allow students to practice engaging in argument with evidence.

b. Have students summarize each investigation in their science notebooks after it has been presented.

You might consider writing a concluding sentence on the board or chart paper if your students need this level of support. Let students know they will need to understand all of the investigations to answer the Analysis items.

4. (LITERACY, ARG ASSESSMENT) Students write an individual response to Analysis item 1.

a. Instruct students to write a response to Analysis item 1.

This item can be assessed using the ENGAGING IN ARGUMENT FROM EVIDENCE (ARG) Scoring Guide.

Consider distributing Literacy Student Sheet 4b, "Writing Frame—Engaging in Argument," to students to help them construct their written arguments.

This item corresponds to the Performance Expectation MS-LS1-4, focusing on animal traits.

5. Students address Analysis item 2.

a. Instruct groups to read Analysis item 2 and decide which traits are affected by genes and which are effected by the environment.

b. Have a class discussion to encourage some debate about genes versus the environment.

6. Students write a response to Analysis item 3 on Group Size in Meerkats.

a. Instruct students to write a response to Analysis item 3.

This question shows another factor that influence reproductive success of dominant females: group size. The larger a group, the higher the probability of a dominant female breeding.

b. Let student know they should use the same process for developing their argument that they used for their first investigation.

c. Facilitate a whole-class discussion in which groups share their arguments and challenge the arguments of others.

See Teacher Discussion Starters in the Literacy Strategies section of Teacher Resources II, "Diverse Learners," to help foster productive classroom discourse. Also consider having your students use Developing Communication Skills in Appendix E in their student books to help them interact productively.

SAMPLE RESPONSES TO ANALYSIS

1. (ARG ASSESSMENT) For the investigation your group presented, write an argument that explains how that trait increases an organism's reproductive success.

SAMPLE LEVEL-4 RESPONSES

Long-tailed widowbird—Long tails increase reproductive success by attracting more mates. The evidence supporting this claim is that male long-tailed widowbirds who were given longer tails had more nests in their territories than did males whose tail length stayed the same, and even more than males whose tails were shortened. Males whose tails were shortened had fewer nests than males whose tail length stayed the same, although that difference was smaller. The overall pattern is that a longer tail leads to having more nests. We can reason that the birds with more nests had more mates. Having more mates means that more offspring can be produced, so having a longer tail results in greater reproductive success. Males with longer tails may be able to attract more mates because they are easier to see when they are flying over their territories. Males with shorter tails may be harder to see.

Egg color—The ability to recognize and reject a parasite's egg increases a host's reproductive success. The evidence for this is that hosts who had artificial cuckoo finch eggs placed in their nests were more likely to reject the eggs if they were very different in color and pattern from their own. If the eggs had the same color or pattern, the hosts were less likely to reject the eggs. Since evidence also shows that having brood parasite eggs in their nests can reduce the hosts' number of offspring, we can reason that the ability to reject parasite eggs increases reproductive success. If the hosts can recognize the parasite's egg, then they can reject that egg and have a higher reproductive success than if they can't recognize it. Hosts that can easily tell the difference between their own and others' eggs have the highest reproductive success.

Deer antlers—Male red deer with large antlers have greater reproductive success than male red deer with smaller antlers. The evidence shows that male red deer who had antlers larger than the median antler size had more offspring in their lifetimes than did male deer with antlers smaller than the median. This difference was four offspring, which is more than the median number of three offspring for males with smaller antlers. Since having more offspring is, by definition, greater reproductive success, we can conclude that male deer with large antlers have greater reproductive success. Having larger antlers may help a male fight with other males to become the dominant male. The dominant male has the most mates, and more mates leads to more offspring and greater reproductive success.

Meerkats—The reproductive success of a dominant female meerkat is related to her weight. The evidence for this is that dominant female meerkats that are heavier for their age have a greater probability of breeding than do dominant females who are lighter for their age. We can reason that the higher probability of breeding leads to more offspring, so the larger a dominant female is for her age, the greater her reproductive success. Larger females may be better able to get resources, especially food, that are required for reproduction. Because meerkats live in groups, larger females may also get more support from the other meerkats in their group than do smaller females.

2. Which of the traits in the examples above are likely to be affected primarily by genetics? by the environment? by a combination of both? Explain your reasoning.

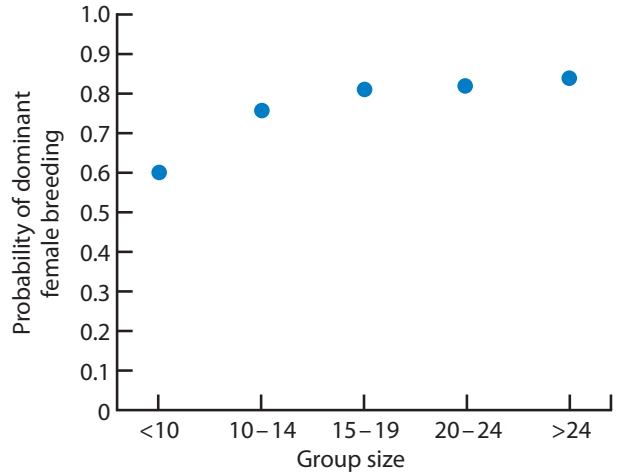
   The trait most likely to be influenced primarily by genetics is egg color, because we read that robin eggs are always blue, so that is likely a genetic trait. Being able to recognize egg color may be both genetic and learned, but it is difficult to know based on the data we were given. Tail length and antler size are probably influenced by both. We know that offspring look like their parents, so taller parents have taller offspring. But offspring might grow taller if they have more food, or not grow as tall if they don't have enough food. A bird may grow a longer tail and a deer may grow longer antlers if they have more food. With the meerkats, a dominant female's body size is probably also determined by both factors for the same reasons. A larger female probably had larger parents, but she can grow larger if she eats more.

3. The researchers studying the meerkats also looked at other relationships that influence the reproductive success of dominant females.

   a. What pattern(s) do you see in the data below?

      This graph shows points that start lower on the left and get higher towards the right, but then level off. The probability of a dominant female breeding is lowest for a group size below 10. For a group size larger than 24, the probability is the highest, although it's not that much greater than for a group of 21–24 meerkats.

Meerkat Group Size Results



b. Explain what these patterns tell you.

A higher probability of breeding means a higher reproductive success. So a dominant female has a higher reproductive success if she's in a bigger group. Group size is not a genetic trait, so a dominant female's reproductive success depends on environmental factors along with genetic factors like body size.

REVISIT THE GUIDING QUESTION

How do animal behaviors and other traits affect the probability of successful reproduction?

Animals have many different traits or adaptations that increase their reproductive success by increasing their chances of getting and competing for a mate, protecting their offspring, acquiring resources needed to breed, and helping their genetic relatives.

ACTIVITY RESOURCES

KEY VOCABULARY

reproductive success

BACKGROUND INFORMATION

SEXUAL SELECTION

Sexual selection is a kind of natural selection where traits evolve because they increase an organism's ability to obtain a mate. There are two ways such traits can be favored: female choice or male–male competition. (Whereas male choice and female–female competition do occur, the overwhelming pattern in nature is for males to possess elaborated traits like the peacock's tail or crab's claws.) In this activity, tail length in the long-tailed widowbird and antler size in red deer are both sexually selected traits. Tail length in the widowbird is likely the result of female choice, with females choosing males with longer tails because they signal to the female that the male is in good genetic condition. Antler size in deer is likely a trait to enhance a male's ability to compete with other males.

KIN SELECTION

Kin selection is a form of natural selection where traits can evolve because they increase the reproductive success of an organism's genetic relatives, even if it reduces the organism's own survival and reproduction. Alarm calling in Belding's ground squirrels is an example of kin selection. Giving a trill warning call poses a

risk to the caller. Because females are living among genetic relatives, even if they are killed by a hawk after trilling, they may be increasing their indirect reproductive success by ensuring the survival of their kin. Adult males, on the other hands, are living with fewer relatives because they disperse. Trilling imposes a risk that is not outweighed by benefits to kin. Whistle alarm calls do not pose a risk to the caller, and males and females are equally likely to whistle.

REFERENCES

Andersson, M. (1982, October 28). Female choice selects for extreme tail length in a widowbird. *Nature, 299,* 818–820. doi:10.1038/299818a0

Hodge, S. J., Manica, A., Flower, T. P., & Clutton-Brock, T. H. (2008). Determinants of reproductive success in dominant female meerkats. *Journal of Animal Ecology 77*, 92–102. doi:10.1111/j.1365-2656.2007.01318.x

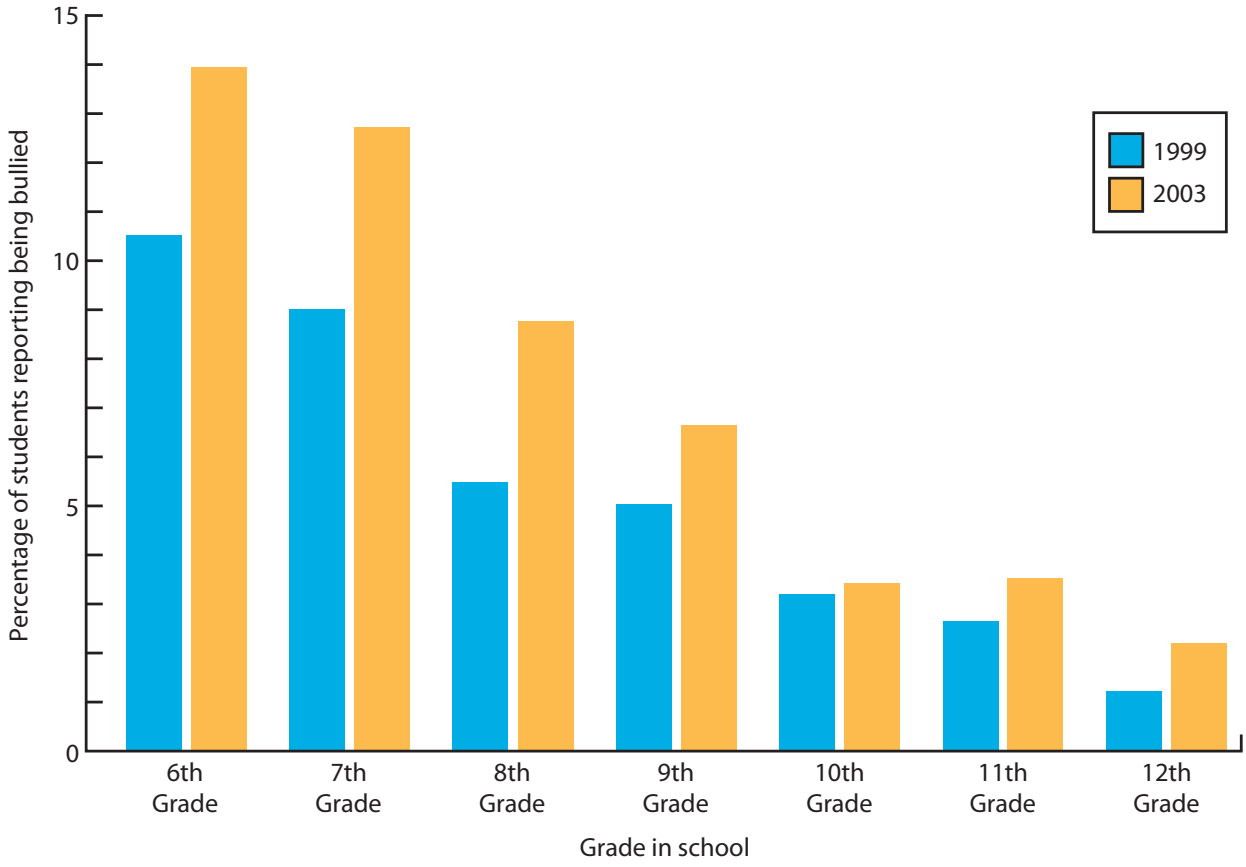
Kruuk, L. E. B., Slate, J., Pemberton, J. M., Brotherstone, S., Guinness, S. F. & Clutton-Brock, T. (2002). Antler size in red deer: Heritability and selection but no evolution. *Evolution, 56,* 1683–1695. doi:10.1111/j.0014-3820.2002.tb01480.x

