9 Breeding Critters—More Traits

INVESTIGATION

1–2 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

Students model and explain additional patterns of inheritance as they explore cause-and-effect relationships for additional traits of the critters. These patterns help them model and explain the wide variation that can result from sexual reproduction. The activity provides an opportunity to assess student work related to Performance Expectation MS-LS3-2.

NGSS CORRELATIONS

Performance Expectations

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-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: 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

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

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

Crosscutting Concepts

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

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

Common Core State Standards—Mathematics

6.SP.B.5: Summarize numerical data sets in relation to their context.

Common Core State Standards—ELA/Literacy

RST.6-8.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics.

WHAT STUDENTS DO

Students model the diversity of offspring possible from two parents and discover patterns of inheritance other than strict dominant/recessive traits.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*
  - * green, red, blue, and orange markers
  - *9 plastic containers (or more, for setting out critter parts)
  - 1 Scoring Guide: DEVELOPING AND USING MODELS (MOD)
  - 1 Scoring Guide: CONSTRUCTING EXPLANATIONS (EXP)
  - 1 Visual Aid 9.1, "Breeding Critters—More Traits"
  - 1 Visual Aid 9.2, "Diversity and Traits"

- *For the class*
  - 56 foam balls (1-1/2 inches; for critter body segments)
  - 16 foam balls (1 inch; for critter heads)
  - 16 blue chenille stems, cut in half
  - 16 orange chenille stems, cut in half
  - 100 round-head brass fasteners
  - 40 red straws, cut into six equal lengths
  - 50 green straws, cut into four equal lengths
  - 60 blue straws, cut into six equal lengths

50 yellow paper clips
40 blue thumbtacks
100 toothpicks
16 speech bubble sticky notes

- *For each group of four students*

1 plastic cup
colored pencils

- *For each pair of students*

1 Student Sheet 9.1, "Critter Breeding Results"
*2 pennies

- *For each student*

1 Scoring Guide: DEVELOPING AND USING MODELS (MOD) (optional)
1 Scoring Guide: CONSTRUCTING EXPLANATIONS (EXP) (optional)

**not included in kit*

Cut each chenille stem in half. Cut the green straws into four equal lengths. (The lengths don't need to be perfect quarters. You can cut 3–5 straws at a time.) Cut the red and blue straws into six equal lengths.

Decide how you will distribute the materials for the critter assembly. It is probably best to have one or two stations, with each critter component in a separate plastic container or cup and the foam balls in a box or bag. One student from each table can obtain the critter pieces for the whole group after they finish their coin tossing. Each student group should have a clear plastic cup for their used pieces after they disassemble their critters, and one group member must be responsible for returning used pieces to the central stations. You may prefer blue sequins and glue for the critter eyes rather than the map pins provided in the kit. Remember that glue and sequins will be harder to clean up.

If the foam balls become damaged as students use them, stale marshmallows can be used instead for the body segments and head. (Make sure students do not eat the marshmallows.)

SAFETY NOTE

Caution students to use care when they use the thumbtacks, and monitor their use.

TEACHING SUMMARY

GET STARTED

1. Introduce the investigation of more critter traits to learn about variations in the pattern of inheritance discovered by Mendel.

   a. Use Visual Aid 9.1, "Breeding Critters—More Traits," and the introduction to show that Skye and Poppy actually have a number of other genetic differences.

   b. Ask students, "Skye has the dominant tail color. Whose traits seem to be dominant for the other characteristics?"

   c. Review the model that students have developed for explaining the inheritance of traits in critters, and point out the results in the "First and Second Generation Traits" table, which provides more information about the 100 offspring.

   d. Point out that one of the traits they will look at is a behavioral trait rather than a structural trait.

DO THE ACTIVITY

2. Students conduct the critter breeding simulation and build the next generation of offspring critters.

   a. Distribute Student Sheet 9.1, "Critter Breeding Results," and review Procedure Steps 1–6.

   b. When students have completed their tosses and filled in the offspring's genes and sex chromosomes on Student Sheet 9.1, have them obtain materials and proceed to Step 7 of the Procedure.

   c. Have students display and observe the class's critters.

BUILD UNDERSTANDING

3. Facilitate a class discussion of the sources of variation in the critter offspring.

   a. Use Analysis items 1–4 as the basis for a discussion of the various inheritance patterns modeled in the activity.

   b. Ask students to explain the sources of the diversity they observe.

   c. Use Visual Aid 9.2, "Diversity and Traits," to help students systematically explore the variation added by each additional trait considered in critters.

   d. Have students consider the variation possible in humans, who have 30,000 pairs of genes.

e. Discuss with the class the role of genes and environment in determining straight versus curly tails in critters.

f. Discuss with the class that traits can be behaviors, not just structures.

g. Discuss with the class the mechanism of sex determination.

4. Review the Analysis and assess students' abilities to model and explain (Analysis items 7 and 8) inheritance of traits and variation in offspring.

a. (MOD ASSESSMENT) Introduce the MOD assessment in Analysis item 7.

b. (EXP ASSESSMENT) Introduce the EXP assessment in Analysis item 8.

TEACHING STEPS

GET STARTED

1. Introduce the investigation of more critter traits to learn about variations in the pattern of inheritance discovered by Mendel.

a. Use Visual Aid 9.1, "Breeding Critters—More Traits," and the introduction to show that Skye and Poppy actually have a number of other genetic differences.

In earlier activities, we focused on just tail color to look at the level of just one characteristic. Because all other critters on Skye's island look like Skye and all other critters on Poppy's island look like Poppy, scientists assume that each critter carries two identical alleles for every trait and that their second-generation offspring are heterozygous for every gene.

b. Ask students, "Skye has the dominant tail color. Whose traits seem to be dominant for the other characteristics?"

Students should notice that Skye and Poppy each had some dominant traits that appear in Ocean and Lucy. For example, Poppy has the dominant number of body segments (3) and antennae (2), while Skye has the dominant number of eyes (2) and leg color (blue). Students should also notice two traits that don't follow the usual pattern—number of spikes and whether the tail is curly or straight.

c. Review the model in the Student Book and point out the results in the "First and Second Generation Traits" table, which provides more information about the 100 offspring.

