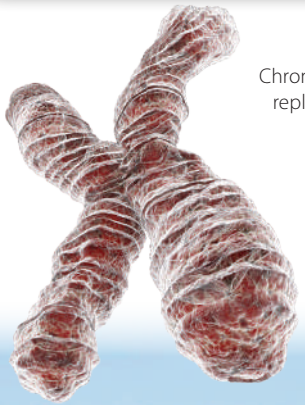
Genetics:
Why are living things different from one another?

Science Literacy



Teacher Guide



Chromosome replication

Genetic variation in plants





Genetic variation in animals

GRADE 8 Core Knowledge Science®

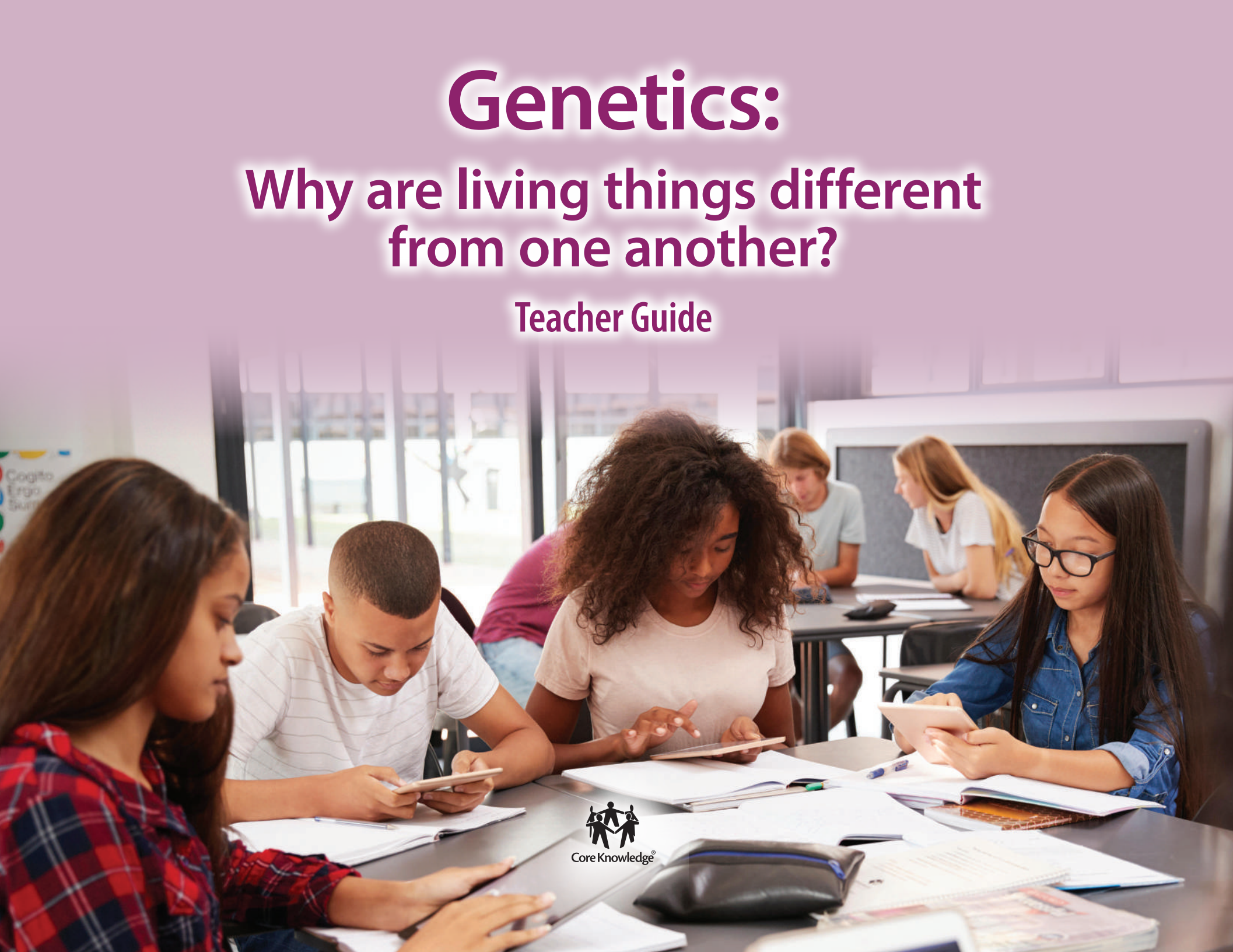
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This unit is a modified version of a unit that has earned the NGSS Design Badge. The sole instructional modification is the addition of Core Knowledge Science Literacy content. The modification has not been reviewed.

Genetics:

Why are living things different from one another?

Teacher Guide



Core Knowledge®

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Genetics:

Why are living things different from one another?

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BEFORE YOU BEGIN

Before introducing the unit, please become fully acquainted with the program instructional model and classroom routines by reading the online resource **Teacher Handbook: Overview of the Core Knowledge Middle School Science Program**.

Online Resources



Use this link to download the **CKSci Online Resources Guide** for this unit, which includes specific links to:

- the unit's comprehensive materials list
- a full unit pacing snapshot
- lesson guidance slides
- all other recommended resources.

www.coreknowledge.org/cksci-online-resources

Student Work Pages



All student handouts and exercise pages are included in the consumable Student Work Pages book so that there is no need to print copies of these resources.

Student Books



All student handouts and exercise pages are included in the consumable Student Work Pages book so that there is no need to print copies of these resources. Students also will use the Student Procedure Guide and the Science Literacy Student Reader throughout the unit.

UNIT OVERVIEW

Why are living things different from one another?

This unit on genetics starts out with students noticing and wondering about photos of two cattle, one of whom has significantly more muscle than the other. The students then observe photos of other animals with similar differences in musculature: dogs, fish, rabbits, and mice. After developing initial models for the possible causes of these differences in musculature, students explore a collection of photos showing a range of visible differences. Students gather other examples of trait variation they've seen in their lives and share them with the class. The photos they've seen and discussions they've had about trait variation spark questions and ideas for investigations generally around why there are differences among living things and specifically around the causes of these extra-big muscles.

In the first lesson set, students use videos, photos, data sets, and readings to investigate what causes an animal to get extra-big muscles. Students figure out how muscles typically develop as a result of environmental factors such as exercise and diet. Then, students work with cattle pedigrees, including data about chromosomes and proteins, to figure out genetic factors that influence the heavily muscled phenotype. Students obtain information from articles that the MSTN gene causes the myostatin protein, which impacts muscle growth. From there, students explore selective breeding in cattle. In the second lesson set, students use what they've learned from explaining cattle musculature to help them explain other trait variations they've seen. They investigate plant reproduction, including selective breeding and asexual reproduction (in plants and other organisms) and other examples of traits that are influenced by genetic and environmental factors. Students figure out that environmental and genetic factors together play a role in the differences we see among living things.

Through these investigations, students do the following:

- Obtain, evaluate, and communicate information about muscle substructure, the influence of exercise on muscle development, the function of the myostatin protein, selective breeding, examples of asexual reproduction, and how different traits are influenced by environmental and genetic factors.
- Use mathematics and computational thinking to find the probability of offspring with certain genotypes from parents with certain genotypes.
- Develop and use a model to explain how genes provide instructions to rearrange building blocks from food into proteins, which then influence phenotypes.
- Construct an explanation for how specialized plant structures support sexual and asexual reproduction in plants.
- Develop and use a model to explain that environmental and genetics factors both influence trait variations in different amounts depending on the specific situation.

Building Toward NGSS Performance Expectations

MS-LS1-2: Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.

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.

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

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 the organism.

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.

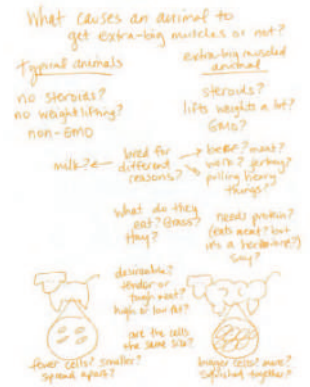
MS-LS4-5: Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.

UNIT STORYLINE

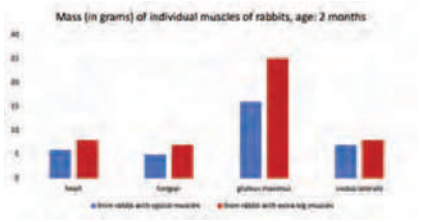
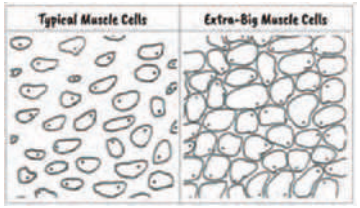
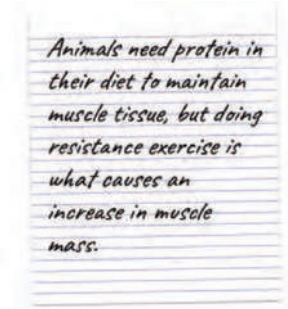
How students will engage with each of the phenomena

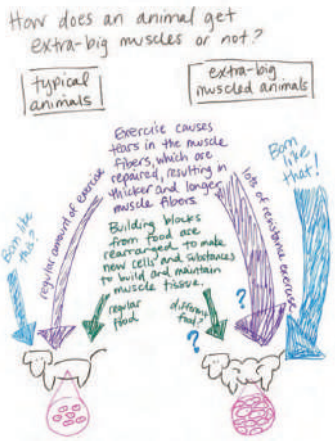
HANDS-ON/ LAB ACTIVITIES	VIDEOS OR IMAGES	DATA SETS	READINGS	COMPUTER INTERACTIVES

Why are living things different from one another?

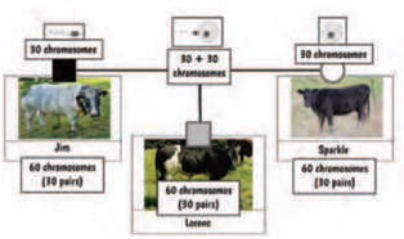
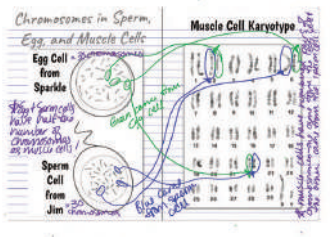
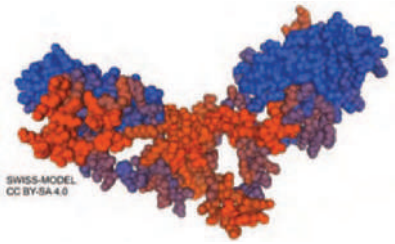
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 1 **3 days** **How do organisms get their differences?** Anchoring Phenomenon	 *There are cattle (and several other animals) that have extra-big muscles.*	We observe a bull and other animals that have extra-big muscles. We develop initial models to explain what could be causing this phenomenon. We also realize that there is a range of musculature in animals, and we identify variations in traits other than musculature in different organisms. After listing related phenomena, we develop a Driving Question Board and ideas for future investigations. We figure out these ideas: • Some cattle and other animals have extra-big muscles like we have never seen before, and we are not sure how they got that way. • There are many variations of characteristics (traits) in living things. • We have a lot of questions and ideas to pursue.	