Stevens, M., Trosciankso, J., & Spottiswoode, C. N. (2013). Repeated targeting of the same hosts by a brood parasite compromises host egg rejection. *Nature Communications 4*, 2475. doi:10.1038/ncomms3475

VISUAL AID 10.1

READING AND INTERPRETING GRAPHS

Reports of Students Being Bullied at School, 1999 and 2003



What patterns do you observe in this graph?

What is your interpretation of the graph?

11 Plant–Animal Interactions

INVESTIGATION

1 CLASS SESSION

ACTIVITY OVERVIEW

NGSS CONNECTIONS

Students obtain information about flower pollination and its importance to plant reproduction. They consider a number of adaptive plant structures and traits that attract animal pollinators. Students construct an argument for which kinds of pollinators are associated with different flower types. By looking for patterns among plant–animal interactions, students develop arguments for how these traits cause the individual plant to have a higher reproductive success than those with different traits. The activity provides an opportunity to assess student work related to Performance Expectation MS-LS1-4, focusing on plant–animal interactions.

NGSS CORRELATIONS

Performance Expectations

MS-LS1-4: Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.

Disciplinary Core Ideas

MS-LS1.B Growth and Development of Organisms:

Animals engage in characteristic behaviors that increase the odds of reproduction.

Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.

MS-LS4.C Adaptation: Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.

Science and Engineering Practices

Engaging in Argument from Evidence: Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

Obtaining, Evaluating, and Communicating Information: Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings.

Crosscutting Concepts

Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural systems.

Patterns: Patterns can be used to identify cause and effect relationships.

Structure and Function: Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts, therefore, complex natural and designed structures/systems can be analyzed to determine how they function.

Common Core State Standards—ELA/Literacy

RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

R.I.6.8: Trace and evaluate the argument and specific claims in a text, distinguishing claims that are supported by reason and evidence from claims that are not.

WHST.6-8.1: Write arguments focused on discipline-specific content.

WHAT STUDENTS DO

Students read about four different flowers, making note of some traits that may be important in pollination, like color, shape, size, and odor. Then they read about four different animal pollinators and develop an argument based on evidence in the reading for which of the four animals pollinates each of the four flowers. Students add to their arguments by matching four different scents with the flowers and their pollinators.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*
  - 1 Scoring Guide: ENGAGING IN ARGUMENT FROM EVIDENCE (ARG)
- *For each group of four students*
  - 1 Scratch-and-Sniff card
- *For each student*
  - 1 Scoring Guide: ENGAGING IN ARGUMENT FROM EVIDENCE (ARG) (optional)

SAFETY NOTE

If any of your students are sensitive to strong odors, they should not smell the scents on the scratch-and-sniff cards.

TEACHING SUMMARY

GET STARTED

1. Students think about traits that plants might have to increase their reproductive success.
   a. Ask students, "Do plants, like animals, have traits that increase their reproductive success? What are some of these traits?"
   b. Read or have a student read aloud the scenario that introduces the idea of plant–animal interactions.

DO THE ACTIVITY

2. In Procedure Part A, students obtain information about four kinds of flowers, four flower scents, and four potential pollinators.
   a. Instruct groups to follow the Procedure, which begins with obtaining information about flowers and recording that information in their notebooks.
   b. Circulate throughout the room to ensure that students understand the text box, Function of Flowers, and bring the class together to discuss it if many students are struggling.
   c. Direct students to continue obtaining information about animal pollinators.

d. Pass out the scratch-and-sniff cards when groups reach Procedure Step 4, pointing out the safety notice should any students be exceptionally sensitive to strong odors.

e. Direct students to Procedure Step 5, which has students matching each flower with its scent and with its animal pollinator.

BUILD UNDERSTANDING

3. Students respond to Analysis item 1, which asks them to create an argument that explains their matching of plants, scents, and pollinators.

   a. Direct students to Analysis item 1, and explain your expectations for how they may portray their arguments.

   b. Briefly summarize the overall patterns as a class by writing the patterns on the board or chart paper.

4. In Part B, students are presented with two additional flowers and are asked to create an argument for how these flowers are pollinated.

   a. Instruct students to read about the two additional flowers in Part B and, in their groups, develop a consensus response for each flower.

   b. Hold a class discussion to arrive at a class consensus.

   c. After students have presented their arguments, share that California poppies are pollinated by many types of insects, especially a beetle, and that big bluestem is wind-pollinated.

   d. (ARG ASSESSMENT) Instruct students to complete the Analysis.

TEACHING STEPS

GET STARTED

1. Students think about traits that plants might have to increase their reproductive success.

   a. Ask students, "Do plants, like animals, have traits that increase their reproductive success? What are some of these traits?"

      Accept all answers, although students may not have many suggestions. If necessary, prompt students to think about flowers, especially color and shape.

   b. Read or have a student read aloud the scenario that introduces the idea of plant–animal interactions.

DO THE ACTIVITY

2. In Procedure Part A, students obtain information about four kinds of flowers, four flower scents, and four potential pollinators.

   a. Instruct groups to follow the Procedure, which begins with obtaining information about flowers and recording that information in their notebooks.

      Decide how much guidance you want to give your students about how to organize their notes. If your class or individual students need support, you may want to suggest creating a table with columns for color, scent, shape, and size.

   b. Circulate throughout the room to ensure that students understand the text box, Function of Flowers, in Procedure Step 2.

      Consider bringing the class together to discuss the function of flowers and the importance of pollination to flowers.

   c. Direct students to continue obtaining information about animal pollinators.

      Provide supports, as you did with the section on flowers, with organizing the information they obtain.

   d. Pass out the Scratch-and-Sniff cards when groups reach Procedure Step 4, pointing out the safety note should any students be exceptionally sensitive to strong odors.

      Remind students to scratch the cards lightly because the cards will need to be reused in later classes. A spare set is provided if the scent dissipates too quickly.

   e. Direct students to Procedure Step 5, which has students matching each flower and its scent with its animal pollinator.

      Students will need to be able to create an argument for how they created their matches for Analysis item 1.

Most Likely Plant–Animal Pollinator Pairs

Plant	Scent	Animal pollinator
gardenia	2	moth
agave	3	bat
cardinal flower	1	hummingbird
corpse flower	4	fly

BUILD UNDERSTANDING

3. Students respond to Analysis item 1, which asks them to create an argument that explains their matching of plants, scents, and pollinators.

    a. Direct students to Analysis item 1, and explain your expectations for how they may portray their arguments.

    Consider allowing students to present their arguments graphically or as written arguments to allow for differentiation.

    b. Briefly summarize the overall patterns as a class by writing the patterns on the board or chart paper.

    Red flowers, tubular shape, no scent—hummingbirds

    White flowers, flat shape, sweet scent—moths

    Pale yellow or green flowers, large, fruit scent—bats

    Brown flowers, flat shape, rotting flesh scent—flies

4. In Part B, students are presented with two additional flowers and are asked to create an argument for how these flowers are pollinated.

    a. Instruct students to read about the two additional flowers in Part B and, in their groups, develop a consensus response for each flower.

    b. Hold a class discussion to arrive at a class consensus.

    Note that the question asks *how* these flowers are pollinated instead of what type of animal pollinates them because big bluestem is wind pollinated, whereas California poppy is pollinated by several types of pollinators (beetles, bees, flies, and more).

    Do not attempt to steer students towards the "right" answer, but instead encourage them to use what they have learned so far to construct an argument. These examples help students develop a better understanding of the role of argumentation in science, which often entails collecting more evidence to evaluate the strength of an argument.

    See the Teacher Discussion Starters in the Literacy Strategies section of Teacher Resources II, "Diverse Learners," to help foster productive classroom discourse. Also consider having your students use Developing Communication Skills in Appendix E in their student books to help them interact productively.

PROCEDURE STEP 7 SAMPLE STUDENT RESPONSE

California poppies are pollinated by hummingbirds. The flowers are orange and do not produce a strong fragrance. If these flowers were pollinated by insects, the flowers would produce a fragrance, either sweet or smelly. They would also be white or blue because insects don't see orange. These flowers are more like the cardinal flower, which is pollinated by hummingbirds. They are orange, which hummingbirds can see, and because hummingbirds don't have a strong sense of smell, the flower wouldn't produce a fragrance to attract the hummingbird. The one observation that doesn't fit with birds is the shape of the flower. Hummingbirds have long bills and tongues to stick down into flowers, and the California poppy isn't shaped like the cardinal flower.

Big bluestem plants are pollinated by a very small insect like ants. Although we didn't have an example of flowers pollinated by ants, for a flower to be pollinated by hummingbirds or bats, the flowers would need to be bigger. Also, for hummingbirds to be the pollinators, we would expect the flower to be red or orange. Insects are more likely the pollinator because of the color, although flies and moths can't see green.

c. After students have presented their arguments, share that California poppies are pollinated by many types of insects, especially a beetle, and that big bluestem is wind-pollinated.

   Consider using these examples as an opportunity to talk about the importance of testing arguments by making observations. Although the pollinator patterns are true for many flowers, there are many exceptions that present interesting opportunities for study.

d. (ARG ASSESSMENT) Instruct students to complete the Analysis.