Point out that all 100 offspring of Skye and Poppy are identical except for their sex and the fact that approximately 50% have curly tails. Tell students that sex determination and straight versus curly tails are two of the interesting characteristics they will investigate in this activity.

d. Point out that one of the traits they will look at is a behavioral trait rather than a structural trait.

In this model, calling behavior is a genetically determined behavioral trait. Whistling is dominant to clicking. Introducing a behavioral trait will help prepare students for the next activity, where the focus is on animal behaviors that increase the probability of reproducing.

DO THE ACTIVITY

2. Students conduct the critter breeding simulation and build the next generation of offspring critters.

a. Distribute Student Sheet 9.1, "Critter Breeding Results," and review Procedure Steps 1–6.

Have students look carefully at how the Student Sheet is set up before they complete Procedure Steps 1–6. One student in the pair tosses a penny to determine which allele Ocean contributes, while the other tosses a penny to determine Lucy's contribution. The students should work together and determine one trait at a time by using the Student Sheet and the "Critter Code" table in the Student Book.

This may be a good breaking point if you plan to spend two sessions on this activity.

b. When students have completed their tosses and filled in the offspring's genes and sex chromosomes on Student Sheet 9.1, have them obtain materials and proceed to Step 7 of the Procedure.

Remind them to use the smaller foam balls for the critters' heads. You might wish to have them take photographs of their critters instead of drawing them.

c. Have students display and observe the class's critters.

Consider setting up a display of the variety of critters (or photos of the critters) produced. After students have observed and or photographed the critters, have them disassemble their creations and return the materials.

BUILD UNDERSTANDING

3. Facilitate a class discussion of the sources of variation in the critter offspring.

   a. Use Analysis items 1–4 as the basis for a discussion of the various inheritance patterns modeled in the activity.

   By looking at the class's critter nursery, students will observe that some traits, shown in the table below, show the pattern of dominant and recessive traits similar to tail color (Analysis item 2). However, other traits show incomplete dominance (Analysis item 3), co-dominance (Analysis item 4), or environmental effects (Analysis item 5).

   Critter Dominant and Recessive Traits

Characteristic	Dominant trait	Recessive trait
Number of body segments	3 segments	2 segments
Leg color	Blue	Red
Number of eyes	2	3
Tail color	Blue	Orange
Number of antennae	2	1
Calling behavior	Whistling	Clicking

   b. Ask students to explain the sources of the diversity they observe.

   These include which specific combination of alleles an offspring inherits from each parent, how these alleles interact (simple dominance, co-dominance for the spikes, or incomplete dominance for nose length), and whether environmental factors affect the appearance of certain traits. You might wish to point out that there are human traits that show incomplete or co-dominance.

   The cross between Ocean and Lucy should give an approximately 3:1 ratio for each of the traits that show simple dominance, although this might not be evident given the sample size in the classroom. Have students determine the ratios only if you have plenty of extra time for them to do so.

   c. Use Visual Aid 9.2, "Diversity and Traits," to help students systematically explore the variation added by each additional trait considered in critters.

For example, if only tail color varies with blue and orange colors possible, then there are two possible appearances of the critters: blue tail or orange tail, represented by Critters 1 and 2 in Visual Aid 9.2. If tail color and body segment number vary, there are four possible appearances: blue tail and two segments, orange tail and two segments, blue tail and three segments, or orange tail and three segments, as represented by Critters 1–4 on the visual aid. If a third trait, such as number of antennae, comes in two variations, this number will be doubled, for eight possible critters, represented by Critters 5–12 on the visual aid. Although not shown, a trait with three versions, such as nose length, would triple the number of variations.

Students are usually surprised at the variety of siblings. Point out that only a few traits are considered in this activity. With more traits, the siblings would show even more diversity.

d. Have students consider the variation possible in humans, who have 30,000 pairs of genes.

Remind students that in the previous activity, "Show Me the Genes!," they learned that humans have 30,000 pairs of genes, so the potential variability is very great. However, point out that many of these variations are not immediately (or ever) visible. For example, a gene for a condition such as baldness isn't apparent for a number of years. Blood type is not visible, but it matters during blood transfusions.

e. Discuss with the class the role of genes and environment in determining straight versus curly tails in critters.

This trait is intended to reinforce the concept that both genes and the environment determine traits. Students should be able to tie this example to the results they obtained with the seedlings.

f. Discuss with the class that traits can be behaviors, not just structures.

The critter whistling and clicking calls are included as an example of animal behaviors with a genetic component. Explain that many genes code for proteins that play a role in the nervous system. Variations in these proteins can affect how the nervous system functions. As a result, some animal behaviors are influenced by genetic factors in addition to factors in the environment. Some examples of animal behavior with genetic components are sounds produced by animals and courtship and mating calls and rituals. This topic is introduced in this activity as a transition to animal behaviors related to animal reproduction and plant pollination in the next two activities. You might wish to explain to students that evidence collected from studies of identical twins indicates that there is a genetic component to human behavior. However, the contribution of genetic and environmental factors in influencing most behaviors is still a subject of research.

g. Discuss with the class the mechanism of sex determination.

This depends primarily on the sex chromosomes in many organisms. Explain that in humans, as in critters, females have two X chromosomes, and males have an X and a Y chromosome. Explain that in many organisms, such as birds, this situation is reversed and the females have two different sex chromosomes while the males have two similar sex chromosomes.

Note that there are exceptions to this generalization that involve individuals with three sex chromosomes, hormonal effects that alter the function of the genes on the sex chromosomes, or mutations in sex-determining genes.

You might wish to share the interesting exception to sex determination by chromosomes exhibited by crocodiles, most turtles, and certain other groups of reptiles. In these organisms, the incubation temperature of the egg during one part of development determines whether the organism will be male or female. In the case of these organisms, sex determination is environmental rather than genetic.