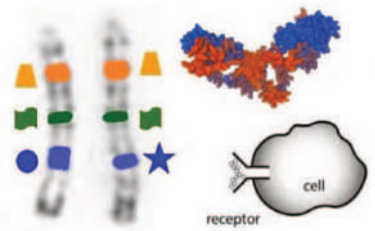
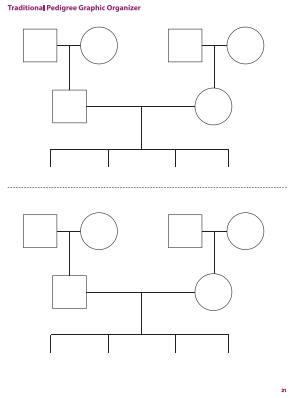
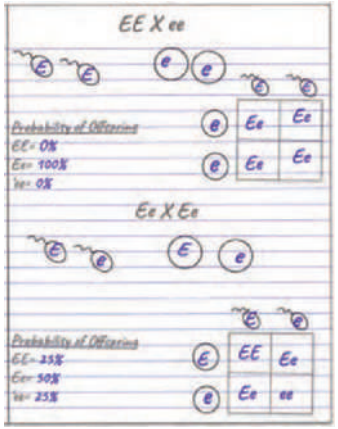
⇩ **Navigation to Next Lesson:** We think investigating how these animals got their extra-big muscles will help us figure out variations in many living things. We already have some ideas about muscles, but we're wondering what we would see if we could look more closely at them and compare the muscles of animals with extra-big muscles to those with typical muscles. And how do muscles even work? Can we zoom in even closer than the cells?

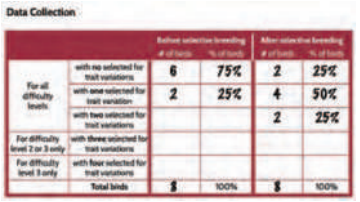
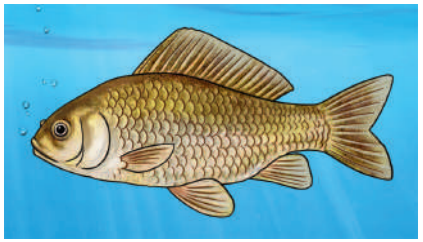
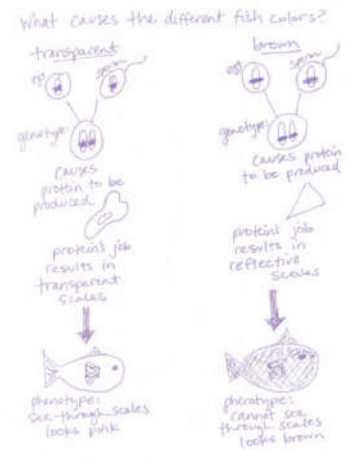
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 2 **1 day** **How do extra-big muscles compare to typical ones up close?** Investigation	 *Students view videos and images of muscle composition and analyze data from extra-big-muscled animals versus typically muscled animals showing differences in muscle cells.*	We observe images and video animations about what muscles look like up close and how muscles work. We compare photos and data about muscle cells from extra-big-muscled animals and typical ones. We figure out these ideas: • Proteins are important structures in the body made of atoms. • Muscles move by shortening (contracting) and lengthening (relaxing) with help from specific proteins called actin and myosin. • Extra-big muscles have more muscle cells than typical ones, those cells are larger in area, and they have more mass.	
⇩ **Navigation to Next Lesson:** Since we figured out that bigger muscles have more cells, more area, and more mass, we're wondering where that matter is coming from to make those bigger muscles. We think that matter comes from food, but we also think exercise makes bigger muscles, so next we want to explore how diet and exercise affect muscle size.			
LESSON 3 **1 day** **How do diet and exercise affect muscle size?** Investigation	 *Data in text, images, graphs, and charts show the effect of diet and exercise on muscle growth.*	We evaluate information in texts, images, graphs, and tables in order to determine the effect of diet and exercise on muscle growth. We figure out these ideas: • Exercise and diet play important roles in building muscles. Exercise has a large influence on musculature. Diet has a small influence on musculature. • During exercise, tension on the muscle fibers leads to microtears, which interfere with actin and myosin. These tears are repaired, resulting in thicker and longer muscle fibers. • Protein from food is required to build and maintain muscle.	
⇩ **Navigation to Next Lesson:** Since we have figured out the role of diet and exercise in building muscles, we want to investigate what these cattle are eating and how they are exercising to get their extra-big muscles.			

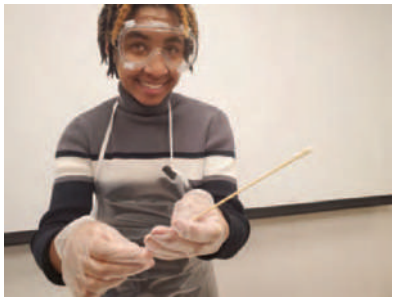
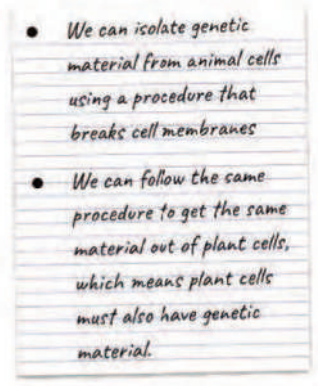
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 4 **1 day** **What is different about the food and exercise for cattle with extra-big muscles?** **Problematizing**	 *A farmer talks about the lifestyle and diet of extra-big, heavily muscled cattle. Images of baby cattle show that heavily muscled animals are born with bigger muscles.*	We update our classroom consensus model to include our findings about the role diet and exercise play in making muscles. We attempt to apply our class model to explain how the extra-muscled cattle would have developed their muscles, but we realize the model cannot explain the differences in musculature we see. We learn more about the diet and habits of these cattle by listening to a farmer who raises them, and we also find out that the calves that grow up to be heavily muscled are born with more muscles than calves that don't grow up to be heavily muscled. We discuss how this information impacts our model. We figure out these ideas: • Diet has a small influence on musculature for cattle with extra-big muscles. • Exercise also has a small influence on musculature for cattle with extra-big muscles. • Diet and exercise can't explain all the variation we see in musculature so there must be other factors involved.	

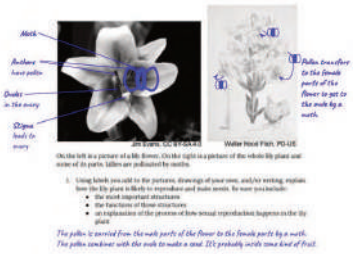
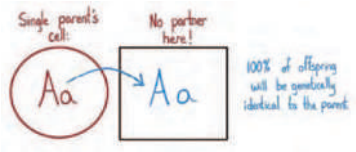
⇩ **Navigation to Next Lesson:** Now that we know that heavily muscled cattle are born like that, we are wondering what else (other than diet and exercise) might be causing this difference, and we think it is related to their families.

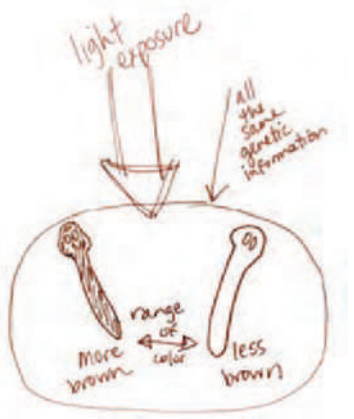
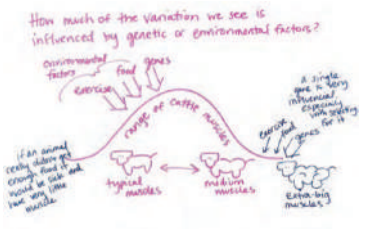
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 5 **2 days** **Where do the babies with extra-big muscles get that trait variation?** Investigation	 *Pedigrees of cattle show patterns between relatedness and musculature. We can see chromosomes in images of sperm, eggs, and muscle cells.*	We analyze cattle family photos to find patterns between relatedness and musculature. We wonder how muscles actually get from parents to offspring, and we zoom in to look at the chromosomes inside sperm and egg cells. We make connections between the karyotype of an offspring's muscle cell and chromosomes in the sex cells of the parents. We figure out these ideas: • If an individual is heavily muscled, both parents have extra-big or medium muscles. • Chromosomes are passed from parents to offspring when the sperm and egg fuse during fertilization. • Egg and sperm each have half the number of chromosomes as the muscle cells. • The karyotype shows that muscle cells have two of each kind of chromosome. • In each pair of chromosomes shown on the karyotype, one chromosome is from the egg the other is from the sperm.	
⇩ **Navigation to Next Lesson:** We figured out that phenotypes of offspring result from something parents pass on, and we also saw that an offspring's chromosomes result from the parents' egg and sperm. We wonder how chromosomes might be connected to an individual's phenotype.			
LESSON 6 **2 days** **How do chromosomes cause cattle to be born with extra-big muscles?** Investigation	 *The cattle photo cards we analyzed last time and organized into pedigrees now include images of protein(s) found in their bodies and data about their genotype, so we can look for patterns related to the heavily muscled phenotype.*	We consider the scale of chromosomes and proteins, then reorganize cattle photos that include new information about each individual's chromosomes and myostatin proteins. We construct initial models showing the patterns we found, and construct a consensus model to explain the correlations we see. We read and synthesize articles to find evidence of cause-effect relationships among allele, protein, and phenotype. We figure out these ideas: • Chromosomes have specific regions called genes, and the different possible forms of the genes are called alleles. • The different alleles of the genes (the genotype) determine the protein(s) that gets made. • Different forms of a protein, like myostatin, can lead to variations, like extra-big or typical muscles.	
⇩ **Navigation to Next Lesson:** We have figured out so many parts of our anchoring phenomenon that we're ready to put the pieces together and update our consensus model next time, and then we can decide where we need to go after that.			