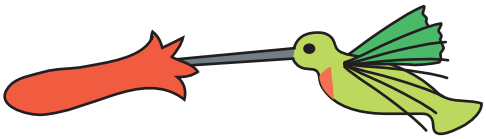
   Analysis item 1 can be assessed using the ENGAGING IN ARGUMENT FROM EVIDENCE (ARG) Scoring Guide. Consider distributing Literacy Student Sheet 4b, "Writing Frame—Engaging in Argument," to students to help them construct their written arguments.

   This item corresponds to the Performance Expectation MS-LS1-4, focusing on plant–animal interactions.

SAMPLE RESPONSES TO ANALYSIS

1. (ARG ASSESSMENT) Create an argument that explains your matching of plants, scents, and pollinators.

SAMPLE LEVEL-4 RESPONSE

FLOWER SHAPE AND COLOR	*POLLINATOR*	*SCENT (HOW IT SMELLS TO ME)*
 *Hummingbirds see red colors, so this flower is probably pollinated by them.*	*Tubular shape of flower matches long bill of hummingbird*	 *Hummingbirds can't smell well, so flowers that are pollinated by them probably don't have a scent.*
 *Moths don't see most colors but they have a strong sense of smell. These white, sweet-smelling flowers probably attract moths. Moths could land on these flowers and feed from them.*		 *Moths are attracted to sweet smells, so flowers pollinated by them smell nice and sweet.*
 *Size and position of flowers on a tall stalk could be reached by bats while they hover.*	*Bats don't see in color so the flowers they pollinate probably aren't colored.*	 *Bats have a good sense of smell, so the flowers they pollinate probably have a strong smell.*
 *The shape and size of this flower means that it could attract lots of flies.*	*Flies don't see in color, but this flower is red with dark spots. Not sure how the color fits, but nothing else would pollinate this.*	 *Flies have a strong sense of smell, and some of them feed on animal tissue.This smells like dead meat so it probably attracts flies.*

2. If you wanted to plant a garden that would attract butterflies and hummingbirds, what types of flowers would you want to plant and why?

I would plant red flowers with tubes to attract hummingbirds. It wouldn't matter if they produce a scent because hummingbirds can't smell very well. To attract butterflies, I would plant white or yellow flowers that have a strong fragrance that is either sweet like fruit or smells like something nice. I wouldn't plant flowers that smell like rotting flesh because that might attract flies.

3. Bees are important pollinators for many wildflowers, but they are also important for pollination of fruit crops, like apples, melons, and cherries. Populations of bees are declining because of pesticides and diseases. Predict what will happen if bee populations continue to decline.

   If bee populations keep getting smaller, some of these flowers may go extinct. This might happen because for some flowers that are pollinated by animals, they have only one kind of pollinator. If the pollinator goes extinct, then the plant can't reproduce. For crops that are pollinated by bees, people may need to start breeding new kinds of plants that can be pollinated by other kinds of animals. We may not have any almonds left if bees keep declining.

REVISIT THE GUIDING QUESTION

How do specialized plant structures and traits affect the probability of successful reproduction in plants?

Plant flowers have particular colors, shapes, sizes, and scents to attract certain types of animal pollinators. These pollinators are essential for the plants to be able to reproduce. Although some plants have only one specific kind of pollinator, some may have more than one kind. Some plants do not rely on animals at all and, instead, rely on the wind for pollination.

ACTIVITY RESOURCES

KEY VOCABULARY

pollination

pollinator

BACKGROUND INFORMATION

POLLINATION OR POLLINATOR SYNDROMES

Pollination or pollinator syndromes describe suites of flower characteristics, or traits, that may attract particular types of animal pollinators. These syndromes were first described by botanists in the 19th century. These suites of traits can be used to predict the type of pollinator important to a particular plant. A combination of color, scent, flower structure, and other traits relating to the quantity and quality of nectar and pollen can each affect a potential pollinator's ability to locate a flower and its food resources. Although these patterns have been widely applied and have proven useful to scientists, there are many exceptions to them.

12 How Do Genes Produce Traits?

MODELING

1-2 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

This activity introduces the concept that a gene encodes for a protein, which has a specific structure essential to its function in the cell. These protein functions manifest as traits in the body. Students use a coated wire and chenille stems to model and generate explanations for how a gene's DNA sequence codes for a protein sequence. They continue using this model to explore how the protein sequence determines the protein structure and function. As students model structure and function, they also examine cause-and-effect relationships between gene sequence and protein function.

NGSS CORRELATIONS

Performance Expectations

Working towards MS-LS3-1: Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of an organism.

Working towards MS-LS3-2: Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.

Disciplinary Core Ideas

MS-LS3.A Inheritance of Traits: Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.

Science and Engineering Practices

Developing and Using Models: Develop a model to describe unobservable mechanisms.

Constructing Explanations and Designing Solutions: Apply scientific ideas to construct an explanation for real-world phenomena, examples, or events.

Crosscutting Concepts

Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural systems.

Structure and Function: Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function.

Common Core State Standards—ELA/Literacy

RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

WHAT STUDENTS DO

Students use a physical model to learn how a gene encodes for a protein. Students determine a protein sequence from a given DNA sequence. They use a coated wire and chenille stems to model the protein backbone and protein subunits. Students then fold the coated wire into a three-dimensional structure that obeys rules of interaction between the subunits.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*

1	wire (1-m)
10	red chenille stems
10	blue chenille stems
1	white chenille stem
1	green chenille stem
1	roll of electrical tape
1	Visual Aid 12.1, "DNA and Protein Sequences"
*1	pair of scissors

- *For each pair of students*
  - 1 wire (1-m)
  - 10 red chenille stems
  - 10 blue chenille stems
  - 5 white chenille stems
  - 5 green chenille stems

- *For each student*
  - 1 Student Sheet 12.1, "Converting DNA to Proteins"

Full-length chenille stems should be cut into four equal pieces before use.

The flexible wire inside the coated wires may extend past the coating. For safety, use electrical tape to wrap each end of the 1-meter coated wires. You may find it necessary to trim the excess wire with scissors before taping.

Fold a fibrillin protein model using the coated wire and chenille stems.

Students will need to refer to their completed Student Sheet 12.1 in the "Fault in the Genes" activity so you may want to collect them at the end of this activity.

TEACHING SUMMARY

GET STARTED

1. Review DNA and genes. Elicit students' ideas about the relationship between a gene and a protein.
   a. Ask students, "What have we learned so far in this unit about DNA and genes?"
   b. Ask students, "What do you think the connection is between a gene (or DNA) and a protein?"
   c. Have students read the introduction to the activity and the Guiding Question.
2. Introduce the relationship between protein structure and function.
   a. Elicit students' ideas about how proteins exist inside the cell.
   b. Ask students to think of other proteins that they know about and what functions they might perform.

DO THE ACTIVITY

3. Students read about DNA and protein sequences.
    a. Have students learn about DNA and protein sequences by completing Step 1 of Procedure Part A: Determine the Protein Sequence.
    b. Emphasize that the final product of a gene is a protein and that proteins have many functions in cells.
4. Students determine part of the fibrillin protein sequence using Student Sheet 12.1, "Converting DNA to Proteins."
5. Students read about fibrillin protein structure and function (Part B).
    a. Discuss the function of fibrillin.
    b. Review the different types of protein subunits.
6. Students fold their protein sequences into three-dimensional structures.
    a. Instruct students to read about how their materials will model a protein and demonstrate how to build the model (Step 5).
    b. Remind students to review the table that indicates how different protein subunits interact with each other and with water.
    c. Instruct students to fold their coated wires into three-dimensional structures based on protein subunit interactions.
7. Students compare their folded fibrillin protein molecules with others.
    a. Instruct students to compare their folded fibrillin protein molecules with those created by other pairs.
    b. It might be helpful to take pictures of all the structures and display them on a screen so everyone can more easily compare.

BUILD UNDERSTANDING

8. Students discuss what they have learned about the relationship between DNA sequences and proteins.
    a. Review the Analysis items.
    b. Use Analysis item 3 to relate what students have learned about DNA and proteins to Joe's story.
    c. Ask students to discuss in their groups how the crosscutting concept of structure and function relates to this activity.

9. Collect completed Student Sheets and prepare materials for the next activity.
    a. Collect completed Student Sheets for use in the next activity.
    b. Consider having students leave the chenille stems on the coated wire.

TEACHING STEPS

GET STARTED

1. Review DNA and genes. Elicit students' ideas about the relationship between a gene and a protein.
    a. Ask students, "What have we learned so far in this unit about DNA and genes?"

        Students should recall from the "Show Me the Genes!" activity that DNA is the cellular component in a chromosome that contains the information that influences how you look and behave. The DNA in each chromosome is composed of hundreds to thousands of genes. Each gene is a bit of information that determines or contributes to determining a trait.

    b. Ask students, "What do you think the connection is between a gene (or DNA) and a protein?"

        This prompt is to elicit students' prior understanding. Some students may say that DNA or genes make proteins. At this point, students may not understand that there is a connection, which is okay.

    c. Have students read the introduction to the activity and the Guiding question.

        This introduction starts to provide more details about the relationship between DNA and proteins.

2. Introduce the relationship between protein structure and function.
    a. Elicit students' ideas about how proteins exist inside the cell.

        Consider using Elicit, Probe, and Challenge Questions while facilitating this discussion. As an Elicit question, ask, "How do you think proteins exist inside a cell?" When students respond, Probe them to elaborate on their ideas. The Challenge part of the discussion is revisited in the "Fault in the Genes" activity. See the Literacy section on Discussion Strategies in Teacher Resources II, "Diverse Learners."

        Based on the short introduction, students should say that proteins are folded up into specific shapes. A protein's structure determines its function and the function usually manifests as a trait. Students may have a

wide variety of ideas about how proteins exist in the cell. That is okay as the point is to elicit all responses rather than determine right or wrong responses.

There is an example protein structure shown in the Student Book at the end of the introduction. Note that proteins can fold into many different shapes, but a given protein will always fold into the same shape. Hemoglobin is a protein found in blood cells that binds oxygen.

You may also want to point out that a given cell is full of thousands of folded proteins.

b. Ask students to think of other proteins that they know about and what functions they might perform.

Students should be able to tell you that fibrillin is a protein. They should recall from the introductory video in "Joe's Situation" that fibrillin functions in connective tissues.

It is possible that students will not be able to name other proteins. Some may suggest that muscle is a protein. You should correct them by saying that muscle is actually a tissue that is made up of lots of protein filaments or chains. Some might suggest that hemoglobin or certain hormones, like insulin, are proteins.