4. Review the Analysis and assess students' abilities to model and explain (Analysis items 7 and 8) inheritance of traits and variation in offspring.

a. (MOD ASSESSMENT) Introduce the MOD assessment in Analysis item 7.

Analysis item 7 in this activity can be assessed using the DEVELOPING AND USING MODELS (MOD) Scoring Guide. A sample Level-4 response follows. For more information, see Teacher Resources III, "Assessment." This is the final assessment for MS-LS3-2.

b. (EXP ASSESSMENT) Introduce the EXP assessment in Analysis item 8.

Analysis item 8 in this activity can be assessed using the CONSTRUCTING EXPLANATIONS (EXP) Scoring Guide. A sample Level-4 response follows. For more information, see Teacher Resources III, "Assessment."

SAMPLE RESPONSES TO ANALYSIS

1. Look at the other critters made by your classmates. They are all siblings (brothers and sisters).

   a. What are their similarities and differences?

   The critters look different in that most have different combinations of traits. They are similar in that all have similar head and body parts and similar shapes for their legs, eyes, and noses. A few of the offspring resemble each other in many features, but others look quite different.

   b. Use the ideas you have learned in this unit and the model you used in this activity to explain to Joe why some siblings, like Joe and his sister, look a lot alike, whereas others, like Joe's brother, look very different from each other.

   Which alleles an offspring gets from each parent is random. Sometimes siblings get some similar alleles that make them look alike. But other times, they get different alleles that result in a different set of traits that might not be present in either of the parents or any of their siblings. A good example is the recessive orange tails that aren't observed in Ocean and Lucy but show up in some of their offspring.

2. Which characteristics show a simple dominant/recessive pattern like tail color? List them in a table, and indicate which version is dominant and which is recessive for each trait.

   Hint: Look at the "First and Second Generation Traits" table to see which traits have this pattern.

   The number of body segments, leg color, the number of eyes, tail color, and the number of antennae all show a simple dominance vs. recessive pattern. In other words, one trait completely dominates, or masks, the other, but the recessive trait reappears in some members of the next generation.

Some traits do not show a simple dominant versus recessive pattern. Look at the "First and Second Generation Traits" table to help you answer Questions 3–5.

3. For which characteristic do some offspring have traits in between Skye's and Poppy's traits? Explain. (For example, in some plants, a cross between a red- and white-flowered plant will give pink-flowered offspring. This is called *incomplete dominance*.)

The nose-length characteristic shows an intermediate trait in the offspring: Ocean and Lucy each have a nose in between the lengths of their parents' (Skye and Poppy) long and short noses. Neither the short nor the long trait is dominant.

4. For which characteristic do some offspring have both Skye's and Poppy's traits? Explain. (For example, in humans, a person with type A blood and a person with type B blood can have a child with type AB blood. This is called *co-dominance*, as both traits appear in the offspring.)

   Ocean and Lucy have both the green spikes from one parent and the blue spike from the other parent. Both traits are dominant because only one allele is sufficient for the trait to appear.

5. Which critter trait is affected by an environmental factor, such as light, temperature, or diet? Explain.

   The inheritance pattern for tail style represents the role of environmental factors. In this case, the ***SS*** *critters will have curly tails no matter what, but the* ***Ss*** *critters will develop curly tails only if they receive enough of a nutrient called* crittric acid.

6. Consider the pattern for sex determination.

   a. How is a critter's sex determined?

      A critter's sex is determined by a pair of chromosomes. For critters (and humans), if the individual has two X chromosomes, it is a female. If the individual has one X and one Y chromosome, it is a male.

   b. Whose genetic contribution—Ocean's or Lucy's—determines the sex of the offspring?

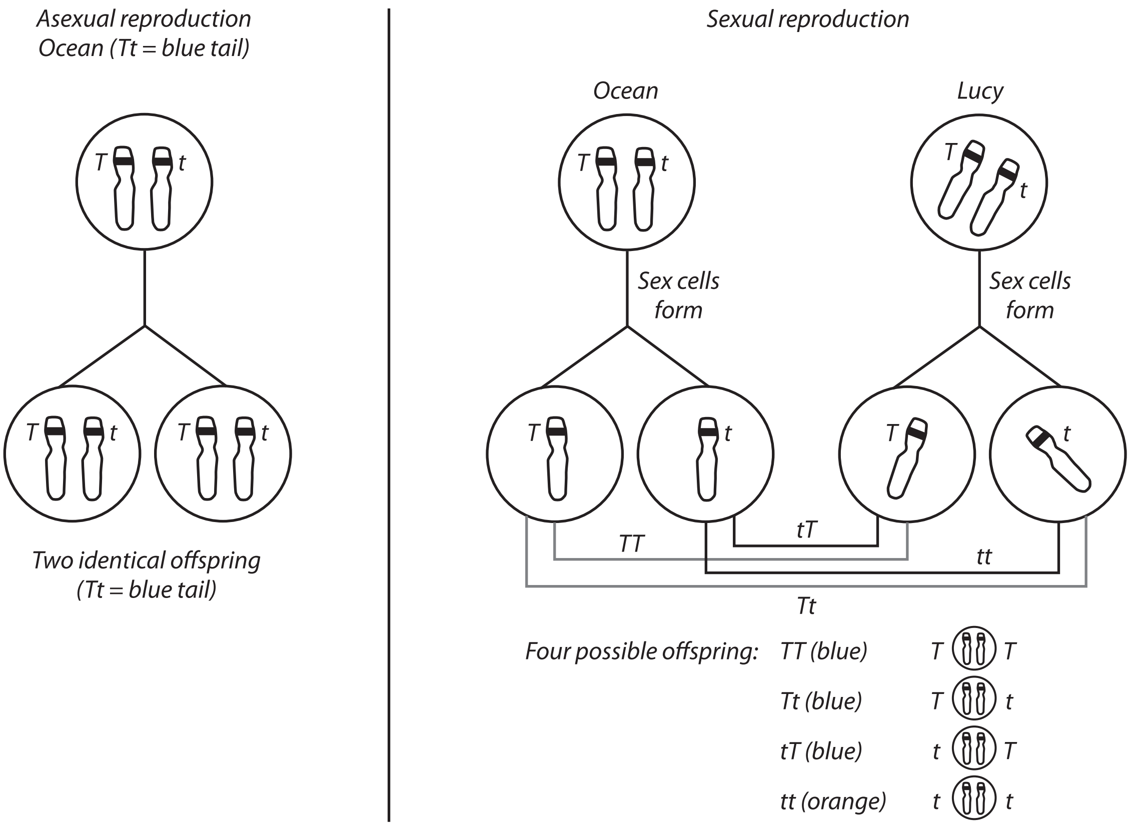
      Ocean's genetic contribution determines the sex of the offspring because Ocean can contribute either an X or Y chromosome. Lucy can contribute only an X chromosome.