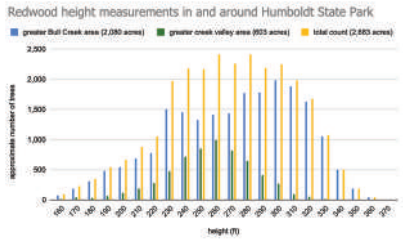
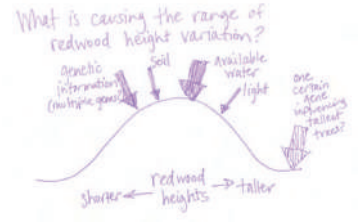
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 7 **2 days** **How does an animal get extra-big muscles?** Putting Pieces Together	 *Students put together the pieces of recent phenomena: cattle karyotypes; chromosomes in sperm, egg, and offspring's cells; genotype; and myostatin data.*	We update our classroom consensus model and revise our initial models to include our recent findings about the roles of genes, alleles, and the myostatin protein in development of the typically, medium-, and heavily muscled phenotypes. Using our model, we predict that a sibling's phenotype will be the same, but we see examples of cattle siblings with different phenotypes, so we need to figure out more about that next time. We figure out these ideas: • The alleles an animal gets from the sperm and egg of its parents (its genotype) determine the myostatin protein(s) that animal produces, which influences the musculature (phenotype) we see. • Our model predicts that siblings will look the same, but that's not the case for actual cattle (or other examples we know).	
⇩ **Navigation to Next Lesson:** According to our model, offspring get alleles from their parents which give directions for proteins that lead to the phenotype we see. So then, siblings should all look the same, but they don't. Why is that?			
LESSON 8 **2 days** **Why don't offspring always look like their parents or their siblings?** Investigation	 *Offspring don't always look like their parents or their siblings even though biological siblings get their genes from the same two parents.*	We investigate the inheritance patterns of the myostatin gene by comparing the proportion of different genotypes collected from pedigrees that show the results of known crosses. We use simple mathematical models to help us predict the outcome of known genetic crosses. We figure out these ideas: • We can predict the proportion of offspring with different genotypes, and hence phenotypes, based on the genotypes of the parents. • The likelihood of getting various phenotypes based on the parents' genotypes for the myostatin protein is linked to the phenomenon that alleles separate into different sex cells and can recombine at fertilization in ways different than what was seen in either parent.	
⇩ **Navigation to Next Lesson:** We figure out we have the tools to choose certain individuals to mate in order to get offspring with the most desirable phenotypes, and we wonder if the cattle farmers are also doing this, and if so, how?			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 9 **2 days** **How do farmers control the variation in their animals?** Investigation	 *Articles and a computer simulation allow the class to work with selective breeding to see how certain combinations of alleles lead to generations with costly or beneficial outcomes.*	We read three articles about how farmers breed animals for selected-for trait variations, and we run a computer simulation to control breeding in order to create individuals with selected-for trait variations. We figure out these ideas: • Over time, farmers can use selective breeding to change the trait variations in a population of sexually reproducing organisms. • Some mutations can have beneficial effects and some can have negative effects on an organism. • In selective breeding, people choose which individuals with beneficial trait variations are bred more often together than individuals without those beneficial trait variations.	 Data Collection
⇩ **Navigation to Next Lesson:** We've done a lot to work toward answering our original question about why living things are different from each other. Let's check in on the DQB and pick some questions we'd like to address next time we meet.			
LESSON 10 **1 day** **How can we use our model to explain a different trait variation?** Putting Pieces Together	 *The probability of a goldfish offspring having certain color scales (brown, transparent, or speckled) can be predicted based on the phenotype of its parents.*	After a brief navigation conversation, we work independently to demonstrate understanding on a midpoint assessment—a transfer task involving goldfish breeding. We figure out these ideas: • Our model to explain trait variations from the parents' genotypes to the offspring's phenotype can be used to explain a phenomenon other than cattle musculature.	 What causes the different fish colors?
⇩ **Navigation to Next Lesson:** We want to revisit our DQB to take stock of what we've figured out and what questions we still have to answer.			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 11 **1 day** **How can we answer the rest of our questions?** Problematizing	 *Organisms have traits with patterns of variation that are different from what we saw in the cattle musculature.*	We check in on our DQB to acknowledge what we've figured out so far and take note of where we still have questions about organisms other than cattle and traits other than muscles. We sort images of other organisms and discover that their variations encompass a continuous range rather than a few distinct phenotypes. Based on our model, we record new questions to drive further investigation. We figure out these ideas: • Variations can be a continuous range, not always distinct types or categories. • We have a lot of questions about other organisms and the variations we see in their traits.	
⇩ **Navigation to Next Lesson:** We want to investigate whether plants even have genetic material so we know if our model applies to them.			
LESSON 12 **1 day** **Do plants have genetic material?** Investigation	 *Genetic material can be visualized inside both animal and plant cells.*	We question whether plants also have genetic material and wonder if there is an investigation that would allow us to see that material. We watch a video of a scientist isolating genetic material from animal cells and then we plan an investigation to break open plant cells (strawberries) and see if we can isolate the same material from them. We carry out our investigations and discuss the results as a class. We figure out these ideas: • Genetic material is so small we can't see it when it is from only a single cell (and we usually can't see single cells without a microscope). • There is a lot of genetic material in each cell because there are thousands of genes in each cell. • There are many cells in a small sample of muscle or plant tissue, so we are able to get enough genetic material out of the cells to see it.	
⇩ **Navigation to Next Lesson:** We figured out that plants have genetic material like animals do, and we are wondering if they also pass on genetic material to their offspring using sperm and eggs like animals do.			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 13 **2 days** **How do plants reproduce?** Investigation	 *The structures of flowers have similar functions to the reproductive structures in humans, which can help us discern the reproductive process in plants.*	After determining that flowers are involved in plant reproduction, we investigate their structures, comparing their functions to reproductive structures in humans. We obtain information about how the structures of flowers can interact specifically with different pollinators. Revisiting the trait variations that we saw in Lesson 11, we read and watch videos about how farmers breed and propagate plants. We figure out these ideas: • Flowers have structures involved in sexual reproduction, including structures equivalent to sperm and egg cells. • Some structures of flowers (and/or seeds) increase the chances of the plant's reproduction by attracting and using animals. • Sexual reproduction in plants results in genetic variation that people can take advantage of to selectively breed for desirable trait variations. • Some plants can also reproduce asexually (on their own or with human assistance), resulting in offspring with the identical phenotype as their parents.	
⇩ **Navigation to Next Lesson:** We know that many plants can reproduce and pass on their variations both sexually and asexually. But cattle can only reproduce sexually. There are a lot of other organisms with variations. How do they reproduce?			
LESSON 14 **2 days** **(How) do other organisms reproduce without sperm and eggs?** Investigation	 *Planaria reproduce asexually by being cut into pieces then regenerating, as shown in a video. Other organisms also reproduce asexually.*	We work in small groups to research and share about an organism that uses asexual reproduction. We discuss how the genetic information of offspring from asexual reproduction compares to that of the parent. We observe a video of planarian regeneration, and we discover that the resulting planaria do not always look identical. We figure out these ideas: • Several different methods of asexual reproduction all result in genetically identical offspring. • We test our asexual reproduction model by looking at planeria and find they are not identical.	
⇩ **Navigation to Next Lesson:** The planaria we have observed have different phenotypes, yet they have the same genetic information. What could be causing these phenotype differences?			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 15 **1 day** **How do we get variations if the genetic information is exactly the same?** Investigation	 *When exposed to light, planaria lose their pigment. Apple redness depends on temperature and light, among other factors. Flamingos get their pink color from the food they eat.*	We integrate information from images and text about how planaria color was affected by light exposure, and we consider how environmental factors like light might influence other ranges of variation we've seen. We obtain scientific information from texts about color variation in apples and flamingos and then construct and use models to explain the different environmental factors that cause the range of variation we see in apple and flamingo colors. We figure out these ideas: • Environmental factors can cause a continuous range of variation. • We begin to notice that different environmental factors and genetic factors can influence trait variation to different degrees.	
⇩ **Navigation to Next Lesson:** The three phenotypes we saw in cattle musculature were caused by genetic influences, and now we've seen examples of more-continuous ranges of variation caused by environmental factors. We want to investigate more examples of variation to see if that pattern holds true: Do environmental factors always result in a range of variation, and do genetic factors result in distinct groups?			
LESSON 16 **2 days** **How much of trait variation in a population is controlled by genes or by the environment?** Investigation	 *Articles about trait variation in organisms show that the variations are due to a combination of genetic and environmental factors.*	We investigate the variation found in wheat kernel coloration to learn this trait is controlled by more than one pigment-producing gene. We use this new idea in addition to what we learned about environmental factors in Lesson 15 to update our classroom consensus model explaining variation we see in cattle musculature. We investigate the distribution of human arm span lengths and independently use our model to explain which factor(s) affect arm span. Finally, we share our models in small groups and hold a Consensus Discussion about what we figured out about these influences on all traits. We figure out these ideas: • Different traits and variations are influenced differently by genes and environment. • Most trait variations are influenced by a combination of multiple genes and the environment and to varying degrees depending on the trait. • It is rare to have a single gene influence a trait variation.	
⇩ **Navigation to Next Lesson:** We think we're ready to close out our DQB—we can answer our driving question now!			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 17 **2 days** **Why are living things different from one another?** **Putting Pieces Together**	 *Coast redwood trees have variation in their heights in different areas of their environment. Coast redwoods are more successful at reproducing asexually than sexually, although they can do both.*	We revisit our Driving Question Board to evaluate and answer our questions. We use this time to ask any clarifying questions to refine our understanding about our models for how living things are different from one another. Then we demonstrate understanding on a summative assessment transfer task involving redwood trees.	
LESSONS 1-17 **28 days total**			

TEACHER BACKGROUND KNOWLEDGE

Lab Safety Requirements for Science Investigations

It is important to adopt and follow appropriate safety practices within the context of hands-on investigations and demonstrations, whether student scientists are working in a classroom, traditional laboratory setting, or in the field. In this way, teachers need to be aware of any school or district safety policies, legal safety standards, and better professional practices that are applicable to hands-on science activities being undertaken.

Science safety practices in laboratories or classrooms require engineering controls and personal protective equipment (e.g., safety goggles, nonlatex aprons and gloves, eyewash and shower station, fume hood, fire extinguishers). Science investigations should always be directly supervised by qualified adults, and safety procedures should be reviewed annually prior to initiating any hands-on activities or demonstrations. Prior to each investigation, students should also be reminded of the safety procedures that need to be specifically followed. Each of the lessons within the units includes teacher guidelines for applicable safety procedures for setting up and running an investigation as well as taking down, disposing of, and storing materials.

Prior to the first science investigation of the year, a safety acknowledgement form for students and parents or guardians should be provided and signed. You can access a model safety acknowledgement form for middle school activities at the following location: See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**

Disclaimer: The safety precautions of each activity are based in part on use of the specifically recommended materials and instructions, legal safety standards, and better professional safety practices. Be aware that the selection of alternative materials or procedures for these activities may jeopardize the level of safety and therefore is at the user's own risk.

Please follow these lab safety recommendations for any lesson with an investigation:

1. Wear safety goggles (specifically, indirectly vented chemical splash goggles), a nonlatex apron, and nonlatex gloves during the setup, hands-on investigation, and take-down segments of the activity.
2. Immediately wipe up any spilled water and/or granules on the floor as this is a slip-and-fall hazard.
3. Follow your *Teacher Guide* for instructions on disposing of waste materials and/or storage of materials.
4. Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
5. Wash your hands with soap and water immediately after completing this activity.
6. Never eat any food items used in a lab activity.
7. Never taste any substance or chemical in the lab.



Specific safety precautions are called out within the lesson using this icon and a callout box.

What is the anchoring phenomenon and why was it chosen?

The anchoring phenomenon of this unit is the trait variation of extra-big muscles originally caused by a mutation to the gene related to the production of the myostatin protein, which gave rise to a new allele that can be inherited from parents by offspring. While the heavily muscled phenotype has been identified in several animals, this unit focuses on cattle. This phenomenon provides a rich context in which to investigate inheritance patterns, artificial selection, and environmental influences on trait variation. Once students figure out what causes some cattle to have extra-big muscles, they apply that model to explain other trait variations to determine that the differences we see in living things are caused by both environmental and genetic factors.

Each unit's anchoring phenomenon is chosen from a group of possible phenomena after analyzing student interest survey results and consulting with external advisory panels. We chose cattle with extra-big muscles as the anchoring phenomenon for this unit for these reasons:

- Genetic and environmental factors contribute to variation in the trait of muscle mass.
- Students can observe this variation in familiar animals and bring ideas into the unit about the causes of bigger muscles.
- Students can see the phenotypic differences influenced by the structure and function of specific proteins that result from changes to the structure of a gene.
- Field-test students and teachers reported high engagement with this phenomenon.
- Our state steering committee and advisors recommended that we avoid focusing the unit on a human disease because

- *Unit 7.3: How do things inside our bodies work together to make us feel the way we do? (Inside Our Bodies Unit)* is already anchored in a student's health concerns,
- the genetic basis of most human disease is very complex and the concepts needed to understand it are well above grade band, and
- learning about inherited diseases that do have a simpler genetic etiology (like sickle cell disease or cystic fibrosis) can indirectly lead to prejudice by reinforcing the misconception that there is greater genetic diversity between compared to within racial groups, when in fact, there is more genetic diversity within races than between races. (See the "What are some frequently asked questions about genetics?" section for more details.)

What are the NGSS Dimensions developed in this context?