DO THE ACTIVITY

3. Students read about DNA and protein sequences.

a. Have students learn about DNA and protein sequences by completing Step 1 of Procedure Part A: Determine the Protein Sequence.

Use Visual Aid 12.1, "DNA and Protein Sequences" to walk students through the figure in Part A.

If appropriate, define that a *subunit* is a smaller part of a whole unit. Students might be familiar with other words that start with the sub- prefix, such as subtitle, subcategory, or submarine.

Students should also understand that the DNA sequence or the protein sequence is simply the order of the subunits in a series or a chain of subunits.

b. Emphasize that the final product of a gene is a protein and that proteins have many functions in cells.

Continue using Visual Aid 12.1 to review the diagrams in the DNA and Protein Sequences box in the Student Book that illustrates the

relationship between DNA and protein. The final product of a gene is a functional protein. The DNA sequence dictates the protein sequence.

4. Students determine part of the fibrillin protein sequence using Student Sheet 12.1, "Converting DNA to Proteins."

   In this part of the activity, students will determine which protein subunits are coded for by a given DNA sequence. They will refer to the "Subunit Code" table on Student Sheet 12.1 that indicates which protein subunit is coded for by a given DNA code. For simplicity, only the DNA codes present in the given fibrillin sequence are included. In reality, there are 64 different DNA codes.

   The sequence provided in the Student Book is only the first 15 subunits out of the ~79,000 amino acid sequence for fibrillin.

5. Students read about fibrillin protein structure and function (Part B).

   a. Discuss the function of fibrillin.

      Emphasize the location of connective tissue throughout the body.

      This explains why one cause (the mutation in fibrillin) can lead to a variety of symptoms.

   b. Review the different types of protein subunits.

      The protein subunits dictate how the protein will fold into a specific structure (shape). Three-dimensional structure is necessary for proper function of the protein.

      Protein subunits can be classified into four different types—hydrophilic, hydrophobic, positive, and negative. You may want to review what hydrophobic and hydrophilic mean. Inside the cell, it is an aqueous (watery) environment, so hydrophobic protein subunits, which do not interact with water molecules, tend to be buried inside the structure to be far away from the water, while hydrophilic subunits are attracted to water and tend to be on the surface of the protein.

      Positively and negatively charged molecules or portions of molecules attract each other. As a result, positively and negatively charged subunits of the protein chain tend to face towards each other.

6. Students fold their protein sequences into three-dimensional structures.

   a. Instruct students to read about how their materials will model a protein and demonstrate how to build the model (Step 5).

Take a coated wire and show how it can be folded into a three-dimensional structure. Point out the surface of the protein is the outside of the structure. This area is accessible to water. Point out the core of the structure. Note that this region is protected from water by the surrounding protein structure.

Demonstrate how to attach the chenille stems. Loop one end around the coated wire—ensuring that the remaining part of the chenille stem extends away from the coated wire—and twist it just enough to hold in place. Be sure the chenille stems extend away from the coated wire because they represent the space occupied by the subunits. The chenille stems can extend in different directions from the coated wire.

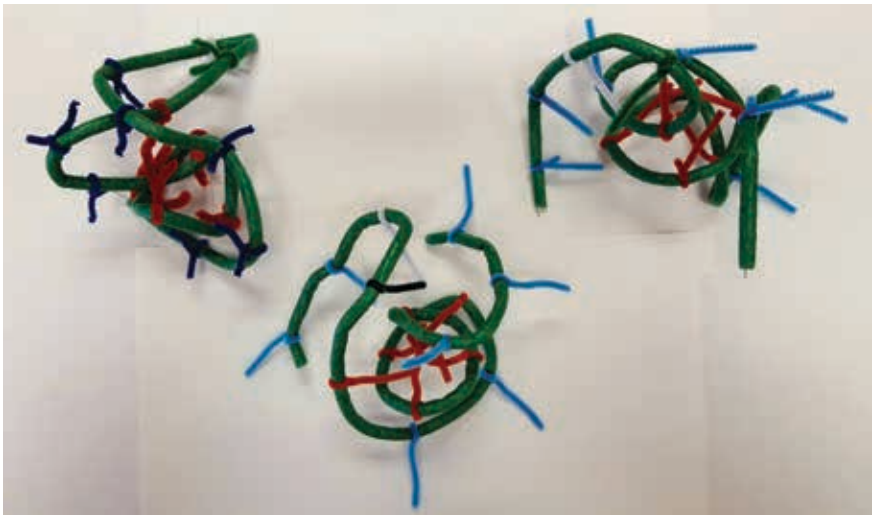
b. Remind students to review the table that indicates how different protein subunits interact with each other and with water.

You may want to refer back to the figures of protein structures and point out that subunits that are not next to each other can and will interact.

c. Instruct students to fold their coated wires into three-dimensional structures based on protein subunit interactions.

It is helpful to space out the chenille stems along the length of the coated wire before attaching them. This ensures that all the subunits are spread out over the length of the whole coated wire.

PROCEDURE STEP 7 SAMPLE STUDENT PRODUCTS



Three examples of the folded fibrillin protein are shown above. Each structure is folded slightly different, but in general, all the structures have a central core composed of the red, hydrophobic subunits. The other subunits fold around the red ones and the green and white subunits are

touching. In reality, the same protein sequence is folded exactly the same every time the protein is made.

When folding, students should start by grouping the hydrophobic subunits into a core structure that the other subunits surround.

Circulate around the room to check that students are using the folding rules and to see what kinds of structures they produce.

7. Students compare their folded fibrillin protein molecules with others.

   a. Instruct students to compare their folded fibrillin protein molecules with those created by other pairs.

      All pairs have folded the same sequence. If they obey the subunit interactions, the structures should look relatively similar. If students misread a table, they may incorrectly place a protein subunit into their sequence. Students may also incorrectly interpret hydrophilic and hydrophobic.

   b. It might be helpful to take pictures of all the structures and display them on a screen so everyone can more easily compare.

      You could also fold the protein ahead of time and take a picture to display for the students.

BUILD UNDERSTANDING

8. Students discuss what they have learned about the relationship between DNA sequences and proteins.

   a. Review the Analysis items.

      Analysis item 1 relates to how the DNA sequence is read in three-letter codes (analogous to words in a sentence) to determine protein sequence. If students are having difficulty, you might want to have them reflect on the fibrillin sequence they looked at in Part A.

      Analysis item 2 has students make the connection between a protein's structure and its function. For a protein to be functional, it must fold into a correct three-dimensional structure. Since the folding is dependent on the interactions between the protein subunits and between the subunits and water, the same sequence should fold the same way every time it is made.

   b. Use Analysis item 3 to relate what students have learned about DNA and proteins to Joe's story.

      It might be helpful to have students make a list of Marfan syndrome symptoms. Ask if these symptoms could be due to problems with fibrillin.

Do not go into detail about how a mutation in fibrillin could lead to structure and function problems, as that is the focus of the upcoming "Fault in the Genes" activity.

c. Ask students to discuss in their groups how the crosscutting concept of structure and function relates to this activity.

Have a group briefly report its ideas, and then have other groups volunteer any additional suggestions. Emphasize the relationship between the structure of DNA (its sequence of codes) and its function in providing genetic information. In turn, it leads to a protein structure (both the sequence of subunits and the shape of the protein that results) that is essential for it to function properly within the human body.

9. Collect complete Student Sheets and prepare materials for the next activity.

a. Collect completed Student Sheets for use in the next activity.

Students will need to refer to their completed Student Sheet in the "Fault in the Genes" activity. If appropriate, collect the sheets or have students place them in their science notebooks.

b. Consider having students leave the chenille stems on the coated wire.

At the start of the next activity, students are asked to refold their fibrillin models. To save time, you may want your last class to leave the chenille stems attached to the coated wire. You can straighten the wires so that the next group of students will have to refold the structure.

SAMPLE RESPONSES TO ANALYSIS

1. The cell has a way of knowing where to start reading a DNA sequence in order to determine the correct three-subunit codes.

a. Why do you think that is important?

Since each gene makes a specific protein, each time it is made it should have the same sequence. The sequence determines how the protein is folded and its function. If the gene is read from a different starting point each time, it could end up making lots of different proteins.

b. If the cell started reading one or two letters later, what effect might that have?

Any combination of three DNA letters or subunits can be read as a word in the code. If the cell doesn't know where to start reading or starts a letter or two off, the codes will be off, and the cell will end up with a protein with a totally incorrect sequence.

2. The same protein sequence always folds into the same three-dimensional structure (shape) within a cell. Why do you think this is important?

   Proteins have specific functions in the cell. The structure (shape) of the protein is important for it to do its function. If the same protein folds differently each time it is made, the different structures will likely not be able to do the same function.

3. Joe doesn't understand how one gene affecting one protein can cause all the symptoms related to Marfan syndrome. Based on what you know now, how can you start to explain the relationship between the fibrillin gene and the symptoms of Marfan syndrome?

   Fibrillin is a gene that makes the fibrillin protein. Fibrillin protein is part of the connective tissue in the body. It helps provide strength and flexibility. If something causes the fibrillin protein to be made incorrectly, it won't function properly in the body. Connective tissue is in your bones, muscles, ligaments, blood vessels, and heart valves. If you have a bad fibrillin gene, it could cause all kinds of problems with those parts of your body, leading to symptoms of Marfan syndrome.

4. In this activity you investigated how a gene leads to a protein with a structural function. How do you think a gene could code for a protein that influences an organism's behavior?

   Answers will vary. The purpose of this question is to get students thinking about the possible effects of genes on the brain and senses. One sample response follows.

   I think a gene might code for a protein that affects the brain or for a sense like vision, and that could influence an organism's behavior.

REVISIT THE GUIDING QUESTION

How does a gene produce a trait?

Throughout the activity and Analysis items, students should be able to answer this question. A gene codes for a protein. This protein has a unique subunit sequence. Based on interactions between protein subunits and between subunits and water, a protein sequence will fold into a three-dimensional structure. This structured protein has a function inside the body. The protein's function will manifest as a trait.

ACTIVITY RESOURCES

KEY VOCABULARY

DNA

gene

protein

BACKGROUND INFORMATION

DNA STRUCTURE

DNA, or deoxynucleic acid, contains the genetic information inside all of our cells. Within each cell nucleus, there is approximate two meters of DNA (if it were stretched out in a single linear molecule). In reality, human DNA is not one long string; rather, it is supercoiled and organized into 23 different chromosomes, and each chromosome is composed of thousands of genes.

DNA is composed of four basic subunits: nitrogen bases called adenine, cytosine, guanine, and thymine. Each gene has a specific combination and sequence of these four bases that encodes for a unique protein.