7. (MOD ASSESSMENT) Draw a model and use it to describe why asexual reproduction leads to identical offspring and sexual reproduction leads to variation. You can use the offspring of the cross between Ocean and Lucy as your example. Be sure to include the following:

   - a diagram or other model that shows the inheritance of a chromosome pair and alleles for a characteristic like tail color
   - an explanation of how inheritance of two characteristics (for example, tail color and number of body segments in critters) would lead to more variation in critter offspring
   - what would happen if there were more pairs of chromosomes and more genes shown.

Students may choose to use a Punnett square or other approaches to creating their models. One sample Level-4 response is shown here:

SAMPLE LEVEL-4 RESPONSE



The model above shows that asexual reproduction leads to inheritance of identical chromosomes, which results in identical genes. This means there is only one possible outcome for the offspring. If Ocean or Lucy reproduced asexually, all of their offspring would have blue tails. There would be just one kind of offspring and no variation.

But in sexual reproduction, each offspring receives only one of their two chromosomes (in each pair) from each parent. This means the offspring can have different combinations of chromosomes, and different combinations of genes, from either parent. When they reproduce sexually, Ocean and Lucy can produce offspring with blue tails or orange tails.

If you look at another trait, like number of body segments, sexual reproduction leads to more variation. If they reproduced asexually Ocean and Lucy could only produce offspring with blue tails and two segments. When they reproduce sexually Ocean and Lucy can produce four kinds of offspring: blue tails and two segments, blue tails and three segments, orange tails and two segments, and orange tails and three segments.

If there are more chromosomes and genes, there is even more variation.

8. (EXP ASSESSMENT) Consider Joe's story. Joe's friend says he thinks Joe doesn't have Marfan syndrome because he has hair and eyes like his father's and acts more like his father, and his father doesn't have Marfan syndrome. Based on what you have learned so far, do you agree with Joe's friend that he's unlikely to have Marfan syndrome? Explain in terms of what you know about inheritance of genes and chromosomes.

   Student responses may vary. One sample Level-4 response is shown here:

   SAMPLE LEVEL-4 RESPONSE

   I disagree that Joe is unlikely to have Marfan syndrome just because he looks more like his father. He may look more like his father because of the combination of genes he got from both parents, but he got half of his chromosomes, and half of his genes, from his mother. Since Marfan syndrome is dominant, that means he has a 50% chance of having inherited the dominant gene from his mother and of having Marfan syndrome.

REVISIT THE GUIDING QUESTION

What causes variation between offspring of the same parents?

Variation is a result of the fact that each offspring receives only half of the chromosomes and genes from each parent. The exact alleles inherited will depend on which chromosome out of each pair is passed on. This can result in many different combinations of genes in the offspring, as shown in the critters.

ACTIVITY RESOURCES

KEY VOCABULARY

allele

chromosome

diversity

dominant

gene, genetics

recessive

trait

BACKGROUND INFORMATION

THE CRITTER SIMULATION

This activity provides an opportunity for students to model the variety of offspring that can be produced by two parents. In this case, the second-generation parents, Ocean and Lucy, are genetically similar. However, a great deal of variety arises in their offspring because Ocean and Lucy are heterozygous for every gene. The model also simulates co-dominance, incomplete dominance, environmental effects on inherited traits, inherited behaviors, and sex determination.

Five of the nine traits (number of body segments, leg color, number of eyes, tail color, and number of antennae) show a dominant versus recessive mechanism of inheritance. The other traits show interesting deviations from this pattern. These include incomplete dominance, which gives an intermediate appearance in the heterozygote (simulated by nose length) and co-dominance, in which both traits are fully present in the heterozygote (modeled by the blue and green spikes).

The tail-style trait is used to simulate environmental influences. Curly tail is dominant only if the critter's diet includes plenty of the imaginary critter nutrient, crittric acid, during development. This example is intended to be humorous, but it represents the importance of nutrition and other factors in growth and development.

The calling behavior trait reinforces the idea that behavioral traits can be determined by genetic factors.

The inheritance of sex is unusual in that it is determined by the presence or absence of a particular chromosome. In mammals and many other organisms, the presence of a Y chromosome usually results in a male. Because only males have Y chromosomes, only the male parent can donate this chromosome to the offspring. Sex determination varies in different species; for instance, female birds have two different sex chromosomes.