This unit is guided by the key idea that both environmental and genetic factors influence the variation we see in living things. In this unit, students will develop, refine, and apply models to first explain what could be causing some cattle to have such big muscles and then explain what is causing other variations we've noticed around us. As students obtain and evaluate information from farmers, breeders, and research scientists, they see the role that humans often have in selecting for certain trait variations. Students work toward explaining how environmental and genetic factors affect organisms' growth to varying degrees depending on the trait, and they apply what they have learned to explain variations in many organisms other than cattle.

This unit builds toward these performance expectations:

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

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 the organism.

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.

MS-LS4-5. Gather and synthesize information about technologies that have changed the way humans influence the inheritance of desired traits in organisms.

MS-LS1-2.* Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.

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.

*PEs marked with an asterisk are partially developed in this unit and shared with other units, as explained in the DCI column. Also, regarding the strike through LS3.B—"and some are neutral to the organism"—in middle school there is a boundary of scale in working with genetic information. Generally, we stick with the scale of working with chromosomes and do not get into the more-detailed model of genetic information at the DNA level. We do not learn about base pairs, the four nucleotides, or the sequencing of those nucleotides because those are reserved for high school. Because of this boundary, it makes building an evidence-based model of neutral mutations on an organism very difficult. This is because the evidence the class needs that a change in the structure of genetic information occurs without seeing an effect at the phenotype level happens at the nucleotide sequence level. For this reason, we limited the effect of mutations to those where students can detect a phenotypic difference.

Focal DCIs*	Focal Science and Engineering Practices	Focal Crosscutting Concepts
LS1.B. Genetic factors as well as local conditions affect the growth of the adult plant. Students specifically investigate the combination of local environmental effects and genetic influences on plant growth in Lessons 13, 15, and 17. In Lesson 3, students investigate environmental effects on musculature and the combination of environmental effects with genetic influences on other trait variations in Lessons 15 and 16. Students are focused on determining how genetic factors influence the growth of organisms in Lessons 4, 5, 6, 7, 8, 9, 10, 11, 12, and 14. This DCI element is shared with *Unit 7.3: How do things inside our bodies work together to make us feel the way we do? (Inside Our Bodies Unit)*. **LS1.B. Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring.** Transferring genetic information via sexual reproduction is the focus of Lesson 5 specifically (in animals) and Lesson 13 (in plants), where students also encounter asexual reproduction, and they continue to explore how organisms reproduce asexually in Lesson 14. **LS3.A. 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.** Students investigate cattle karyotypes in Lesson 5 and then connect chromosomes to genes, alleles, and proteins in Lesson 6, where they also encounter an example of genetic modification that resulted in changes to the myostatin protein, thereby affecting the structure of animals' musculature. Students continue to explore the gene-to-protein-to-trait story in Lessons 7 and 8, where they hear about the original mutation that led to a new allele, which gave rise to heavy musculature. Additional mutation examples are added in Lessons 13 and 16.	**Obtaining, Evaluating, and Communicating Information:** This unit **intentionally develops** this practice. Students work with a new element (evaluating competing accounts in Lesson 9) and gradually become more independent in their use of all the other elements of this practice. Throughout the unit students obtain and evaluate information from a variety of sources, including articles, audio interviews, videos, charts, graphs, and images. They have formal and informal opportunities to communicate information orally and in writing. To support their use of this practice, in Lesson 3 students co-construct a version of the checklist tool they've used in prior units and use it in Lessons 6, 10, 13, 14, and 15 with opportunities to obtain, evaluate, and communicate increasingly complex information. Students are formally assessed on this practice in Lesson 10, and then they reflect on their use of this practice in a self-assessment in Lesson 14.	**Cause and Effect:** This crosscutting concept is **key to the sensemaking** students do in this unit. Students' more independent use of cause-effect thinking is supported by removing scaffolds and applying these ideas to explain increasingly complex phenomena. They begin by using a cause-and-effect framing tool from *Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)* to predict outcomes and summarize investigation findings in Lesson 3, and this tool is revisited with less scaffolding in Lessons 4, 6, 12, and 14. In Lesson 6 students consider whether the relationship among alleles, proteins, and phenotype is causal or correlational. The class develops an initial model in Lesson 1 to explain the possible causes of extra-big muscles, and then in Lesson 4 students revise that model to represent multiple causes contributing to the phenotype they see. In Lesson 10 they revise a cause-effect chain tool to include multiple causes, carefully considering the language involved. In Lessons 15, 16, and 17 students develop a model to explain how both genetic and environmental factors contribute to the variation we see in living things. In those final models, as well as in their work calculating the probability of offspring phenotypes from various parental crosses in Lessons 8, 10, and 14, students apply the idea that some cause-effect relationships can only be described using probability.

Focal DCIs*	Focal Science and Engineering Practices	Focal Crosscutting Concepts
LS3.A. Variations of inherited traits between parent and offspring arise from genetic differences that result from the sub-set of chromosomes (and therefore genes) inherited. Students contrast the phenotypes of parents and offspring in Lesson 5 and connect those differences to chromosomes (genes) in Lesson 6. In Lesson 14, students specifically contrast the variation between parent and offspring due to sexual reproduction with the inheritance of identical genetic information due to asexual reproduction. **LS3.B. 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 are harmful, ~~and some are neutral to the organism~~.** Students are introduced to the natural mutation that leads to extra-big muscles in Lesson 8, and they explore the benefits and drawbacks of this mutation in Lesson 9. In Lesson 16 students encounter other examples of mutations and again consider their effects and how rare they are. **LS3.B. 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 Lesson 5, students discover that sex cells contain single copies of chromosomes, and these combine so offspring have two sets of chromosomes. They connect genes and alleles to this pattern in Lesson 6, and in Lesson 8 students use their understanding of random assortment along with probability calculations, and Punnett squares to determine the chances of possible genotypic outcomes of various parent crosses. They apply that algorithm to other organisms in Lesson 10, Lesson 13, and Lesson 16.	**Using Mathematics and Computational Thinking:** This unit **intentionally develops** the practice of using mathematics and computational thinking. Students calculate the probability of offspring phenotypes from various parental crosses in Lessons 8, 10, 14, and 16. In Lesson 8 students take note that the series of ordered steps they're using is an algorithm (an element of this practice they have not used previously). In addition, students use digital tools to analyze very large data sets for patterns and trends in Lesson 16. **Developing and Using Models:** Modeling is **key to the sensemaking** in this unit. Although no new elements of this practice are introduced, students use models to make sense of and explain almost every aspect of what they figure out in this unit. Students have frequent opportunities to develop models with a partner, in small groups, or as a class when they are making sense of new science ideas. Students then use models independently to explain those science ideas and relationships on assessments in Lessons 7, 10, and 17. These models represent multiple cause-and-effect relationships at multiple scales, and as such this unit offers a comprehensive opportunity to practice developing and using models to explain complex phenomena.	**Structure and Function:** This crosscutting concept is **key to the sensemaking** in this unit. Students explicitly use a structure-function lens to consider several of the ideas they're developing in this unit. Specific wording in videos and readings as well as guiding questions on handouts and slides and in discussions scaffold students as they explore structure-function relationships in complex biological systems. They investigate how proteins have specific structures to do their jobs (Lessons 2 and 6), and they learn that if there is a change to the structure of a gene it can affect the protein produced (Lesson 7). Students also investigate the specialized structures of plants that affect the probability of successful reproduction (Lesson 13). The following crosscutting concepts are also **key to the sensemaking** in the unit: • Patterns • Scale, proportion, and quantity

Focal DCIs*	Focal Science and Engineering Practices	Focal Crosscutting Concepts
LS4.B. In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring. Students explore selective breeding in Lessons 9 (in animals) and 13 (in plants). **LS4.B. In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.** Students explore selective breeding in Lessons 9 (in animals) and 13 (in plants). **LS1.B. Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.** Students investigate plant reproductive structures in Lesson 13, focusing on how certain pollinators interact with specialized flower parts. The PE related to this DCI element is shared with *Unit 8.6: How could things living today be connected to the things that lived long ago? (Penguins Unit)*. **LS1.A. Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell.** In Lesson 2, students investigate the structure and function of muscle cells, building on knowledge they bring from *Unit 6.6: How do living things heal? (Healing Unit)*, which shares this DCI element. Then in Lesson 5 and beyond when students investigate chromosomes, they are able to build on their previous understanding of the structure and function of the nucleus specifically.	The following practices are also **key to the sensemaking** in the unit: • Asking questions and defining problems • Planning and carrying out investigations • Constructing explanations and designing solutions	

**Disciplinary core ideas are reproduced verbatim from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. DOI: https://doi.org/10.17226/13165. National Research Council; Division of Behavioral and Social Sciences and Education; Board on Science Education; Committee on a Conceptual Framework for New K-12 Science Education Standards. National Academies Press, Washington, DC. This material may be reproduced and used by other parties with this attribution. If the original material is altered in any way, the attribution must state that the material is adapted from the original.

Connections to the Nature of Science

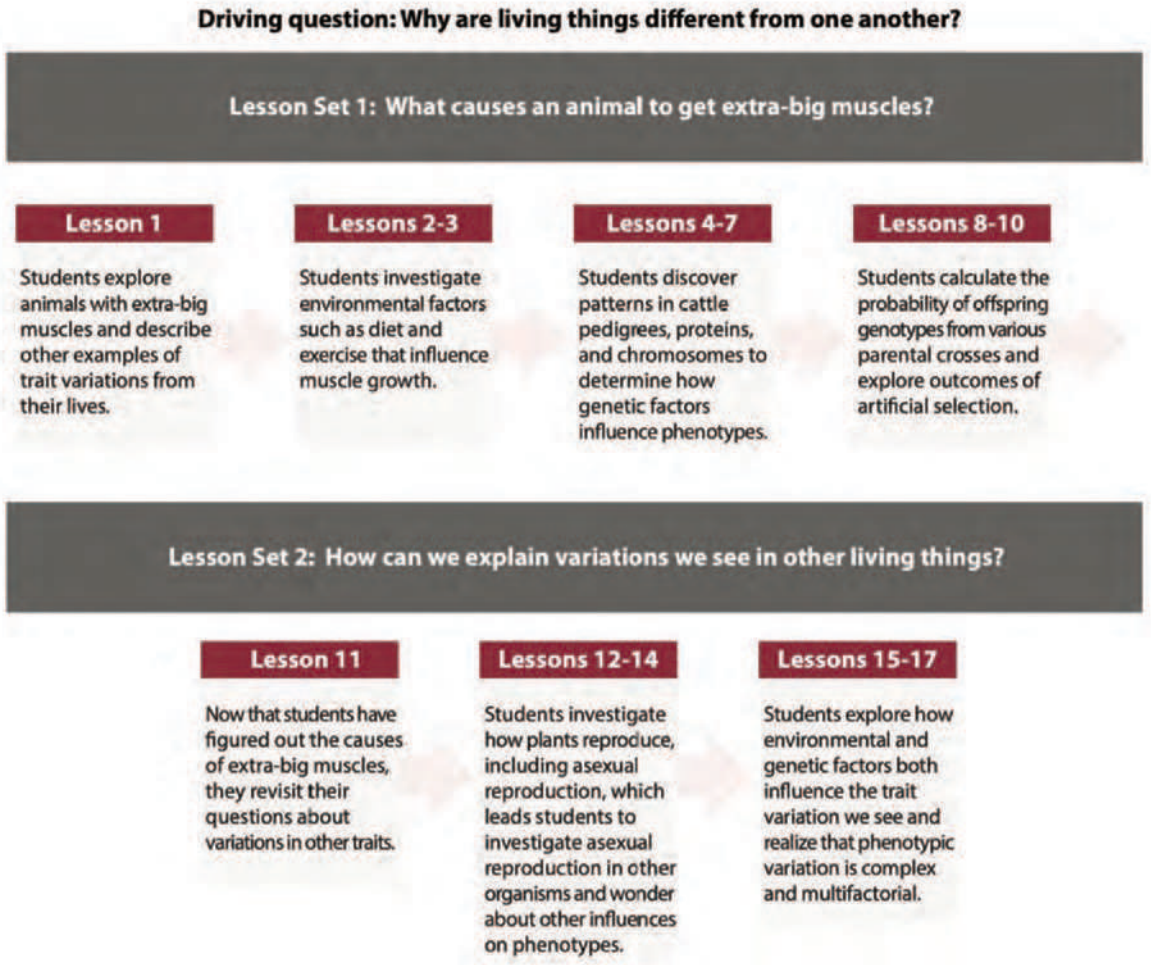
Which elements of NOS are developed in the unit?	How are they developed?
• Scientific values function as criteria in distinguishing between science and non-science. (NOS-SEP) • Science carefully considers and evaluates anomalies in data and evidence. (NOS-CCC)	• Students read, evaluate, and synthesize information from multiple appropriate sources and assess the credibility and possible bias of each source, and describe how they are supported or not supported by evidence. • Students use histograms to find patterns in data describing population-level trait variation and explain the varying influences that can cause that variation, including for the extremes/outliers of that data.