PROTEIN STRUCTURE

Cells require thousands of proteins if they are to live and function. Proteins are the "doers" or "workhorses" of most living processes and can be classified into eight groups: enzymes, transport proteins (e.g., hemoglobin), motor proteins, signaling proteins (e.g., hormones, such as insulin), receptor proteins, proteins of the immune system (e.g., antibodies), storage proteins, and structural proteins (e.g., fibrillin).

Proteins are macromolecules made up of chains of subunits called *amino acids*. There are 20 amino acid building blocks, and they are arranged in varying sequences and numbers to make each kind of protein. The amino acids are linked together by a covalent bond called a *peptide bond*. A single linear chain of amino acids is a *polypeptide*. Some proteins are made of just one polypeptide chain, whereas others are made of two or more joined together. The sequence of amino acids is referred to as the primary structure of the protein.

As soon as it is synthesized, each protein folds into a specific three-dimensional shape that is essential for it to function properly. This folding takes place as a result of disulfide bonds and weak interactions, such as hydrogen bonds, that form spontaneously between amino acids at various points in the amino acid chain, and between amino acids and water molecules in the cellular environment.

TRANSCRIPTION AND TRANSLATION

Within a cell, the DNA always remains in the nucleus. For a gene to result in a protein, there are several processes that must take place. These processes are further described here but omitted from the Student Book as they are not covered at the middle school level.

The first step of gene expression is to copy, or *transcribe*, the gene sequence of interest from the DNA in the nucleus. Specific reactions, which depend on an array of protein machineries that function as enzymes, copy the DNA into a secondary message called *RNA*, or *ribonucleic acid*, in a process called *transcription*. The RNA message moves into the cytoplasm. There it is then translated to produce a protein by another set of reactions that require cellular structures (ribosomes) and enzymes. Through the process of translation, the RNA sequence is read three bases at a time, and the corresponding amino acids are linked together to form the protein sequence.

The flow of genetic information from DNA to RNA (by transcription) and RNA to protein (by translation) is known as the central dogma of molecular biology.

Name _____ Date _____

STUDENT SHEET 12.1

CONVERTING DNA TO PROTEINS

DNA code	Protein subunit (chenille stem color)	Type of subunit
AGT		
TGT		
CGA		
GAA		
CTT		
CAA		
TGT		
CCC		
GTT		
GGT		
ATT		
CCC		
TGC		
CAG		
CAA		

Subunit Code

DNA code	Protein subunit (chenille stem color)
AGT CAA CAG TGC TGT	Blue
ATT CCC CTT GGT GTT	Red
CGA	White
GAA	Green

Name *Sample student response* Date____________

STUDENT SHEET 12.1

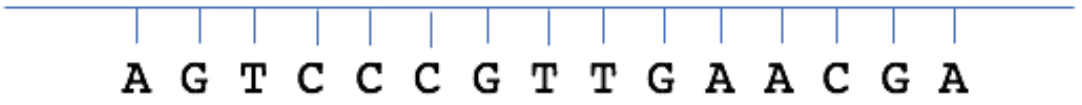
CONVERTING DNA TO PROTEINS

DNA code	Protein subunit (chenille stem color)	Type of subunit
AGT	*blue*	*hydrophilic*
TGT	*blue*	*hydrophilic*
CGA	*white*	*positive*
GAA	*green*	*negative*
CTT	*red*	*hydrophobic*
CAA	*blue*	*hydrophilic*
TGT	*blue*	*hydrophilic*
CCC	*red*	*hydrophobic*
GTT	*red*	*hydrophobic*
GGT	*red*	*hydrophobic*
ATT	*red*	*hydrophobic*
CCC	*red*	*hydrophobic*
TGC	*blue*	*hydrophilic*
CAG	*blue*	*hydrophilic*
CAA	*blue*	*hydrophilic*

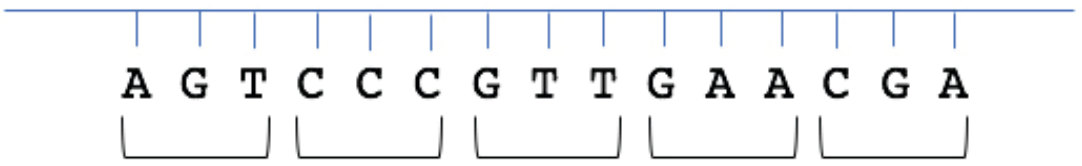
Subunit Code

DNA code	Protein subunit (chenille stem color)
AGT CAA CAG TGC TGT	Blue
ATT CCC CTT GGT GTT	Red
CGA	White
GAA	Green

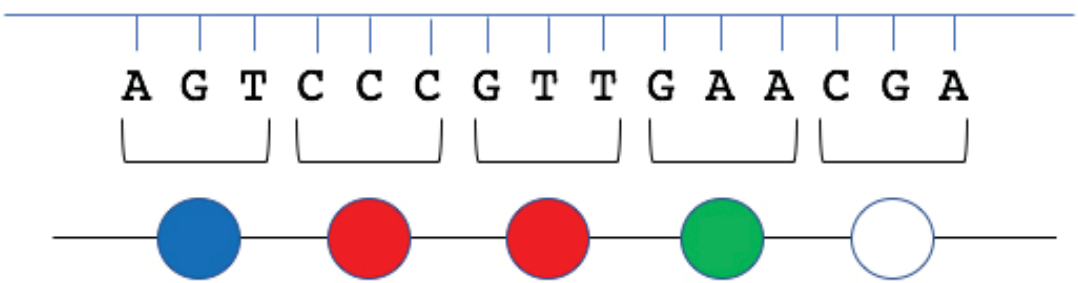
A gene is a long sequence of DNA subunits. The letters below (A, T, C, and G) represent the four DNA subunits.



A DNA sequence is read in three-subunit codes. The brackets below show the codes in this piece of DNA.



Each code specifies a protein subunit in a protein sequence. The circles below represent the four types of protein subunits.



13 Fault in the Genes

MODELING

1–2 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

Students return to their three-dimensional protein models to begin investigating the cause-and-effect relationship between mutations and protein structure and function. The activity begins with a game that introduces students to different types of mutations: deletions, additions, and substitutions. Students then make predictions about how different mutations may affect their protein structures. Using the coated wires and chenille stems, students model the mutations and the resulting changes to their protein structure. After investigating different types of mutations, students construct an explanation for how a mutation in a gene leads to changes in body function, specifically how a mutation in the fibrillin gene leads to Marfan syndrome symptoms. The activity provides an opportunity to assess student work related to Performance Expectation MS-LS3-1.

NGSS CORRELATIONS

Performance Expectations

MS-LS3-1: Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of an organism.

Applying MS-LS3-2: Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.

Disciplinary Core Ideas

MS-LS3.A Inheritance of Traits: Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.

MS-LS3.B Variation of Traits:

In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.

In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.

Science and Engineering Practices

Developing and Using Models: Develop a model to describe unobservable mechanisms.

Constructing Explanations and Designing Solutions: Apply scientific ideas to construct an explanation for real-world phenomena, examples, or events.

Analyzing and Interpreting Data: Analyze and interpret data to provide evidence for phenomena.

Crosscutting Concepts

Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural systems.

Structure and Function: Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts, therefore, complex natural and designed structures/systems can be analyzed to determine how they function.

Common Core State Standards—ELA/Literacy

RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

WHAT STUDENTS DO

Students return to their protein coated wire model and predict the effects of mutations on their protein's structure and function. They also consider how a mutation in the fibrillin gene can lead to changes in structure and function and to symptoms of Marfan syndrome.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*
  - 1 wire (1-m)
  - 10 red chenille stems
  - 10 blue chenille stems
  - 1 white chenille stem
  - 1 green chenille stem
  - 1 Visual Aid 13.1, "Analogies for Types of Mutations"
  - 1 Scoring Guide: DEVELOPING AND USING MODELS (MOD)
  - Access to video, *How Do People Get Marfan Syndrome?*

- *For each pair of students*
  - 1 wire (1-m)
  - 10 red chenille stems
  - 10 blue chenille stems
  - 5 white chenille stems
  - 5 green chenille stems
  - 1 6-sided number cube

- *For each student*
  - 1 Science Skill Sheet 7, "Analyzing Models"
  - Completed Student Sheet 12.1, "Converting DNA to Proteins," from the "How Do Genes Produce Traits?" activity
  - 1 Scoring Guide: DEVELOPING AND USING MODELS (MOD) (optional)

Preview the "How Do People Get Marfan Syndrome" video. For a link to the video, see the teacher page of the *SEPUP Third Edition Reproduction* website at *http://www.sepuplhs.org/middle/third-edition*.

If you collected Student Sheet 12.1 at the end of the last activity, you will need to return them to the students for reference in this activity.

TEACHING SUMMARY

GET STARTED

1. Review what students learned in "How Do Genes Produce Traits?" about how a gene encodes a protein.

   Begin by asking students how a gene leads to a function or a trait.

2. Explain the format and goals of this activity.

a. Have students read the introduction and clarify the goal of the activity.

b. Review the term *mutation*, which was formally defined in the Student Book in the "Do Genes Determine Everything?" activity.

c. Use Visual Aid 13.1, "Analogies for Types of Mutations," to introduce the different types of mutations.

DO THE ACTIVITY

3. Students return to their coated wire models in order to model how mutations affect a protein's structure and function.

   a. Have students refold their proteins from the "How Do Genes Become Traits?" activity.

   b. Have groups of four students discuss how a single letter change in the DNA sequence could affect the protein's structure and function.

   c. Instruct students to predict how specific mutations will affect their proteins' structure and function.

   d. Point out that not all mutations will cause a change to the structure.

   e. After making their predictions, instruct students to alter their models and, if necessary, refold the proteins. Have students record how the mutations affected the shapes of the proteins.

BUILD UNDERSTANDING

4. Students discuss their predictions and results for how a mutation affects their proteins' structure and function.

   a. Have pairs of students compare their mutations and resulting changes.

   b. As a class, briefly go over all six possible mutations.

5. Students analyze the effectiveness of the coated wire model.

   Distribute Science Skills Sheet 7, "Analyzing Models," and have students use it to identify the different parts of the model and what they represent in the real world for Analysis item 1.

6. Students construct explanations about mutations and their effects on protein structure and function.

   Lead students through an analysis of results caused by the six different mutations.

7. Help students relate back what they have learned about genes and protein structure and function to Joe and Marfan syndrome to answer Analysis item 4.

a. Help students identify what they have learned so far about Marfan syndrome and fibrillin.

b. Show the video from The Marfan Foundation, *How Do People Get Marfan Syndrome?*

c. (MOD ASSESSMENT) Have students individually draw models that show cause and effect between the fibrillin gene, fibrillin protein, and traits/symptoms for a person with and without Marfan syndrome.