Name____ Date____________

STUDENT SHEET 9.1

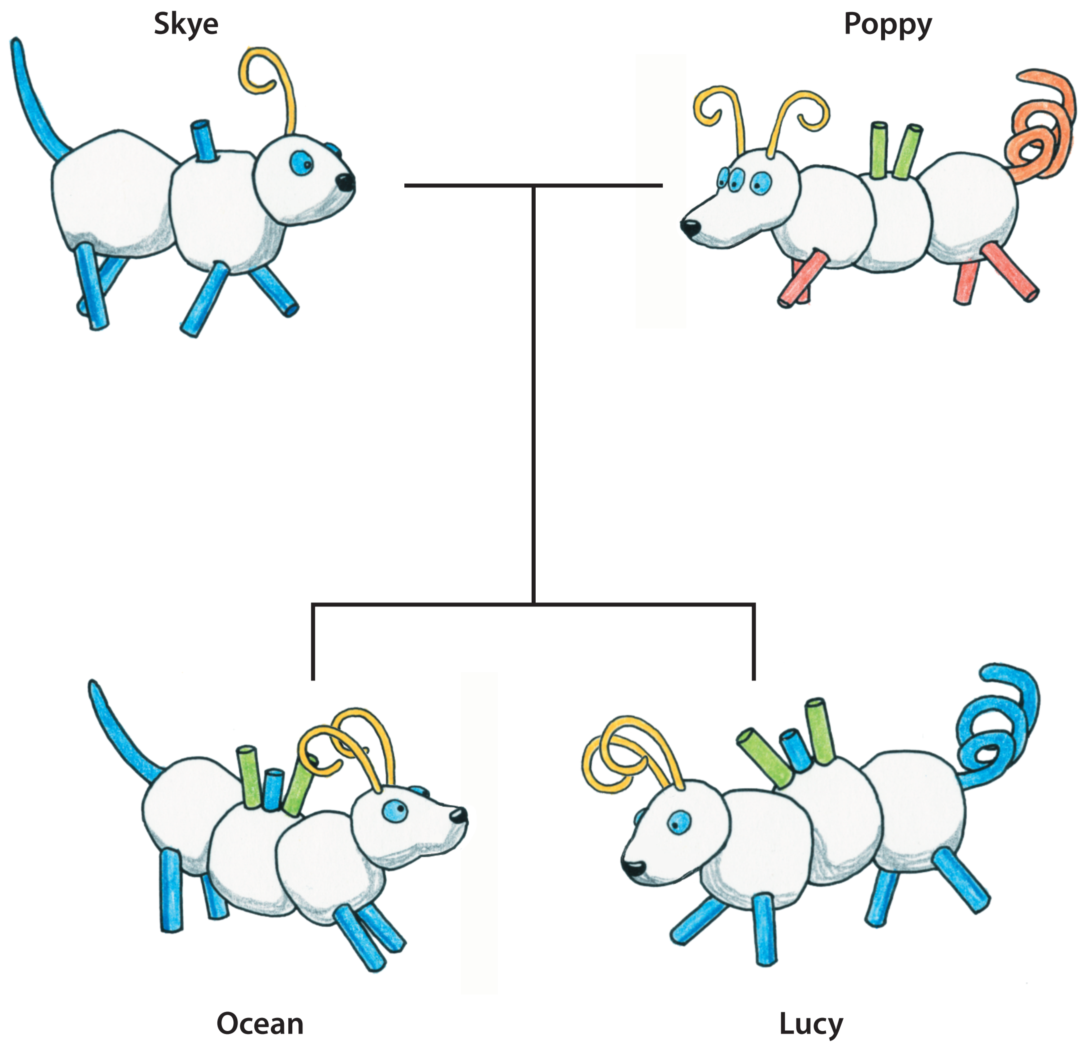
CRITTER BREEDING RESULTS

Trait	Ocean's alleles		Offspring's genes		Offspring's trait	Lucy's alleles	
	heads	tails	From Ocean	From Lucy	(Use Critter Code to fill this in)	Heads	Tails
1. Body segments	B	b				B	b
2. Leg color	L	l				L	l
3. Eyes	E	e				E	e
4. Nose length	N	n				N	n
5. Tail color	T	t				T	t
6. Tail style	S	s				S	s
7. Antennae	A	a				A	a
8. Spikes	G	H				G	H
9. Calling behavior	W	w				W	w

	Ocean's sex chromosomes		Offspring's sex chromosomes		Offspring's sex	Lucy's sex chromosomes	
10. Sex	Heads	Tails	From Ocean	From Lucy		Heads	Tails
	X	Y				X	X