Connections to Engineering, Technology, and Applications of Science

Which elements of ETS are developed in the unit?	How are they developed?
• The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.	• Students synthesize information from reliable sources about technologies that have changed the way humans influence the inheritance of desired traits in organisms (via selective breeding and genetic modification). They consider the reasons people choose to select for certain trait variations, such as demand for agricultural products and to seek answers to scientific questions.

How is the unit structured?

The unit is organized into two lesson sets. Lesson set 1 consists of Lessons 1-10. The class decides at the end of Lesson 1 to focus on figuring out how animals can get extra-big muscles, expecting that making progress on understanding that phenomenon will help us be able to explain other variations we've noticed in other organisms. We first explore possible causes for building muscles that we have in our background knowledge, but after hearing from a farmer that heavily muscled cattle do not exercise nor eat a special diet and see pictures of baby cattle born with extra-big muscles, we investigate how animals can inherit this trait variation. We end this lesson set by applying the model we figured out about cattle muscles to explain selective breeding in goldfish. Lesson set 2 consists of Lessons 11-17. The focus of this lesson set is to explain variations we see in other living things. We are first curious to see how our model will work with plants, since they seem very different from cattle, and then we go on to investigate other examples of organisms whose trait variation is caused by multiple genetic and environmental factors. In the final lesson, students apply this more-complex model to explain height variation in redwood trees.

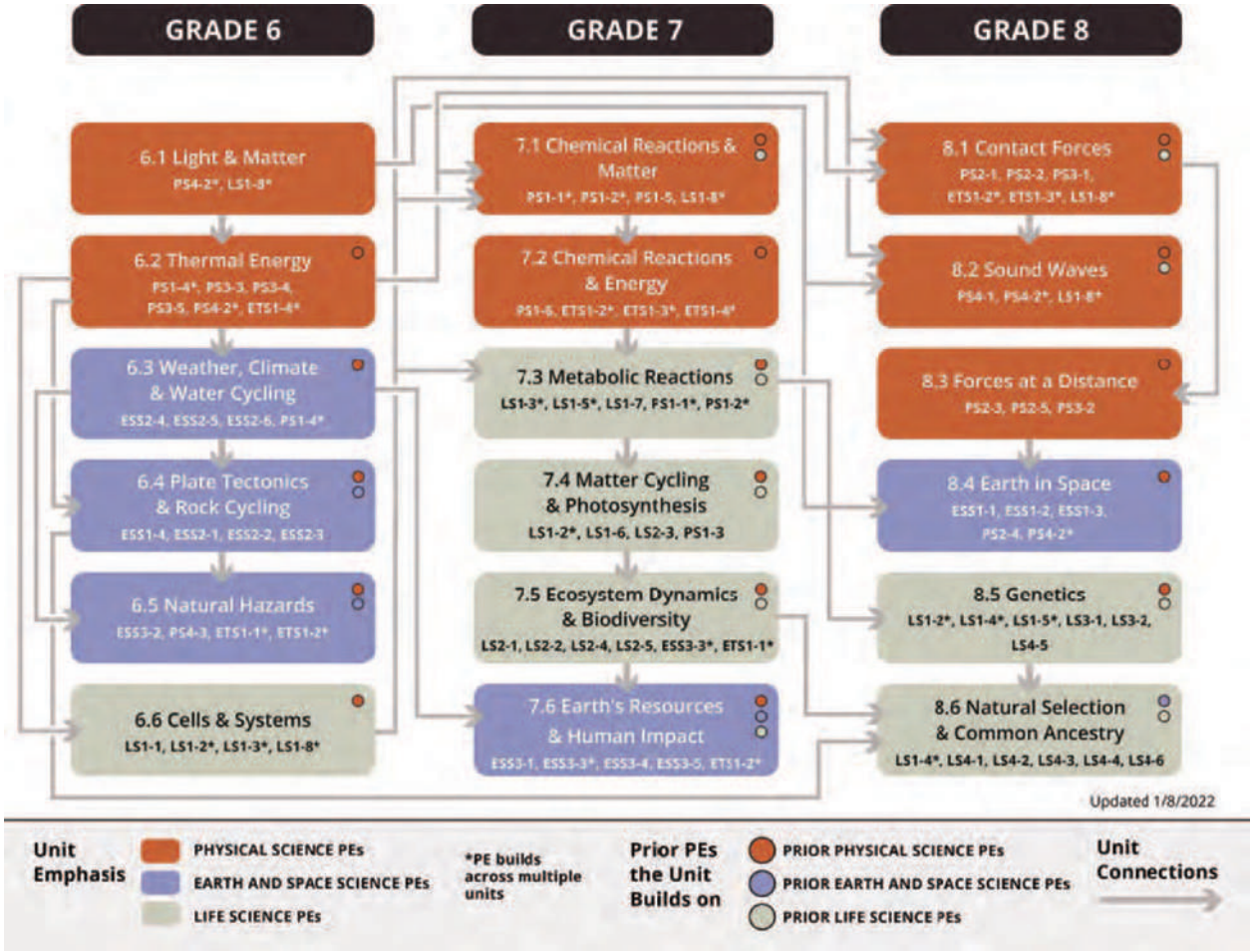


Where does this unit fall within the Scope and Sequence?

This unit is designed to be taught after students have experienced *Unit 6.6: How do living things heal? (Healing Unit)* and *Unit 7.3: How do things inside our bodies work together to make us feel the way we do? (Inside Our Bodies Unit)*. As such, work in this unit can leverage ideas about cell structure and function as well as understanding about how our bodies break down food molecules into smaller pieces that can be used for different functions.

Additionally, this unit uses and builds on "cause and effect" supports that were established in *Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)*, and the checklist for "obtaining, evaluating, and communicating information" that can support students' work in this unit was previously used in *Unit 7.4: Where does food come from, and where does it go next? (Maple Syrup Unit)* and *Healing Unit*.

This unit is designed to be taught prior to *Unit 8.6: How could things living today be connected to the things that lived long ago? (Penguins Unit)*, in which students investigate structures that modern animals do or do not have in common with ancient animals and how certain traits in a population increase some individuals' probability of surviving and reproducing. In that unit, students will build on ideas they developed in this unit about mutations, sexual reproduction, and inheritance.



What additional ideas will my students have or know from earlier grades or units?

In this unit, students build upon ideas from earlier grades and units as listed in the table below. This unit also prepares students for building on this work in high school. Specifically, the unit intentionally brings out the effects of environmental factors on trait variation, which is an important scientific concept that will be further developed in high school. The trait variation we see among living things is almost never due to genetics alone. By the end of the unit, students will grasp that genes and environment are always at play. (In fact, genes and environment substantially interact with each other, but this is beyond the middle school grade band understanding.)

Previous unit or grade-level DCIs	How it is leveraged in this unit
Building upon cell structure and function • **LS1.A. Structure and Function** All living things are made up of cells ... • **LS1.A. Structure and Function** Within cells, special structures are responsible for particular functions ... • **LS1.A. Structure and Function** ... groups of cells that work together to form tissues and organs that are specialized for particular body functions.	In Lesson 1 students are asked to zoom in to model what muscles would look like up close, and it's assumed that they will know that muscles are made up of cells. They further investigate the structure and function of muscle cells in Lesson 2 and observe how extra-big muscles compare to smaller ones at the cellular level. In Lesson 5, when discussing how sex cells combine and the resulting cell becomes a baby calf, students connect to the way they know cells grow and split to form new cells, as they figured out in *Healing Unit*.
Building upon metabolic reactions • **LS1.C. Organization for Matter and Energy Flow in Organisms** Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, support growth, or release energy. • **LS1.B. Growth and Development of Organisms** Genetic factors as well as local conditions affect the growth of the adult plant.	Students previously have seen in *Unit 7.3: How do things inside our bodies work together to make us feel the way we do? (Inside Our Bodies Unit)* how food intake can affect the growth of animals. Our body breaks down food molecules into smaller pieces and can use these for different things, and pieces of broken-down protein can be put back together in new ways (via chemical reactions) to build up or repair body structures (e.g., bones, blood, hair, muscles). Students make the connection in Lesson 7 that genetic information plays a major role in how the building blocks of proteins are rearranged. The genetic information controls the shape of the protein produced.
Building upon molecular structures • **PS1.A. Structure and Properties of Matter** Atoms form molecules that range in size from two to thousands of atoms.	Students should be familiar with this DCI element in order to make sense of the molecular structures of chromosomes when they "zoom in" on them in Lesson 6—they are made up of the same atoms that students will recognize from *Unit 7.1: How can we make something new that was not there before? (Bath Bombs Unit)*, *Unit 7.2: How can we use chemical reactions to design a solution to a problem? (Homemade Heater Unit)*, and *Maple Syrup Unit*. Chromosomes have a 3-D physical structure, and the shape of that structure determines its function, determining the shape of the protein produced.

Previous unit or grade-level DCIs	How it is leveraged in this unit
Building upon third-grade knowledge about inheritance and variation • **LS3.A. Inheritance of Traits** Many characteristics of organisms are inherited from their parents. • **LS3.A. Inheritance of Traits** Other characteristics result from individuals' interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment. • **LS3.B. Variation of Traits** Different organisms vary in how they look and function because they have different inherited information. • **LS3.B. Variation of Traits** The environment also affects the traits that an organism develops.	While students come into this unit with the idea that organisms' characteristics are inherited, they work in Lessons 5, 6, 7, and 8 to use data from cattle pedigrees and other sources to figure out how inheritance of trait variation happens. They also use their understanding of cells and cellular substructures to identify that egg and sperm cells, and the chromosomes inside them, are the physical means of passing on genetic information. While students come into this unit with the idea that the environment also affects an organism's characteristics, they work with multiple examples throughout this unit to understand that environmental and genetic factors both influence trait variation to varying degrees.
Building upon second-grade knowledge of pollinators • **LS2.A. Interdependent Relationships in Ecosystems** Plants depend on animals for pollination or to move their seeds around.	In Lesson 13, it is assumed students know that plants require animals as pollinators and seed dispersers. This unit then builds on that idea as we figure out how plants reproduce and that some of those strategies depend on specialized plant structures and animal behavior.