TEACHING STEPS

GET STARTED

1. Review what students learned in "How Do Genes Produce Traits?" about how a gene encodes a protein.

   Challenge students to explain how a gene leads to a function or a trait.

   Students should recall that a gene encodes a protein. A protein has a specific sequence that dictates how it compacts or folds three-dimensionally since the chemical structure of the subunits determines how they interact with one another and the cellular environment. A protein must fold up properly in order to perform its function.

   In relation to Marfan syndrome, the fibrillin gene makes a fibrillin protein that has a structural function. Fibrillin provides strength and flexibility in connective tissue, which is found all over the body in things like bones, ligaments, muscles, blood vessels, and heart valves.

2. Explain the format and goals of this activity.

   a. Have students read the introduction and clarify the goal of the activity.

      Review the Guiding Question and be sure students understand that the goal of the activity is to figure out how a single change in the structure of a gene can lead to changes in how the body functions.

   b. Review the term *mutation*, which is formally defined in the Student Book in the "Do Genes Determine Everything?" activity.

      A mutation is a random change. In this context, a mutation refers to a change in the original DNA that leads to a change in a protein sequence.

   c. Use Visual Aid 13.1, "Analogies for Types of Mutations," to introduce the different types of mutations.

      - Display the first statement and cover the remaining statements. "I hear that noise," is an example of a gene in a cell. Reveal each subsequent statement as you discuss the different types of mutations.

- When the cell copies its DNA and divides, a mutation may occur resulting in, "I fear that noise." The H has been changed to an F. This is an example of a *substitution mutation,* where one subunit is replaced by another.
- During the next round of DNA replication, another type of mutation occurs, which results in, "I fear that nose." This is a *deletion mutation*, where the I has been left out of "noise."
- Next, the message turns into "I hear that nose." Another substitution mutation changed the F into an H. This mutation can be thought of as beneficial, as it returns that word "hear" back into its original form.
- The last round of DNA replication results in, "I heard that nose." This is an example of an *addition mutation*, where the D is added to a word.

Explain that this was an example to illustrate how a message, or gene, could be changed or mutated. In the cell, mutations occur randomly throughout the DNA sequence and are not targeted to specific places. Ultimately, a DNA mutation can have no effect or can cause a change in the protein's structure and function.

Students will discover in this activity that mutations can be beneficial, harmful, or neutral. When mutations are harmful, they change the DNA or protein sequence such that the resulting structure or function, or both, are disrupted.

DO THE ACTIVITY

3. Students return to their coated wire models in order to model how mutations affect a protein's structure and function.

   a. Have students refold their proteins from the "How Do Genes Produce Traits?" activity.

      Students should refer to Student Sheet 12.1, "Converting DNA to Proteins," that they completed during the "How Do Genes Produce Traits?" activity. Students should reassemble their coated wire and chenille stems models if they have not already done so from the previous activity. Remind students that they need to follow the interaction rules to refold their proteins. Once refolded, have pairs of students check each other's proteins to make sure they followed the rules.

      It may be helpful to have an example protein folded for the groups to base their structures on so that all groups start with a similar structure.

b. Have groups of four students discuss how a single letter change in the DNA sequence could affect the protein's structure and function.

   Ask students, "How might a mutation that causes a single letter change in the DNA sequence affect your protein structure and function?"

   Circulate to see if students are using terms like *sequence*, *DNA*, *protein*, and *interactions*.

   If a mutation changes the type of amino acid in the sequence, it may lead to a slight or dramatic change in the structure. Depending on the structural change, the protein may or may not still be able to perform its function.

c. Instruct students to predict how specific mutations will affect their proteins' structure and function.

   To determine their mutation, students will roll the six-sided number cube and find the corresponding mutation in the given table.

   Before making a change to their models, students should predict and record how that mutation will affect the structure. They should also think about how this change to the structure could affect the function of the protein.

d. Point out that not all mutations will cause a change to the structure.

   Some mutations may not cause a change to the three-dimensional structure of the protein. This happens when the mutation results in a subunit change that still follows the interaction rules. When these mutations occur, they are unlikely to disrupt the protein's function.

   Other mutations can cause more obvious disruptions of the protein structure. For example, replacing a hydrophobic residue in the center of your structure with a hydrophilic residue may cause the whole protein to flip inside out because that hydrophilic residue wants to be on the surface of the protein. These changes to the protein structure are very likely to disrupt the protein's function.

e. After making their predictions, instruct students to alter their models and, if necessary, refold the proteins. Have students record how the mutation affected the shape of the protein.

BUILD UNDERSTANDING

4. Students discuss their predictions and results for how a mutation affects their proteins' structure and function.

   a. Have pairs of students compare their mutations and resulting changes.

      Students should share the mutations they rolled and their predictions and results. If pairs happen to roll the same two numbers, they should discuss whether their predictions and results were similar and, if not, why. If pairs rolled different numbers, the first pair should state its prediction and result. It can then discuss if the other pair of students has a different prediction for that mutation.

   b. As a class, briefly go over all six possible mutations.

      Although students will only discuss a maximum of four mutations within their groups, review all six possible mutations. At this point, you want only to name the mutation, a prediction of what happens to the structure, what actually happened to the structure, and predictions of what may happen to the function. The first and second columns of the table below ("Roll" and "Change to Protein") are shown in the Student Book. The third column indicates what type of mutation occurs and its effect on the structure. The LABsent for this activity displays typical results.

      It may be helpful to have six different students present the six different mutations. Pick students to share based on which mutations they examined in their second round of analysis, so they can use their refolded coated wire model to show the effect on their structure.

Causing Mutations

Roll	Change to protein	Type of mutation & effect on structure
1	Change subunit 9 from a red to blue chenille stem	Substitution—will disrupt the hydrophobic center
2	Change subunit 1 from a blue to red chenille stem	Substitution—subunit 1 now has to fold towards center
3	Add a white chenille stem between subunits 10 and 11	Insertion—needs to fold to be near the other white/green subunits
4	Remove the green chenille stem	Deletion—no significant change; students should wonder what happens to the white subunit
5	Change subunit 12 from a red to blue chenille stem	Substitution—no significant change
6	Change subunit 2 from a blue to green chenille stem	Substitution—no significant change

5. Students analyze the effectiveness of the coated wire model.

   Distribute Science Skills Sheet 7, "Analyzing Models," and have students use it to identify the different parts of the model and what they represent in the real world for Analysis item 1.

   They may need to refer back to the "How Do Genes Produce Traits?" activity.

   After identifying the parts of the model, students should analyze how each part of the model is like the real thing and how it is different. This should get students to think about the advantages to using a model and also the limitations.

   A sample response is provided in Sample Responses to Analysis.

6. Students construct explanations about mutations and their effects on protein structure and function.

   Lead students through an analysis of results caused by the six different mutations.

   Have students review Analysis item 2. Students examined mutations by making substitutions, an addition, or a deletion to their sequence. Students should be able to provide this information as evidence to support their claims.

   In Analysis item 3, students should use their coated wire models as evidence that not all mutations lead to a change in a protein's three-dimensional structure. Additionally, if a mutation does not lead to a change in the structure, it is unlikely to change the function.

7. Help students relate back what they have learned about genes and protein structure and function to Joe and Marfan syndrome to answer Analysis item 4.

   a. Help students identify what they have learned so far about Marfan syndrome and fibrillin.

      It may be helpful to chart or summarize as a whole class or in groups.

   b. Show the video from The Marfan Foundation, *How Do People Get Marfan Syndrome?*

      This video will provide additional information about how changes in the fibrillin gene can lead to Marfan syndrome.

   c. (MOD ASSESSMENT) Have students individually draw models that show cause and effect between the fibrillin gene, fibrillin protein, and traits/symptoms for a person with and without Marfan syndrome.

      Analysis item 4 in this activity can be assessed using the DEVELOPING AND USING MODELS (MOD) Scoring Guide. For more information, see Teacher

Resources III, "Assessment." This item corresponds to Performance Expectation MS-LS3-1.

The model should include a chromosome from mom and a chromosome from dad, indicating where the fibrillin gene is. In the person with Marfan syndrome (e.g., Joe), the fibrillin gene from mom should have a mutation. Genes lead to protein production and either normal functioning connective tissue or problematic connective tissue, resulting in Marfan syndrome symptoms.

In item 4a, the model should indicate two normal alleles, one from dad and one from mom. The normal alleles produce normal fibrillin protein that leads to properly functioning connective tissue and a healthy individual.

In item 4b, the model should clearly indicate that one allele is normal and one is mutated. In Joe's case, the mutated copy of fibrillin would have come from his mom. This mutated gene results in misfolding of half of his fibrillin protein. Even though he will have normal fibrillin from his dad's allele, it is not enough for connective tissue to function properly. So half the normal amount of normal fibrillin leads to problems in connective tissues that manifest as Marfan syndrome traits/symptoms.

SAMPLE RESPONSES TO ANALYSIS

1. In this activity and the "How Do Genes Produce Traits?" activity, you used a coated wire and chenille stems to model protein structure.

   a. Using Science Skills Sheet 7 "Analyzing Models," identify the different parts of the model, what each part represents in the real world, and how each part is similar and different to the real world.

   Hint: You may want to refer to the "How Do Genes Produce Traits?" activity for more information.

Part of the model	Represents which part of the real world?	They are alike because . . .	They are different because . . .
coated wire	*protein backbone*	*they are linear but flexible*	*proteins are longer than 1 meter*
chenille stem	*protein subunit*	*they are small and attach to portions of the protein backbone*	*protein subunits are not chenille stems that can attach and detach*
colors of the chenille stems	*type of subunit*	*four different types of subunits are represented by four different colors*	*protein subunits vary by how they interact with each other and water, not by color*

b. Do you think the coated wire model is an effective model for understanding protein structure and function? Explain.

Responses may vary. One response is shown here:

Yes, the coated wire model is effective because it shows that a protein is more complicated than a linear sequence—the sequence must fold into a three-dimensional protein. It shows how each protein subunit plays a role in determining the protein structure. By introducing mutations in the coated wire, it is easy to visualize how the structure may or may not change.

2. Do all mutations have the same effect on DNA? Why or why not?

No, all mutations are not the same. Mutations can be caused in different ways, including a deletion, an insertion, or a substitution in the DNA sequence. Some are harmful and some have little effect.

3. Consider the effects of mutations on proteins.

a. Do all mutations lead to a change in protein *structure*? What evidence do you have to support this?