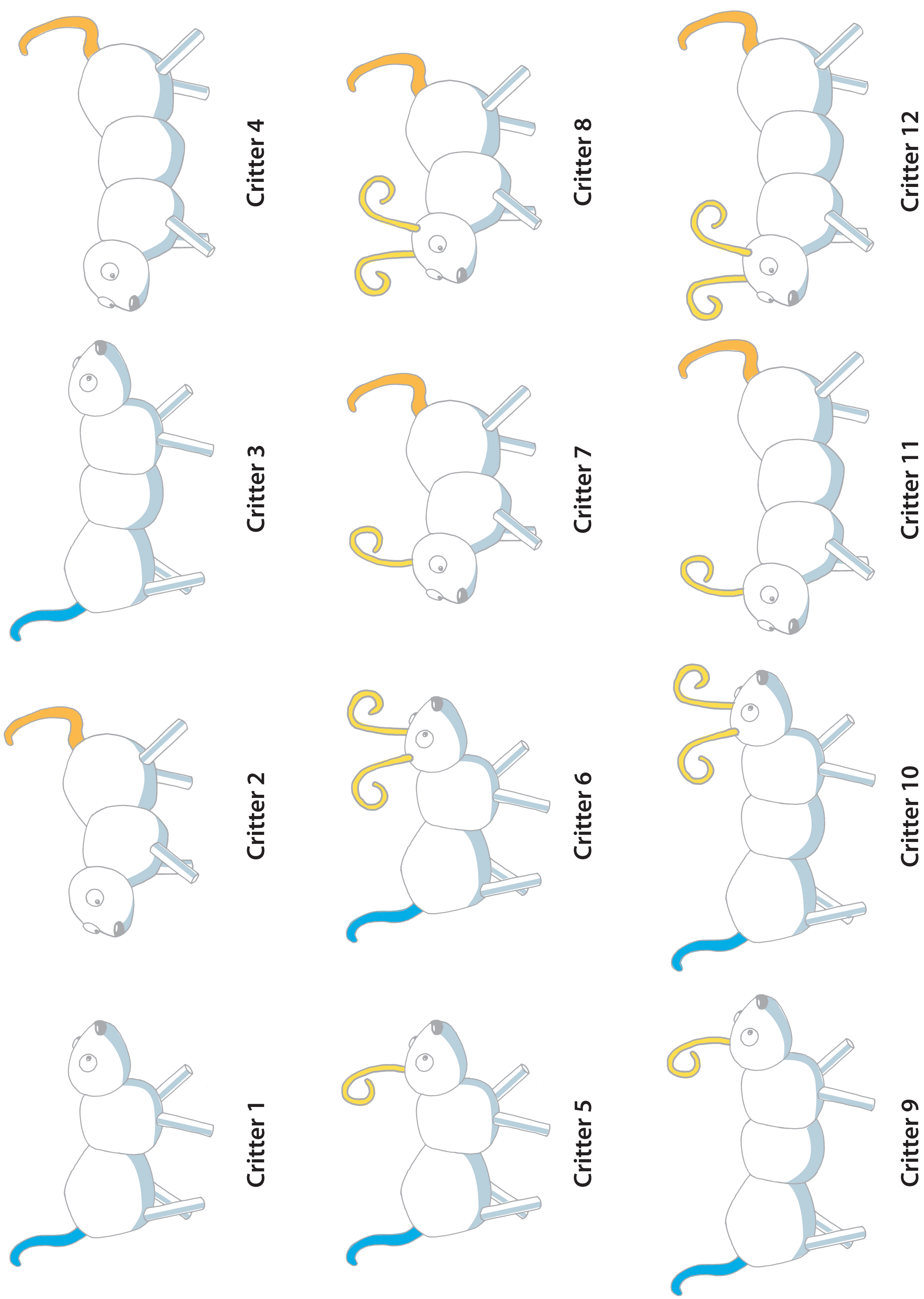
VISUAL AID 9.1

BREEDING CRITTERS—MORE TRAITS



VISUAL AID 9.2

DIVERSITY AND TRAITS



CONSTRUCTING EXPLANATIONS (EXP)

When to use this scoring guide:

This scoring guide is used when students develop their own explanations of phenomena. Their explanations may be based on evidence from their own investigations, on secondary data sets, and/ or on evidence and concepts obtained from text and other media.

What to look for:

- Response include relevant evidence, ideas, and concepts
- Response logically links evidence and concepts to develop a causal mechanism for a phenomenon

Level	Description
Level 4 Complete and correct	The student's explanation: • is supported by sufficient use of appropriate evidence and concepts* AND • links the evidence and concepts to provide a clear and complete causal mechanism for the phenomenon.
Level 3 Almost there	The student's explanation: • is supported by sufficient use of appropriate evidence and concepts* BUT • does not link the evidence and concept to provide a clear and complete causal mechanism for the phenomenon.
Level 2 On the way	The student's response includes some use of evidence and concepts relevant to the phenomenon, BUT some key pieces of evidence and/or concepts are missing.
Level 1 Getting started	The student's response makes little to no use of appropriate evidence and concepts* to develop an explanation for the phenomenon.
Level 0	The student's response is missing, illegible, or irrelevant to the phenomenon.
x	The student had no opportunity to respond.

* concepts may include models, representations, and/or accepted scientific theories

DEVELOPING AND USING MODELS (MOD)

When to use this scoring guide:

This scoring guide is used when students develop their own models or use established models to describe relationships and/or make predictions about scientific phenomena.

What to look for:

- Response accurately represents the phenomenon
- Response includes an explanation of relevant ideas and concepts represented by the model or a prediction based on the relationships between ideas and concepts represented by the model

Level	Description
Level 4 Complete and correct	The student's model completely and accurately represents the components, relationships, and mechanisms of the phenomenon AND the student uses it to develop a complete and correct explanation or prediction.
Level 3 Almost there	The student's model completely and accurately represents the components, relationships, and mechanisms of the phenomenon AND includes a mostly correct use of the model to create an explanation or prediction.
Level 2 On the way	The student's model represents components of the phenomenon AND includes a partially correct representation of the relationships or mechanisms associated with the phenomenon.
Level 1 Getting started	The student's model represents components of the phenomenon BUT provides little or no evidence of the relationships or mechanisms associated with the phenomenon.
Level 0	The student's response is missing, illegible, or irrelevant.
x	The student had no opportunity to respond.

* A model can be a diagram, drawing, physical replica, diorama, dramatization, storyboard or any other graphical, verbal, or mathematical representation. It may include labels or other written text as required by the prompt.

UNIT OVERVIEW

REPRODUCTION

Listed below is a summary of the activities in this unit. Note that the total teaching time is listed as 14–21 periods of approximately 45–50 minutes (approximately 3–4 weeks).

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
1. **View and Reflect: Joe's Situation** Students are introduced to a scenario of a student who has just learned he may have inherited a genetic condition (Marfan syndrome).	genes, genetic disorders LITERACY	Preview the video, preview Activity 7, plan when to set up seedlings for demo.	E&T QUICK CHECK A7	1–2
2. **Modeling: Creature Features** Students develop models to investigate the inheritance of a trait in imaginary creatures.	gene, trait, sexual reproduction, breeding, offspring, inherited, modeling, hypothesis LITERACY	Obtain chart paper; obtain black, blue, and orange markers; copy Student Sheets; make templates; preview Activity 7; plan when to set up seedlings for demo.	MOD QUICK CHECK A2	1–2
3. **Reading: Reproduction** Students read about the differences between sexual and asexual reproduction at the cellular level.	cell, heredity, offspring, asexual reproduction, sexual reproduction, clone, fertilization LITERACY	Copy Student Sheet, preview Activity 7, plan when to set up seedlings for demo.	EXP QUICK CHECK A1 MOD A3	2
4. **Investigation: Gene Combo** Students model the inheritance of single-gene traits by collecting and analyzing data from coin tosses.	gene, inherited, fertilization, allele, dominant, recessive, random, probability, modeling, hypothesis MATHEMATICS	Obtain pennies and small cups (optional), copy Student Sheet.	ODA: Proc ARG QUICK CHECK A6 EXP A8	1–2
5. **Problem Solving: Gene Squares** Students use Punnett squares to model sexual reproduction and predict the approximate frequencies of traits among offspring.	allele, dominant, recessive, carrier, heterozygous, homozygous, Punnett square MATHEMATICS	Copy Student Sheet.	MOD A5	2–3
6. **Reading: Mendel, First Geneticist** Students read about Gregor Mendel's experiments with pea plants.	gene, trait, allele, sexual reproduction, offspring, dominant, recessive, probability, random LITERACY		EXP A5	1–2
7. **Laboratory: Do Genes Determine Everything?** Students design an experiment to investigate the effect of the environment on such plant traits as seedling color.	gene, allele, trait, heredity, heterozygous, homozygous, nature vs. nurture LITERACY, MATHEMATICS	Obtain masking tape, permanent markers.	PCI: Proc. ODA: Proc. AID: A1 EXP: A2	2