This unit also leverages knowledge students may bring from their experiences outside of science class, such as the following:

- Students may have different ideas about how animals get such big muscles (most students suggest that exercise, a protein-rich diet, and/or steroid use would lead to larger muscles). These ideas are brought up in Lesson 1 and motivate investigations in Lessons 2, 3, and 4.
- Students may have a basic understanding of the process of sexual reproduction. Lesson 5 involves the idea of a sperm and egg from parents combining to form a single cell that then grows and splits to make all the cells in the baby calf. This process is revisited when students investigate sexual reproduction in plants in Lesson 13, where an academic understanding of the structures and functions involved in human reproduction will add depth to their investigation of structure-function relationships in flowers. Although this unit assumes students have these basic understandings prior to this unit, they can be successful in the unit if Lesson 5 is the first time they learn those details and if they do not bring additional knowledge to Lesson 13.

Here is the learning progression of DCIs for LS3: Heredity: Inheritance and Variation of Traits:

LS3: Heredity: Inheritance and Variation of Traits				
	Grades K-2	**Grades 3-5**	**Grades 6-8**	**Grades 9-12**
LS3.A. Inheritance of Traits	• Young animals are very much, but not exactly, like their parents. Plants also are very much, but not exactly, like their parents. (1-LS3-1)	• Many characteristics of organisms are inherited from their parents. (3-LS3-1) • Other characteristics result from individuals' interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment. (3-LS3-2)	• 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-LS3-1) • Variations of inherited traits between parent and offspring arise from genetic differences that result from the sub-set of chromosomes (and therefore genes) inherited. (MS-LS3-2)	• Each chromosome consists of a single very long DNA molecule, and each gene on a chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no known function. (HS-LS3-1)
LS3.B. Variation of Traits	• Individuals of the same kind of plant or animal are recognizable as similar but can also vary in many ways. (1-LS3-1)	• Different organisms vary in how they look and function because they have different inherited information. (3-LS3-1) • The environment also affects the traits that an organism develops. (3-LS3-2)	• 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. (MS-LS3-2) • 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 are harmful, and some are neutral to the organism. (MSLS3-1)	• In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. (HS-LS3-2) • Environmental factors also affect expression of traits and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depend on both genetic and environmental factors. (HS-LS3-2), (HS-LS3-3)

How will I need to modify the unit if taught out of sequence?

This is the fifth unit in 8th grade in the Scope and Sequence. Given this placement, several modifications would need to be made if teaching this unit earlier in the middle school curriculum. These include the following:

- Students will need to be introduced to the concept of a Driving Question Board and a shared set of classroom norms. These introductions would not be necessary if any other units have preceded this one.
- Be prepared for supplemental teaching of PE: MS-LS1-1: "Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells." This unit does not introduce cells to students. It uses that prerequisite knowledge to build understanding that the organization of the body goes from cells to systems and that living things are all made up of cells.
- Be prepared for supplemental teaching of PE: MS-LS1-7: "Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism." Students need this understanding in order to bring "building blocks from food" into their genetics models for how genetic information gives the instructions on how the building blocks from proteins are rebuilt into new protein structures.
- Also note that an important math consideration was made when placing this unit in the 8th grade scope and sequence. The understanding of essential CCSS math probability standards does not occur until 7th grade. Specifically, the standards CCSS.MATH.CONTENT.7.SP.C.5, CCSS.MATH.CONTENT.7.SP.C.6, and CCSS.MATH.CONTENT.7.SP.C.7 would need to be taught before starting this unit.

How do I shorten or condense the unit if needed? How can I extend the unit if needed?

The following are example options to shorten or condense parts of the unit without completely eliminating important sensemaking for students:

- **Lesson 2:** If you feel your students already have a solid understanding of muscle structures, skip the video and reading at the beginning of Lesson 2 and start at the gallery walk comparing the muscles from organisms with typical muscles to those with extra-big muscles. Your students will miss an opportunity to practice integrating qualitative scientific information in written text with that contained in media and visual displays to clarify claims and findings, If you make this adjustment, be sure to still put "protein" on the Word Wall and discuss examples such as myosin and actin to support students' understanding of proteins before Lessons 5 and 6, specifically.
- **Lesson 3:** If you feel students can do without evidence that dietary protein and exercise both do influence muscle growth, skip readings 1 and 2 and instead begin with readings 3 and 4 where the class splits into two groups to determine the specific role of each of these environmental factors.
- **Lesson 9:** Rather than having all students read all three articles and compare them, do the readings as a jigsaw activity where students each read only one article. Continue with the comparison discussion as written in the *Teacher Guide*. This adjustment will reduce the time the lesson requires, but it will also limit students' experience with a new element of SEP 8: "Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts". You could also choose to skip the step where students look up some of the sources cited in a reading to develop the habit of checking for credibility, again at the expense of the practice with obtaining and evaluating information.
- **Lesson 12:** Replace the classroom lab extraction of genetic material from strawberries in favor of watching the provided video. Students could also view the provided video of the negative control investigation instead of seeing it as an in-person classroom demonstration.
- **Lesson 13:** If students are already secure in the knowledge that flowers are the part of the plant involved in making seeds and that seeds are plant offspring, you can skip ahead to observing seeds in the fruits themselves. Also, skip the flower dissection and have students go straight to using the plant structures diagram to label plant parts as reproductive structures, if you need to save time. Finally, choose only one opportunity for students to explain what they've figured out about plant reproduction—peer feedback with a partner or completing the exit ticket—rather than doing both.

To extend or enhance the unit, consider the following:

- **Lesson 14:** Students could spend more time researching details about organisms that reproduce asexually and/or students could communicate the information they've learned in a different format than the suggested slide or to a different audience than just their peers.
- **Lesson 16:** Let your students explore the Arm Span Data Set and online data tool by themselves before discussing it as a class.
- **Lesson 17:** Provide time for students to work on the alternate activity described in the *Teacher Guide* where students obtain and evaluate

information about how climate change is affecting redwood trees and then communicate that information to an audience of their choice in a format appropriate for that audience.

- **After Lesson 16 or 17:** Students can return to the specific examples of trait variations they brought in during Lesson 1 and apply the model they've developed in this unit to explain those. As additional practice with "obtaining, evaluating, and communicating information", students could do additional research to find details about those trait variations, such as the function of specific protein(s), the number of genes, and/or the specific environmental factors that influence that trait variation.

What mathematics is required to fully access the unit's learning experiences?

In Lesson 2, students analyze muscle cell data presented in box plots. Prerequisite math concepts that may be helpful include the following:

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

In Lesson 3, students analyze and interpret data from graphs and charts about the effects of dietary protein and exercise on muscle growth. This work draws upon multiple Common Core Mathematics Standards from elementary grades 1-5 within the domain of Measurement and Data, under the category of Represent and Interpret Data. For example:

- CCSS.MATH.CONTENT.3.MD.B.3: Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step "how many more" and "how many less" problems using information presented in scaled bar graphs.

In Lesson 8, students examine several examples of pedigrees to discover patterns in the proportion of genotypes in offspring that result from specific crosses. They also use simple mathematical models to help predict the probability that a known cross will result in a particular genotype. Prerequisite math concepts that may be helpful include the following:

- CCSS.MATH.CONTENT.7.SP.C.5: Understand that the probability of a chance event is a number between 0 and 1 that expresses the likelihood of the event occurring. Larger numbers indicate greater likelihood. A probability near 0 indicates an unlikely event, a probability around 1/2 indicates an event that is neither unlikely nor likely, and a probability near 1 indicates a likely event.
- CCSS.MATH.CONTENT.7.SP.C.6: Approximate the probability of a chance event by collecting data on the chance process that produces it and observing its long-run relative frequency, and predict the approximate relative frequency given the probability.
- CCSS.MATH.CONTENT.7.SP.C.7: Develop a probability model and use it to find probabilities of events. Compare probabilities from a model to observed frequencies; if the agreement is not good, explain possible sources of the discrepancy.
- CCSS.MATH.CONTENT.7.RP.A.2: Recognize and represent proportional relationships between quantities.
- CCSS.MATH.CONTENT.5.NF.B.4: Apply and extend previous understandings of multiplication to multiply a fraction or whole number by a fraction.

In Lesson 16, students co-construct and analyze a histogram from arm-span length data. Prerequisite math concepts that may be helpful include the following:

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

What additional strategies are available to support equitable science learning in this unit?

Units are designed to promote equitable access to high-quality science learning experiences for all students. Each unit includes strategies which are integrated throughout the routines and are intended to increase relevance and provide access to science learning for all students. units support these equity goals through several specific strategies such as (1) integrating Universal Design for Learning (UDL) Principles during the unit design process to reduce potential barriers and provide more-accessible ways in which students can engage in learning experiences; (2) developing and supporting classroom norms that provide a safe learning culture; (3) supporting classroom discourse to promote students in developing, sharing, and revising their ideas; and (4) specific strategies to supporting emerging multilingual students in science classrooms.

Many of these strategies are discussed in the *Teacher Guides* in sidebar callout boxes titled "Attending to Equity" and subheadings such as "Supporting Emerging Multilingual Learners" or "Supporting Universal Design for Learning." Other callout boxes with strategies are found as "Additional Guidance", "Alternate Activity," and "Key Ideas" and various discussion callouts. Finally, each unit includes the development of a Word Wall as part of students' routines to "earning" or "encountering" scientific language.

For more information about each of these different strategies with example artifacts, please see the *Teacher Handbook*.

How can we work toward a more-powerful and equitable genetics education?

Teachers may notice some important differences in how this unit treats the topic of genetics from what they have seen in prior curriculum materials. There are two important reasons for these shifts. First, the *Framework for K-12 Science* and the NGSS call for changes in what we should teach. Second, research shows that conventional ways of teaching genetics can lead to problematic views about race and ethnicity.

(1) Shifts in standards about genetics: Historically, Mendelian genetics and the associated terminology (e.g., dominant, recessive) have been the major focus of much teaching about genetics. The *Framework for K-12 Science Education* and the NGSS de-emphasize these topics and the ability to use them to compute the likelihood of traits resulting from combinations of genetic information. In their place, the *Framework* and the NGSS emphasize three key ideas at the middle school level: (a) almost all traits show great variation, (b) this variation is due to *both* environmental and genetic factors, and (c) the genetic information influences the trait that appears through cellular and molecular mechanisms.

Therefore, we have anchored the genetics unit in a phenomenon in which both genetics and environmental factors contribute to variation in a trait and where students can see how changes to the structure of genes alter the structure and function of proteins that influence the trait. We selected the trait of muscle mass, which we can see in familiar animals, including humans.

(2) Reducing likelihood of problematic views about race: The choice to focus on more-complex genetics rather than on only simple dominant/recessive relationships was also driven by research that shows there is a potential for social harm associated with teaching overly simplified models of inheritance.

Discussion and examples of traits determined by a single gene are prevalent in current K-12 textbooks and curricula (Dougherty, Pleasants, Solow, Wong, & Zhang, 2011). Historically, educators have felt that using only examples of how dominant/recessive inheritance patterns of a single gene lead to phenotype is a productive first step toward understanding genetics. Yet traits affected by a single gene reflect only a tiny fraction of known traits, so these models of Mendelian inheritance patterns have limited explanatory power. Differences in most traits do not follow simple inheritance patterns, and such patterns have little predictive power in explaining the wide array of variation in these traits. If we focus instruction solely on these simplistic models, we leave students ill-prepared to reason about the myriad of genetic phenomena they are likely to encounter in the real world (Dougherty, 2009; Lanie et al., 2011), and if we teach these models as the central explanatory model of genetics, students' understanding in terms of these oversimplified models may become an obstacle to understanding the more-complex models.