Evidence may vary based on which mutations the students analyzed in Part B, but all students should be able to cite evidence from the changes they made. One response is shown here:

Not all mutations lead to a change in protein structure. Since several DNA word codes can result in the same protein subunits, it is possible that a change in the DNA results in the same protein subunit, so there would be no change in structure. There are four main classes of how protein subunits interact with each other and with water. There could be a mutation in the protein subunit that changes its identity but keeps it in the same class of interactions. This protein would still fold the same way as the normal protein.

b. Do all mutations lead to a change in protein *function*? What evidence do you have to support this?

Evidence may vary based on which mutations the students analyzed in Part B, but all students should be able to cite evidence from the changes they made. Once response is shown here:

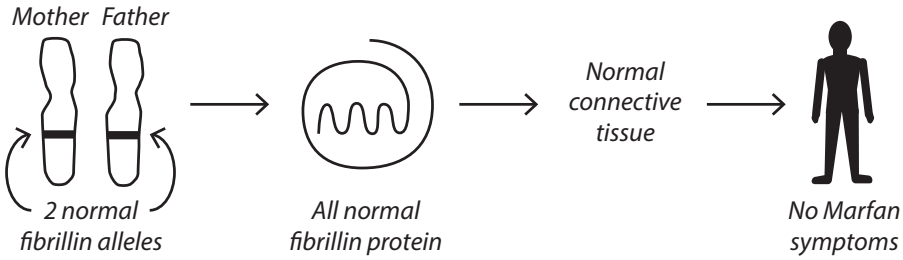
No. Since some mutations (as described in 3a) do not change the protein's structure, those mutations are likely to not change the function either.

4. (MOD ASSESSMENT) Think back to what you know about Marfan syndrome and fibrillin. Draw a labeled diagram that models the cause-and-effect

relationship between the fibrillin gene, fibrillin protein, and traits/symptoms for

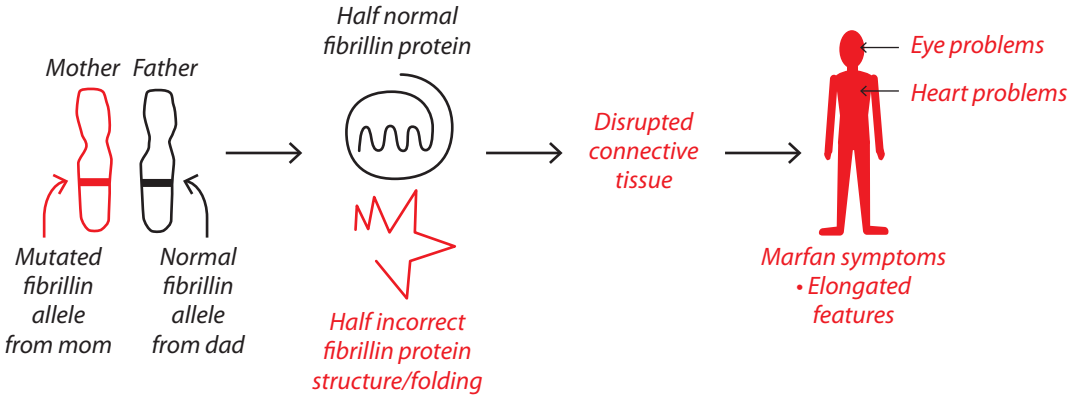
SAMPLE LEVEL-4 RESPONSE

a. a person *without* Marfan syndrome.



b. a person *with* Marfan syndrome.

Hint: Joe (like all humans) has two alleles for the fibrillin gene, one from mom and one from dad.



REVISIT THE GUIDING QUESTION

How can a change in a gene, like the gene linked to Marfan syndrome, lead to a change in the function of a person's body?

Review the idea that genes encode for proteins. Proteins have specific functions inside the cell/body. If the gene is mutated, the resulting protein may have a disrupted structure and function. This disrupted function usually displays as traits or symptoms that are different from normal traits.

ACTIVITY RESOURCES

KEY VOCABULARY

mutation

BACKGROUND INFORMATION

TYPES OF PROTEIN MUTATIONS

There are three main types of mutations: insertions, deletions, and substitutions. An *insertion* results when one or more DNA subunits is inserted into the normal sequence. A *deletion* is the removal of one or more DNA subunits. Both an insertion and a deletion often lead to frameshifting, which is when the three-letter DNA "words" now read incorrectly due to the extra or missing subunits, leading to a change in the resulting protein subunits. A *substitution* occurs when one DNA subunit is replaced by one of the other three subunits. This substitution results in a change to the DNA "word," which may also change an individual protein subunit.

Mutations can be considered beneficial, harmful, or neutral based on the resulting effect on the protein's function. A beneficial mutation may increase the function of the protein. A harmful mutation will disrupt the structure and function of the protein. A harmful mutation could also have no effect on the structure but still disrupt the function. A neutral mutation may change the protein subunits but not result in a structure or function change. Alternatively, a neutral mutation may change the structure but not affect the function.

FIBRILLIN AND MARFAN SYNDROME

Patients with Marfan syndrome have a mutation in one copy of their fibrillin-1 gene. Not all patients have the same mutation, in contrast to diseases like sickle cell, which are caused by a single-point mutation. Mutations have been found throughout the entire fibrillin-1 gene, which is over 237,000 nucleotides long. Since there is no one specific mutation or set of mutations linked to Marfan syndrome, genetic testing for Marfan syndrome is complex. Testing for Marfan syndrome requires testing of others in the patient's family in order to identify the fibrillin mutation that is inherited in the family. Testing for Marfan syndrome is much more difficult than testing for sickle cell disease, which always results from a single protein subunit mutation.

VISUAL AID 13.1

ANALOGIES FOR TYPES OF MUTATIONS

I HEAR THAT NOISE.

I FEAR THAT NOISE.

I FEAR THAT NOSE.

I HEAR THAT NOSE.

I HEARD THAT NOSE.

14 Advising Joe

TALKING IT OVER
1–2 CLASS SESSION

OVERVIEW

NGSS RATIONALE

Students apply what they have learned to Joe's scenario and create a written communication that explains the causes and effects of Marfan syndrome and the actions Joe and his family might take.

NGSS CORRELATIONS

Performance Expectations

Applying MS-LS3-2: Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.

Applying MS-LS1-5: Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

Applying MS-LS3-1: Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of an organism.

Disciplinary Core Ideas

MS-LS1.B Growth and Development of Organisms: Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring.

MS-LS3.A Inheritance of Traits:

Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.

Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited.

MS-LS3.B Variation of Traits: In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information: Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings.

Crosscutting Concepts

Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural systems.

Understandings About the Nature of Science: *Science Addresses Questions About the Natural and Material World*: Scientific knowledge can describe consequences of actions but does not prescribe the decisions that society takes.

Common Core State Standards—Mathematics

6.RP.A.1: Understand the concept of a ratio, and use ratio language to describe a ratio between two quantities.

Common Core State Standards—ELA/Literacy

WHST.6-8.2: Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

WHAT STUDENTS DO

Students return to Joe's story and develop a written email explaining his situation and a recommendation about what he might do. This activity provides more information about Marfan syndrome and also allows students to consider further how a diagnosis of a genetic condition might affect a person.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*

  Access to video, *How Do Your Genes Fit?*

  1 Scoring Guide: COMMUNICATING CONCEPTS AND IDEAS (COM)

  1 Scoring Guide: EVIDENCE AND TRADE-OFFS (E&T)

- *For each student*
  - 1 Student Sheet 14.1, "What We Know About Marfan Syndrome"
  - 1 Scoring Guide: COMMUNICATING CONCEPTS AND IDEAS (COM) (optional)
  - 1 Scoring Guide: EVIDENCE AND TRADE-OFFS (E&T) (optional)

For a link to the video, see the teacher page of the *SEPUP Third Edition Reproduction* website at *www.sepuplhs.org/middle/third-edition*.

TEACHING SUMMARY

GET STARTED

1. Review Joe's story.
   a. Tell students that they now have a chance to review Joe's story and to help him by explaining the science of Marfan syndrome and making recommendations to Joe and his family.
   b. Have students read the introduction and Guiding Question for the activity.
   c. Replay the video *How Do Your Genes Fit?*, first shown in "Joe's Situation."

DO THE ACTIVITY

2. Have students complete Procedure Steps 1–4 to review what they have learned about the causes and effects of Marfan syndrome.
   a. Allow students to work in their groups to complete Procedure Steps 1–3, and help them answer any questions that remain.
   b. Distribute Student Sheet 14.1, "What We Know About Marfan Syndrome," and have students work in their groups to complete all of the information.
3. Students write an email to Joe to explain Marfan syndrome and make recommendations to Joe and his family.
   a. (COM ASSESSMENT) Introduce the COMMUNICATING CONCEPTS AND IDEAS (COM) Scoring Guide.
   b. Have students write their responses to Procedure Step 5.

BUILD UNDERSTANDING

4. Conclude the activity and unit by discussing the Analysis and reviewing what students have learned.
   a. Use Analysis item 1 to review the idea that whether a trait is dominant or recessive depends on whether it appears in an individual homozygous for the trait.

b. (E&T ASSESSMENT) Use Analysis item 2 to stimulate a discussion of students' ideas about genetic testing.

TEACHING STEPS

GET STARTED

1. Review Joe's story.

   a. Tell students that they now have a chance to review Joe's story and to help him by explaining the science of Marfan syndrome and making recommendations to Joe and his family.

   b. Have students read the introduction and Guiding Question for the activity.

   c. Replay the video *How Do Your Genes Fit?,* first shown in "Joe's Situation."

      Have students note portions of the video that they now understand better than they did in the first activity of the unit, "Joe's Situation." This should include references to genes, the visuals of DNA, and mentions of the roles of fibrillin and connective tissue.

DO THE ACTIVITY

2. Have students complete Procedure Steps 1–4 to review what they have learned about the causes and effects of Marfan syndrome.

   a. Allow students to work in their groups to complete Procedure Steps 1–3, and help them answer any questions that remain.

   b. Distribute Student Sheet 14.1, "What We Know About Marfan Syndrome," and have students work in their groups to complete all of the information.

      This Student Sheet should provide students an opportunity to review answers to many of the questions they generated in the activity on "Joe's Situation." A sample completed Student Sheet is provided at the end of the activity.

3. Students write an email to Joe to explain Marfan syndrome and make recommendations to Joe and his family.

   a. (COM ASSESSMENT) Introduce the COMMUNICATING CONCEPTS AND IDEAS (COM) Scoring Guide.

      Procedure Step 5 in this activity is the first use of the COMMUNICATING CONCEPTS AND IDEAS (COM) Scoring Guide. Project or distribute the Scoring Guide, and point out how it has the same levels but different

descriptions for each level. Review the levels as needed. For more information, see Teacher Resources III, "Assessment."

b. Have students write their responses to Procedure Step 5.