REPRODUCTION (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
8. **Reading: Show Me the Genes!** Students read about the behavior of chromosomes and the function of DNA during sexual reproduction.	cell, gene, allele, chromosome, DNA, fertilization, mutation, nucleus, sexual reproduction LITERACY		MOD: A1, A3	2
9. **Investigation: Breeding Critters — More Traits** Students create imaginary critter offspring to model patterns of inheritance and develop explanations of what happens in terms of genes, chromosomes, and environmental effects.	allele, chromosome, diversity, dominant, gene, recessive, trait	Obtain pennies, colored pencils; prepare materials (e.g., cut straws), copy Student Sheet.	MOD: A7 EXP: A8	1–2
10. **Investigation: Animal Behavior** Students read one of four real case studies on a behavioral or physical trait in an animal. They examine and interpret graphs to argue for how those traits increase the animal's reproductive success.	reproductive success, animal behavior LITERACY, MATHEMATICS		ARG: A1	2
11. **Investigation: Plant–Animal Interactions** Students read about four different flowers and four different pollinators. They construct an argument for how the structure of the plant increases its reproductive success by attracting a specific type of pollinator.	pollination, pollinator		ARG: A1	1
12. **Modeling: How Do Genes Produce Traits?** Students use a simplified codon table to determine part of the fibrillin protein sequence from a given DNA sequence and explore the protein's three-dimensional structure.	DNA, gene, protein, subunit	Copy Student Sheet.		1–2
13. **Modeling: Fault in the Genes** Students model mutations and their effects on protein sequence and structure.	mutation	Preview video.	MOD: A4	1–2
14. **Talking It Over: Advising Joe** Students revisit the Marfan scenario and use a model to construct an explanation of what is going on and an argument about what Joe should do.	DNA, dominant, heterozygous/ homozygous, mutation, probability, trait	Copy Student Sheet.	COM: Proc. E&T: A2	1–2

NGSS UNIT OVERVIEW

REPRODUCTION

Performance Expectation 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.

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

Performance Expectation 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.

Performance Expectation 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.

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
1. **View and Reflect: Joe's Situation** This activity introduces the fictional scenario of Joe, who has learned that he might have a genetic condition. Students engage in the practices of asking questions and obtaining, gathering, and communicating information as they attempt to understand Joe's story. As they do this, they explore both the causes and effects of a genetic condition, beginning a focus on the crosscutting concepts of cause and effect and structure and function, which run throughout the unit. Also throughout the unit, students apply what they learn to Joe's situation. In the final activity of the unit, they will make a recommendation to Joe.	MS-LS1.B MS-LS3.A	Asking Questions and Defining Problems Obtaining, Evaluating, and Communicating Information	Cause and Effect Structure and Function Connections to Nature of Science: Science Addresses Questions About the Natural and Material World	ELA/Literacy: RST.6-8.2 WHST.6-8.9 SL.8.1
2. **Modeling: Creature Features** Students begin to use the practice of developing and using models to show and revise their ideas about genes and inheritance of traits. The crosscutting concepts of patterns and cause and effect provide helpful lenses for thinking about the results of an imaginary scenario in which animals are bred to produce two generations of offspring. This activity begins a sequence in which students explore core ideas and concepts related to patterns of inheritance of traits as a result of sexual reproduction. Students also begin to engage in scientific argumentation as they evaluate possible hypotheses.	MS-LS1.B MS-LS3.B	Developing and Using Models Constructing Explanations and Designing Solutions Engaging in Argument from Evidence	Patterns Cause and Effect	ELA/Literacy RST.6-8.7 WHST.6-8.1 WHST.6-8.9 SL.8.1

REPRODUCTION (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
3. **Reading: Reproduction** Students engage in the practice of obtaining information as they read about the cellular basis of sexual and asexual reproduction. This information will help them to revise their models and explanations for the inheritance of traits and prepare them for quantitative predictions of the incidence of traits in offspring.	MS-LS1.B MS-LS3.A MS-LS3.B	Constructing Explanations and Designing Solutions Developing and Using Models Obtaining, Evaluating, and Communicating Information	Patterns Cause and Effect	ELA/Literacy: RST.6-8.1 RST.6-8.4 RST.6-8.7 WHST.6-8.2 WHST.6-8.9
4. **Investigation: Gene Combo** Students use a coin-tossing model to investigate quantitatively the outcomes of breeding a second generation of offspring from heterozygous parents. The crosscutting concepts of patterns and cause and effect continue to be emphasized. This activity helps students understand how genes determine traits, distinguish between predicted and actual outcomes of such crosses, and further elaborate their model of inheritance of traits. This will lead into activities where students will learn about Mendel's work and will use Punnett squares as another model for predicting the outcomes of genetic crosses.	MS-LS1.B MS-LS3.A MS-LS3.B	Developing and Using Models Constructing Explanations and Designing Solutions Using Mathematics and Computational Thinking Analyzing and Interpreting Data Engaging in Argument from Evidence	Patterns Cause and Effect Scale, Proportion, and Quantity	Mathematics: 6.RP.A.1 ELA/Literacy: RST.6-8.4
5. **Problem Solving: Gene Squares** This activity introduces the use of Punnett squares as a model for predicting the ratios of both genotypes and phenotypes in the offspring of genetic crosses. Students use crosscutting concepts of patterns and cause and effect as they use Punnett squares to predict outcomes of crosses of various pairs of critters.	MS-LS1.B MS-LS3.A MS-LS3.B	Constructing Explanations and Designing Solutions Developing and Using Models Using Mathematics and Computational Thinking	Patterns Cause and Effect	Mathematics: 6.RP.A.1 ELA/Literacy RST.6-8.2 RST.6-8.4 RST.6-8.7