Research has shown that teaching only traits determined by a single gene can cause harm by leading students to believe in *genetic determinism* and *genetic essentialism*. Genetic determinism is the belief that genes alone determine all of an organism's traits. Genetic essentialism is the belief that racial or gender groups have widely different genes that cause them to differ in physical, cognitive, and behavioral traits. At their extreme, these views can result in blatant prejudice, racism, and the belief that racial and/or social disparities are natural and need not be eliminated through policy interventions (Lynch, Morandini, Dar-Nimrod, & Griffiths, 2018).

Recent research has shown that current approaches to the teaching of genetics can contribute to essentialist and prejudiced views (Donovan, 2017). These views can develop even from seemingly well-intentioned instruction such as discussing the prevalence of genetic conditions like sickle cell anemia and cystic fibrosis in certain ethnic and racial groups (Donovan, 2015; Morning, 2008). Natural cognitive tendencies may cause students to unconsciously extrapolate from the prevalence of single-gene genetic disorders in some population groups to the relationship between complex, multifactorial "traits" such as intelligence, athleticism, morality, and race or ethnicity. Students may come to see complex traits as unchangeable, not affected by the environment, and characteristic of different groups. However, other research indicates that these outcomes can be prevented by providing instruction that develops a more-accurate model of the complexity involved in genetic inheritance (Donovan, 2016).

Therefore, we have chosen to provide students a first encounter with genetic inheritance that uses more-complex, multifactorial genetics in order to reduce the risk of developing or reinforcing deterministic and essentialist mindsets in our students.

References

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What are some frequently asked questions about genetics?

Below we have listed some questions that might arise while teaching the genetics unit and some suggested responses. These anticipated questions may come from either students or teachers. However, these responses are intended as a teacher-facing resource only to support your understanding of this complex topic. Teachers can then choose when and how to share information in response to student questions, taking into account that student questions should always prompt figuring out and sensemaking rather than a direct, explanatory answer.

What is the XY chromosome on the karyotype for? I heard XY were boys and XX were girls. Is this true?

In humans, we have two distinct characteristics, biological sex and gender. Biological sex is determined by an XX/XY system. However, it is really the SRY gene on the Y chromosome that matters most here. A functional SRY gene, once activated, creates testosterone and anti-mullerian hormone, which typically causes the development of a male reproductive system. Without a Y chromosome and functional SRY, an XX embryo develops into a female. While SRY is central, there are many other genes involved in influencing male sex. When SRY is mutated and produces a nonfunctional protein, the individual presents externally as female (and is usually assigned female at birth) but has XY and underdeveloped ovaries (therefore, the individual cannot bear children). There are several other systems for determining sex, some genetic (like XX/XY) and some environmental, like the effect of temperature on sex of reptiles.

One important point to note is that while *biological sex* is genetically determined, *gender* is not. Gender is a social construct that refers to how individuals position themselves and are positioned by others in relation to roles as women or men. Biological sex does not always determine gender identity. In addition, there are more gender identities than just woman or man. Gender definitions, expectations, and roles vary in different cultures, with some cultures embracing multiple gender definitions.

How can we honor and validate human families of all kinds while investigating biological inheritance?

It is important to remember that not all students in your classroom may be living with, or even know, either of their biological parents. Explicitly recognize that human families are created in a variety of ways that are not just biological and acknowledge the validity of all kinds of human families.

As you strive to make your classroom inclusive and accessible for all students, you will want to consider the language that you and your students use to discuss the relationships of the cattle in the pedigrees you're exploring. Use nongender terms like "parent," "offspring," and "sibling" whenever possible. You might specify "female parent" and "male parent" as needed to keep the focus on biological relationships. Do not assume that "father/dad" is synonymous with "male (biological) parent" or "mother/mom" is synonymous with "female (biological) parent" since those words have different meanings in many human families. However, also keep in mind that allowing students to use language that helps them describe the cattle pedigrees, such as "mother" or "son" or "grandpa", can encourage students to participate in discussions. Emergent multilingual learners can share the ways in which their home language(s) mark gendered and non-gendered terms used to describe families. In this way, the teacher can explicitly support metalinguistic conversations to help the entire class make connections between English and the other home languages of students in the classroom, reinforcing that all languages are important resources for science sensemaking.

If Mendelian genetics is problematic, why are we still teaching it (and why is it in the NGSS)?

Mendel's discoveries of independent assortment and segregation and the idea that offspring resulting from sexual reproduction get two variants of each gene (allele) from their parents are critical to understanding inheritance. However, the discrete phenotypes of simple Mendelian inheritance patterns and their typical ratios are fairly rare. That is, Mendelian inheritance patterns provide a simple model that can explain some rather unique variations in some specific traits. But it is important to keep in mind that Mendelian inheritance patterns describe the inheritance of genotype, and in the vast majority of cases, genotype alone does not reliably predict phenotype. For example, we know that mutations in human genes that produce proteins can sometimes result in specific phenotypes, and these are largely predictable

(e.g., known mutations that cause cystic fibrosis). Such knowledge is useful and helpful. However, even in these cases of well-known genetically linked disorders, not all genotypes result in the expected (predicted) phenotypes. For example, there are mutations in the CF gene that result in very mild symptoms, while other mutations result in severe symptoms. Moreover, sometimes the same mutation can result in different severity of symptoms in different individuals (Cooper, Krawczak, Polychronakos, Tyler-Smith, & Kehrer-Sawatzki, 2013). Thus, even "simple" Mendelian inheritance of traits can very rapidly become complex and not so Mendelian.

The larger problem, however, is that most traits are complex and are simply not single-gene traits that follow Mendelian inheritance patterns. Most of the human traits that students (and adults) are familiar with, such as eye color, height, and muscle mass as well as common diseases like diabetes and heart disease, are multifactorial (influenced by more than one thing). These traits are influenced by many genes (not just one) as well as internal and external environmental factors. For most of these traits, scientists cannot accurately predict an individual's phenotype. The website linked here http://udel.edu/~mcdonald/mythintro.html describes human traits that have been traditionally used in classrooms to demonstrate basic single-gene, two-allele genetic patterns but are in fact more complex. While teaching all the complexities involved in multifactorial traits is beyond secondary science education, we need to make sure that students understand the limitations of the simple Mendelian inheritance that we do teach. Furthermore, we need to go beyond this model to introduce the idea of multifactorial inheritance and the interactional effects of multiple genes and the environment in determining trait variations.

Can a genetic test distinguish between siblings or between twins?

The answer depends on the comprehensiveness and specificity of the test. Siblings share some but not all of their genetic material, and there are paternity tests that can distinguish between siblings and between fraternal twins. Most standard genetic tests cannot, however, distinguish between identical twins. There are more-extensive tests that examine more of the DNA and that can even distinguish between identical twins because such twins develop differences in their DNA due to errors in replication and random mutations that can be detected by highly sensitive tests.

I heard that a human has 50% of the same genes as a banana—is that true? And if so, why don't we look more like bananas?

We share about 1% of the DNA of bananas, but that 1% shared DNA accounts for about 50% of our genes. That is, we do share about 50% of our genes with that yummy fruit. People who share more than 50% are obviously sweeter (just kidding). If we share so many genes with bananas, why don't we look like them? That is because the genes we share, and their protein products, are involved in basic life functions such as cellular respiration. Cellular respiration, protein synthesis, DNA replication, and many other basic cellular activities are common to many different living organisms, including bananas and humans. There are also many genes that we do not share with bananas. We share 96% of our genome (genetic information) with fellow apes (such as chimpanzees and gorillas), and we look more like apes than bananas.

Are race and the color of one's skin the same thing? How is skin color determined?

Race and a person's skin color are not the same thing. The biology of skin color is separate from race, which is a social construct. See the *Scientific American* article discussing the scientific understanding of race as a "social construct without biological meaning" for more information. https://www.scientificamerican.com/article/race-is-a-social-construct-scientists-argue/.

The issues around race are complex and should be tackled with specific supports around those issues. This curriculum is not designed to directly address race. The curriculum was designed thoughtfully to avoid certain ways of thinking about genetics that can lead to problematic misconceptions about the essentialist nature of human differences. See the "How can we work toward a more-powerful and equitable genetics education?" section for more information regarding these curriculum design decisions.

There are resources out there to support teachers if you do want to tackle race head-on. Visit the Humane Genetics website to find out more. https://bscs.org/our-work/rd-programs/towards-a-more-humane-genetics-education/. Another option for a more-in-depth discussion could be to collaborate with the social science department at your school with teachers who have training to address issues around race.

Skin color is largely determined by the type and amount of melanin produced in skin cells called melanocytes. These melanocytes produce melanosomes, which are essentially little membrane-bound packages filled with melanin. The size and distribution of melanosomes also impacts skin color. There are multiple genes that influence skin color, each with multiple alleles. In addition, exposure to UV radiation (tanning) can also alter skin color to some extent (and to different degrees in different people). It is also noteworthy that genes involved in skin color do not all influence hair and eye color; these traits are distinct. If you are interested, here is a video resource called How We Get Our Skin Color from HHMI BioInteractive that explains the biology of skin color. https://www.youtube.com/watch?v=VC0TL_IYLm8

Are boys more muscular than girls, and is this because of genetics?

Biological males have more testosterone, which increases muscle mass. Biological females on average have about 40% less muscle than males. Moreover, there are differences in the composition of muscles. Biological males have more type 2 fast-twitch fibers in their muscles, which makes their muscles stronger. They can produce more force and produce it faster. There are many genes that contribute to muscle mass, and some of these genes are expressed differently in males versus females. However, differences in muscle mass are also attributable to diet, fitness level, and age.

If understanding the contribution of genes and the environment to traits is important, why doesn't the unit include anything about twin studies?

Twin studies have been used extensively to try to determine the heritability of traits. Heritability is a statistically estimated measure of how much of the variation in a given trait can be explained by genetic factors. Twin studies compare identical and nonidentical (fraternal) twins to establish an estimate of the heritability measure. A core assumption in twin studies is that identical and fraternal twins share environments to the same extent. That is, identical twins growing up in the same household and fraternal twins growing up in the same household share those environments to the same extent. However, this assumption turns out to be rather problematic, and several studies have shown that identical twins share environments to a greater extent than fraternal twins (Moore & Shenk, 2016). This is because identical twins share a placenta (usually), and thus, in the womb their environment is more shared than fraternal twins who develop in separate placentas. These placental differences do impact gene expression in significant ways. Moreover, similar-looking people (identical twins) tend to evoke similar social responses than different-looking people (fraternal twins). Thus, identical twins likely have more of a shared environment even outside the womb than do nonidentical twins.

Can we say what proportion of the variation of a trait is due to genes or environment?

As mentioned earlier, almost all traits are influenced by *both* the genetic material and the environment of the organism. It may be tempting to think that one can actually separate environmental and genetic influences on traits. But it is too simple to try to say that a certain percentage of a trait is influenced by environment and a certain percentage is influenced by genetics. Rather, all traits are mutually influenced by genes and environment in an integrated way. In other words, it's not like there are two influences that are independent of each other. Instead, it is genes *interacting* with the environment and with other genes that determines an organism's traits. For example, a particular type of environment might be necessary for a particular genetic variation to make a difference. For instance, an individual with a set of multiple alleles that usually result in tall height would not end up being tall without adequate nutrition to support that growth. The notion of heritability as a measure of how much genes *versus* environment influence a trait is therefore misleading.

What is the "environment" that could be influencing trait variation?