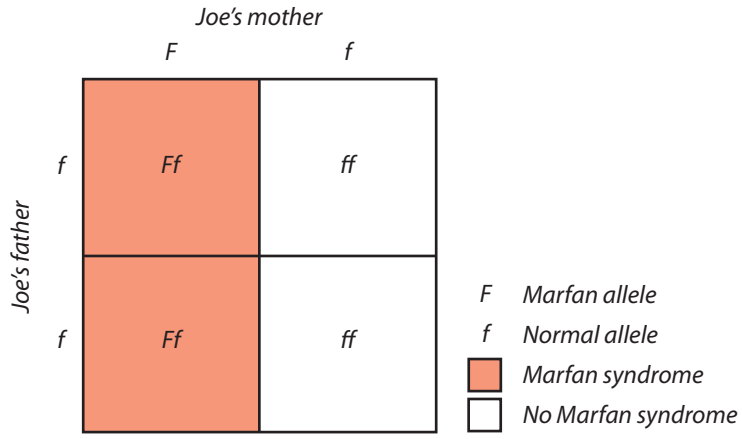
You may wish to have students use the Scoring Guide to review each other's responses and suggest ways to improve them.

PROCEDURE STEP 5 SAMPLE STUDENT RESPONSE

Dear Joe,

Everyone has two copies of the gene that codes for the fibrillin protein—one from their mother and one from their father. Marfan syndrome is caused when one of the copies is mutated. It only takes one copy of the mutated gene to result in Marfan syndrome, which means Marfan syndrome is a dominant trait. Most of the time, the mutated copy of the gene comes from a parent with Marfan syndrome, but sometimes the mutation can happen during copying of the DNA to produce the egg or sperm. When this happens, neither parent has Marfan syndrome, but the resulting child does.

If your mother had Marfan syndrome, you have a 50% chance of having inherited it from her. And you also have a 50% chance of passing it on to your children. My diagram below shows why the chances are 50%.



If you do have Marfan syndrome, the fibrillin in your body has an abnormal three-dimensional shape, which prevents it from functioning properly. Fibrillin is in connective tissue, which is found in many parts of your body. Most important are your eyes and parts of your heart. If you and your family decide to be tested, that might help determine whether you do have Marfan syndrome. They can compare the version of the gene in family members with and without symptoms to see if there is a difference.

There are several things I recommend to you and your father to reduce your risk. First, be sure to see specialists who work with patients who have Marfan syndrome. They can check your eyes and heart. Stay physically active, but don't do any activities that are too strenuous or involve a lot of contact. Remember, whether you have Marfan syndrome is genetic, but how it affects you also depends on your environment and decisions you make.

I know it's been a shock to find out about this, but if it turns out you have Marfan syndrome, be sure to take care of yourself. If you get the right medical attention and take precautions, you can live a long and healthy life.

BUILD UNDERSTANDING

4. Conclude the activity and unit by discussing the Analysis and reviewing what students have learned.

   a. Use Analysis item 1 to review the idea that whether a trait is dominant or recessive depends on whether it appears in an individual homozygous for the trait.

      This is a final chance to emphasize that dominant is not the same as common in the population.

   b. (E&T ASSESSMENT) Use Analysis item 2 to stimulate a discussion of students' ideas about genetic testing.

      Some students might recall that Joe's father was concerned that he might not be able to get health insurance. You might want to share with students some of the information about the Genetic Information Nondiscrimination Act of 2008 that is provided in the Background section of the Teacher Edition for the "Joe's Situation" activity. If you wish to use this as an Evidence and Trade-offs assessment, review the scoring guide with students before they answer the question.

SAMPLE RESPONSES TO ANALYSIS

1. Marfan syndrome is a dominant trait. Write your own definition of *dominant trait* as it is used in genetics. Use evidence from this unit to explain whether the dominant trait is always the most common trait in a human population.

   The dominant trait is whatever trait you see when an individual is heterozygous for a gene. The trait that is dominant might be common or might be rare in the population. Marfan syndrome is an example of a dominant trait that is rare.

2. (E&T ASSESSMENT) Joe and his family have realized that four other family members show some signs of Marfan syndrome: his sister, aunt, cousin, and cousin's baby. Joe's aunt wants everyone in the family who might have Marfan syndrome to be tested to see if their family has a mutation. Their health insurance will not cover the $3,500 it would cost for all of them to be tested. Joe's aunt suggested they pay for the test instead of going away for a summer vacation.

   Do you recommend they have the test? Explain your answer, and be sure to include any trade-offs of your recommendation.

   SAMPLE LEVEL-4 RESPONSES

   I do not recommend they have a genetic test. The doctors can look at all the family members and compare their symptoms to figure out if they have Marfan syndrome. If they have the symptoms, then they can take precautions to live a fairly normal life. If they don't have the test, they can save the money for other things. The trade-offs are that they won't know for sure the cause of their symptoms and won't be able to do a genetic test on Joe's cousin's baby to be sure.

   I do recommend they have a genetic test. The test will let them know for sure if there is a mutation in their family. Then they will be able to test any future children and be sure they get the right medical care from the beginning. Medical care seems to be key to a healthy life with Marfan syndrome. The only trade-off I see is that it will cost money. It seems worth it to me to be sure.

3. **Reflection**: New tests are being developed for genetic conditions as scientists learn more about the genes that cause them. These tests will help people plan their lives, help doctors treat their patients, and lead to actions that help prevent some conditions from having serious effects. But these new tests also raise issues for individuals and for society.

   a. What are some of these issues?

      Some issues include the fact that some genes increase the risk of a condition while others lead to the condition. Other issues are related to whether a person wants to know about possible future conditions that may cause unnecessary stress, whether the information can help the person take action to avoid adverse effects of the genetic condition, and the possible costs of running many tests on many people.

   b. Would you be tested to find out about your genetic makeup? Explain.

      Students' answers may vary. Accept any answer that is responsive to the question. One sample response follows:

      I would only be tested to find out about my genetic makeup if I thought there was something I could do about the test result. Otherwise, I don't see the point in worrying if there's nothing I could do.

c. How would you feel if you were in Joe's situation?

Students' answers may vary. Accept any answer that is responsive to the question. Two sample responses are shown here:

I would be worried if I had the trait that I would have to modify my activities and would maybe be teased by others in school for being really tall with loose joints.

I wouldn't be happy to find out that I had the trait, but I would be relieved to learn that there are medical treatments for the heart problems associated with Marfan syndrome, and there are other things I can do to maintain good health and live a long life.

REVISIT THE GUIDING QUESTION

What have you learned that could help Joe understand and make choices about his situation if he does have Marfan syndrome?

Review with students what they have learned about the causes and effects of Marfan syndrome, as well as the steps Joe can take to maintain his health if he is affected. Knowing about the genetic basis of the disease can help Joe make decisions that might affect any children he might have. Knowing about the effects and treatments can help him monitor his own health and make choices about his lifestyle.

RESOURCES

KEY VOCABULARY

DNA

dominant

homozygous/heterozygous

mutation

probability

trait

Name_____ Date_____

STUDENT SHEET 14.1

WHAT WE KNOW ABOUT MARFAN SYNDROME

1. **What is Marfan syndrome?**

2. **What are the symptoms associated with Marfan syndrome? Do all patients with Marfan syndrome display all the symptoms?**

3. **Who can get Marfan syndrome?**

4. **What causes Marfan syndrome?**

5. **Is Marfan syndrome a dominant or recessive trait?**

6. **If Joe's mother had Marfan syndrome, what is the likelihood that Joe will also have it?**

7. **Do Joe's siblings show symptoms of Marfan syndrome? If this information wasn't presented, based on what you know, should Joe's siblings all have Marfan syndrome if he has it?**

8. **If Joe has Marfan syndrome and has children in the future, what are the chances they will have Marfan syndrome?**

9. **What kind of test will indicate if Joe has Marfan syndrome? Will only Joe need to be tested?**

10. **How do environmental factors affect people with the Marfan syndrome?**

Name *Sample student response* Date_____

STUDENT SHEET 14.1

WHAT WE KNOW ABOUT MARFAN SYNDROME

1. **What is Marfan syndrome?**
   Marfan syndrome is an inherited genetic condition that affects the connective tissue.

2. **What are the symptoms associated with Marfan syndrome? Do all patients with Marfan syndrome display all the symptoms?**
   Symptoms vary but include tall stature and long limbs, loose joints, possible eye problems, and heart problems.

3. **Who can get Marfan syndrome?**
   Children of individuals with Marfan syndrome can inherit it from their parents. However, about one-third of people with Marfan syndrome have it as the result of a new mutation not present in one of the parents. Marfan syndrome is found in people of all races and ethnic groups.

4. **What causes Marfan syndrome?**
   A mutation, or change, of the DNA code in the gene for the protein fibrillin-1.

5. **Is Marfan syndrome a dominant or recessive trait?**
   Marfan syndrome is dominant.

6. **If Joe's mother had Marfan syndrome, what is the likelihood that Joe will also have it?**
   He has a 50% chance of having it, because there is a 50% chance of him getting the mutated allele, rather than the normal allele, from his mother.

7. **Do Joe's siblings show symptoms of Marfan syndrome? Based on what you know, should Joe's siblings all have Marfan syndrome if he has it?**
   Joe's sister shows some symptoms of Marfan syndrome, including having a height and loose joints similar to their mother. If Joe and their mother have Marfan syndrome, his sister has a 50% genetic chance of having it as well, and her symptoms are a concern. Just because one sibling has it doesn't mean all siblings have it. Joe's brother also has a 50% genetic chance, but his lack of symptoms may indicate that he does not have it.

8. **If Joe has Marfan syndrome and has children in the future, what are the chances they will have Marfan syndrome? Explain.**
   His children have a 50%, or 1:1, chance of having Marfan syndrome. We showed this in a previous activity by using Punnett squares to model inheritance of the syndrome from a heterozygous parent.

9. **What kind of test will indicate if Joe has Marfan syndrome? Will only Joe need to be tested?**
   Student responses may vary. Accept answers that refer to testing the sequence of the DNA or the fibrillin protein. A sample response is shown here:
   There are a number of mutations in the fibrillin-1 gene that can lead to Marfan syndrome, so you can't test for a single mutation. Joe and his family will need to be tested to compare their fibrillin-1 sequences. If the members of the family with symptoms have changes in the fibrillin gene that are not observed in the unaffected family members, this indicates that they have Marfan syndrome.

10. **How do environmental factors affect people with Marfan syndrome?**
    Environmental factors such as good medical care, staying active but avoiding contact sports or other activities that are too strenuous, and possibly having surgery for heart problems can all improve the outlook for people with Marfan syndrome. This is important, because life expectancy is greatly improved for people with the syndrome.