REPRODUCTION (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
6. **Reading: Mendel, First Geneticist** A reading on Gregor Mendel's investigations and the principles of genetics he identified through his work provides a perspective on the history and nature of science and the data analysis, recognition of patterns, and use of mathematics central to this important advancement in explaining how genes cause traits. The reading provides data from Mendel's experiments breeding pea plants and his application of ratios to his analysis and interpretation of his results. Students can compare Mendel's findings, analysis, and model to their own work with the critter model.	MS-LS1.B MS-LS3.A MS-LS3.B	Analyzing and Interpreting Data Using Mathematics and Computational Thinking Obtaining, Evaluating, and Communicating Information Constructing Explanations and Designing Solutions Connections to Nature of Science: Science Is a Way of Knowing	Cause and Effect Patterns Scale, Proportion, and Quantity	Mathematics: 6.RP.A.1 ELA/Literacy: RST.6-8.7 RST.6-8.9
7. **Laboratory: Do Genes Determine Everything?** Students are introduced to two traits for seedling color in *Nicotiana* plants. They are then introduced to experimental design before they plan and conduct an investigation to determine how selected environmental factors affect the phenotype of plant seedlings. They analyze their data to explain the interaction between genetic and environmental factors. They use this experience as the basis for a discussion of the interplay of genetic and environmental factors in determining traits in humans, as well as in plants. The activity provides an opportunity to assess student work related to Performance Expectation MS-LS1-5.	MS-LS1.B MS-LS3.B	Analyzing and Interpreting Data Planning and Conducting Investigations Constructing Explanations and Designing Solutions Connections to Nature of Science: Science Is a Way of Knowing	Cause and Effect	Mathematics: 6.RP.A.1 6.SP.B.5
8. **Reading: Show Me the Genes!** Students obtain information from a reading that introduces the location of genes on chromosomes and the number of sets of chromosomes in sex cells and the rest of the body. This information helps explain some of the phenomena related to genes that students have been learning about, and also prepares them for future activities where they will model the cause-and-effect relationships between genes (and mutations) and protein structure and function.	MS-LS1.B MS-LS3.A MS-LS3.B	Developing and Using Models Obtaining, Evaluating, and Communicating Information	Patterns Cause and Effect Structure and Function Scale, Proportion, and Quantity	ELA/Literacy: RST.6-8.2 RST.6-8.4 RST.6-8.7 WHST.6-8.2 WHST.6-8.9

REPRODUCTION (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
9. **Investigation: Breeding Critters — More Traits** Students model and explain additional patterns of inheritance as they explore cause-and-effect relationships for additional traits of the critters. These patterns help them model and explain the wide variation that can result from sexual reproduction. The activity provides an opportunity to assess student work related to Performance Expectation MS-LS3-2.	MS-LS1.B MS-LS3.A MS-LS3.B	Constructing Explanations and Designing Solutions Developing and Using Models	Patterns Cause and Effect	Mathematics: 6.SP.B.5 ELA/Literacy: RST.6-8.4
10. **Investigation: Animal Behavior** 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.	MS-LS1.B MS-LS4.C	Engaging in Argument from Evidence Analyzing and Interpreting Data	Patterns Cause and Effect	Mathematics: 6.SP.A.2 6.SP.B.4 ELA/Literacy: RST.6-8.1 WHST.6-8.1
11. **Investigation: Plant–Animal Interactions** 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 how these traits cause the individual plant to have higher reproductive success than plants with different traits. The activity provides an opportunity to assess student work related to Performance Expectation MS-LS1-4, focusing on plant–animal interactions.	MS-LS1.B MS-LS4.C	Engaging in Argument from Evidence Obtaining, Evaluating, and Communicating Information	Cause and Effect Patterns Structure and Function	ELA/Literacy: RST.6-8.1 R.I.6.8 WHST.6-8.1

REPRODUCTION (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
12. **Modeling: How Do Genes Produce Traits?** This activity introduces the concept that a gene encodes for a protein, which has a specific function in the cell. These protein functions manifest as traits in the body. Students use a toober and pipe cleaners to model and generate explanations for how a gene's 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.	MS-LS3.A	Developing and Using Models Constructing Explanations and Designing Solutions	Cause and Effect Structure and Function	ELA/Literacy: RST.6-8.7
13. **Modeling: Fault in the Genes** 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 structure. Using the toobers and pipe cleaners, students model the mutations and the resulting changes to their protein structures. After investigating different types of mutations, students construct explanations for how a mutation in a gene leads to changes in body function, specifically how a mutation in the fibrillin-1 gene leads to Marfan syndrome symptoms. The activity provides an opportunity to assess student work related to Performance Expectation MS-LS3-1.	MS-LS3.A MS-LS3.B	Developing and Using Models Constructing Explanations and Designing Solutions Analyzing and Interpreting Data	Cause and Effect Structure and Function	ELA/Literacy: RST.6-8.7
14. **Talking it Over: Advising Joe** 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.	MS-LS1.B MS-LS3.A MS-LS3.B	Obtaining, Evaluating, and Communicating Information	Cause and Effect Understandings About the Nature of Science: Science Addresses Questions About the Natural and Material World	Math: 6.RP.A.1 ELA/Literacy WHST.6-8.2