It is tempting to only think of "environment" as the lived-in world that is external to the organism—things like what predators might be around, variations in food availability, temperature, and so on. It's important to realize that the environment includes some factors that are actually inside the organism. A simple example to think about is the womb in which an embryo is developing. There are many factors that might vary in the womb and affect how genes are expressed. The external environment can even include what is happening in the body of the individual—that is still external to what is coded in the genes. For example, the concentration of the substances in the cells could impact some kinds of gene expression. A person under a lot of stress may have increased cortisol levels in their blood, which can affect how particular genes are expressed.

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GUIDANCE FOR DEVELOPING YOUR WORD WALL

This unit refers to two categories of academic language (i.e., vocabulary). Most often in this unit, students will have experiences with and discussions about science ideas before they know the specific vocabulary word that names that idea. After students have developed a deep understanding of a science idea through these experiences, and sometimes because they are looking for a more-efficient way to express that idea, they have "earned" that word and can add the specific term to the class Word Wall. These "words we earn" should be recorded on the Word Wall using the students' own definition whenever possible. On the other hand, "words we encounter" are "given" to students in the course of a reading, video, or other activity, often with a definition clearly stated in the text. Sometimes, words we encounter are helpful just in that lesson and need not be recorded on the Word Wall. However, if a word we encounter will be frequently referred to throughout the unit, it should be added to the Word Wall. As such, the Word Wall becomes an ongoing collection of words we will continue to use, including all the words we earn in the unit and possibly a few key words we encounter.

It is best for students if you create cards for the Word Wall in the moment, using definitions and pictorial representations that the class develops together as they discuss their experiences in the lesson. When they co-create the posted meaning of the word, students "own" the word—it honors their use of language and connects their specific experiences to the vocabulary of science beyond their classroom. It is especially important for emergent multilingual students to have a reference for this important vocabulary, which includes an accessible definition and visual support.

Sometimes creating Word Wall cards in the moment is a challenge. The *Teacher Guide* provides a suggested definition for each term to support you in helping your class develop a student-friendly definition that is also scientifically accurate. If you keep one Word Wall in your classroom for several sections of students, you might choose to record each class's definition separately and then propose an "official" definition to post the next day of classes that captures the collected meaning. The words we earn and words we encounter in this unit are listed in this document and in each lesson to help prepare and to avoid introducing a word before students have earned it. They are not intended as a vocabulary list for students to study before a lesson, as that would undermine the authentic and lasting connection students can make with these words when they are allowed to experience them first as ideas they're trying to figure out.

Lesson	Words we earn	Words we encounter	Words from a previous unit
L1	trait, variation		
L2			protein
L3			
L4			
L5	pedigree, phenotype, sexual reproduction		chromosome, nucleus
L6	genotype	gene, allele	
L7	genetic material, genetic information, homozygous, heterozygous		
L8		mutation	
L9			
L10			
L11			
L12			
L13	asexual reproduction		
L14		varies based on group research texts	
L15			
L16			
L17			

TEACHING SCIENCE LITERACY

How does the Core Knowledge Science Literacy routine integrate with the unit investigations?

The Core Knowledge Science Literacy Student Reader and the weekly Science Literacy routine layer varied reading opportunities into the science unit. In their lives after graduating from high school, most students will not become scientists. They will no longer routinely participate in guided investigations to figure out how phenomena work. They will, however, read text about science and scientific claims, day in and day out. The ability to learn and think about science through reading is a skill unto itself and is important in tandem with investigative learning. It is natural to primarily associate emerging literacy with reading and writing instruction at the elementary level, but middle school is an important time to hone literacy skills—specifically in science in the era of politicization of science topics, polarization among adults, and proliferation of misinformation on social media. Detection and construction of well-reasoned explanations are important not just in science, but throughout everyday life. Using claims and evidence in reasoning is the way that thoughtful people think about things, and writing is thinking in print. Students become voters as they emerge from high school, so it is important that they acquire skills for detection of faulty information and practice legitimate communication about scientific issues in the years leading up to that civic benchmark.

Throughout the course of the unit's investigative lessons, students write in their science notebooks in some fashion almost daily, and significant emphasis is placed on the speaking and listening communication threads of the CCSS. The instructional design of the investigations is deliberately light on having students access disciplinary core content through text. NGSS emphasis is on students investigating phenomena along the storyline, so students' interaction with text within lessons is minimal and in service to the unit's storyline. The Science Literacy routine is integrated to exercise students' ability to interact with text about science topics. The routine presents students with short reading selections in a variety of styles, all related to the unit in which students are engaged. Each reading selection is accompanied

by a brief but thoughtful writing exercise. The subject matter of the reading selections ties back to the unit, but the timing for the assigned readings is such that students do not read about specific facets of the subject before they have completed the lessons to investigate that content. In other words, the reading enhances and reinforces the knowledge that students have built in previous lessons; the reading does not reveal beforehand the key takeaways that students are intended to learn through lesson interactions.

When is it done within a unit?

The Core Knowledge Science Literacy Student Reader includes one reading collection per week for every week of the unit. A week's reading collection relates to the lessons completed in the previous week. The reading is assigned at the beginning of the week with the accompanying writing exercise due at the end of the week.

The reading and writing exercises are designed to be completed by students independently, with brief, supporting, teacher-facilitated discussions at the beginning, midpoint, and end of the week.

How do students typically represent their thinking as part of the routine?

Students generate a written product associated with each reading selection. The products are varied in form, and include graphic organizers, concept maps, cartoons, memes, infographics, storyboards, outlines, and paragraphs. The complexity of the products increases from week to week, with the final product for the unit being a single, thoughtfully reasoned, and wellconstructed paragraph.

Put Yourself in This Scene

Literacy Objective

✓ Initiate thinking about the need to evaluate information in text and images.

Literacy Exercises

- Read a brief scenario to pique interest, launch discussion, and begin to frame expectations.

Instructional Resources



Science Literacy Student Reader, Preface
"Put Yourself in This Scene"

No Prerequisite Investigation

The reading of the Preface is appropriate during the first week of unit instruction. The reading does not preemptively tell students facts about the topic that they are intended to learn throughout the course of their investigations.

Standards and Dimensions

NGSS

Disciplinary Core Idea 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. (MS-LS3-2)

Science and Engineering Practice: Asking Questions and Defining Problems

Crosscutting Concept: Cause and Effect

CCSS

English Language Arts

RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

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.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. No Core Vocabulary terms are highlighted in the Preface.

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

environment
genetics
genes
science literacy

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the Science Literacy Student Reader.
- Friday: Set aside time at the end of the week to facilitate a brief discussion about the reading.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know that for the Science Literacy routine, they will read independently and then complete short writing assignments. The reading selections relate to topics they will be exploring in their Genetics unit science investigations.
- The reading and writing will typically be completed outside of class (unless you have available class time to allocate).
- The first week's reading is a short introductory segment in the book, and there is no accompanying writing exercise as the unit is getting started.
- The class will discuss the reading together at the end of the week.

SUPPORT—The Preface with the scenario about the app to make you jump higher is written at approximately Lexile 1100–1200, which leans toward the high end of the expected text complexity band for middle school. You may wish to introduce a word identification and comprehension convention into your routine to support struggling readers. Hang an envelope near the door with the label, "When we talk about the next reading selection, I could use a little more help understanding the word(s). . . " Encourage students, as they are reading, to jot words, phrases, or sentences that they are unclear about onto small scraps of paper and tuck them into the envelope at any time preceding the discussion of the reading. Whenever you facilitate class discussion about a reading selection, check the envelope first, and layer in added examples and repeat definitions to help students build comprehension and fluency for terms or complex sentences about which they have revealed they are uncertain.

3. Facilitate discussion.

(Friday)

Facilitate a brief class discussion about the Science Literacy Student Reader Preface, entitled "Put Yourself in This Scene."

Pages 2–3 Suggested prompts	Sample student responses
How would you summarize the "scene" referred to in the title?	*It is a conversation between two teens who disagree on whether an exercise app can help people develop the ability to dunk basketballs.*
What does Isaiah mean when he says, "I inherited my mom's legs"?	*that leg traits that make them especially good at jumping were passed from her to him*
What are genes?	*Genes are locations on chromosomes that affect the traits of an individual.*
What tools do the sellers of the VertiCalisthenics app use to convince people to buy?	*They say they have "vertical leap scientists" working on the app and that they have data to back up their claims and testimonials from satisfied users. They also say they are specialists in exercise physiology and that pro athletes and Olympians use their product.*
What variables might affect the ability to dunk?	*how high the basket is* *how tall you are* *how long your legs are* *how many times you practice dunking* *what you eat* *how much sleep you get* *whether your parents could dunk or not*

Student Reader



Preface

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Pages 2–3 Suggested prompts	Sample student responses
What kinds of data would you have to collect to answer the question of how effective the VertiCalisthenics app is?	*what the app tells people to do* *how many people used the app and for how long* *how high people could jump before using the app and after using the app*
What does the author mean by "genetics versus environment" in this article?	*Genetics is the genes and traits you inherit from your parents, and the environment is where you live and everything you do, such as practicing, eating, sleeping, and so on.*
Do you agree with Isaiah that Gabe is wasting his money? Explain.	*No, if the app helps Isaiah keep focused on practicing, stretching, eating right, and getting enough sleep, it might help him.*
How can being scientifically literate generally help when people are thinking of buying goods or services?	*It helps you figure out whether claims by sellers are reasonable or need more research.*

Key Idea—Point out that without an investigation into the effectiveness of the VertiCalisthenics app, there isn't really a way to make an informed decision about whether it is worth spending $9.99 per month on it. Both the investigations and the reading selections in the unit ahead will help students advance to a place where they have more knowledge to apply to the scenario, and they will circle back to the topic of genes and the environment at the end of the unit.

LESSON 1

How do organisms get their differences?

Previous Lesson

There is no previous lesson.

This Lesson

Anchoring Phenomenon

3 DAYS



We observe a bull and other animals that have extra-big muscles. We develop initial models to explain what could be causing these animals to have such big muscles. We realize that muscles don't come in just two sizes, large and small. We also observe photos of other organisms to identify variations in traits other than musculature. After generating a list of related phenomena of other organisms that are generally the same but have wide variations in some of their features, we develop a Driving Question Board and ideas for future investigations.

Next Lesson

We will observe images and video animations to figure out that muscles have specific cell and protein structures. We will compare photos and data about muscle cells from extra-big-muscled animals and typical ones to discover that bigger muscles have more cells, more area, and more mass.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5

What Students Will Do

1.A Develop and/or use a model to predict what is causing these animals to have extra-big muscles.

1.B Ask questions that arise from careful observation of pictures of animals with different musculature to seek information about what causes these variations in populations.

What Students Will Figure Out

- Some cattle and other animals have extra-big muscles like we've never seen before, and we aren't sure how they got that way.
- There are many variations of characteristics (traits) in living things.
- We have a lot of questions and ideas to pursue.

Lesson 1 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	15 min	**OBSERVE PHOTOS OF CATTLE WITH TYPICAL AND SIGNIFICANTLY DIFFERENT MUSCULATURE** Record noticings and wonderings individually in science notebooks while observing photos of two bulls who are generally similar except that one has typical musculature and the other has extra-big muscles.	A-D	Notice and Wonder chart, markers
2	5 min	**MAKE OBSERVATIONS ABOUT OTHER ANIMALS THAT HAVE BIG MUSCLES** View other examples of animals with this significant difference in musculature and begin to look for patterns and possible causes.	E-J	
3	15 min	**CREATE INITIAL MODELS** Develop a model individually to explain how one of these animals might have gotten its extra-big muscles and what the muscles would look like upon "zooming in."	K-L	*Initial Model*, transparent tape
4	10 min	**COMPARE AND CONTRAST INITIAL MODELS** Meet with several different partners to find similarities and differences between initial models.	M	*Initial Model*
				End of day 1
5	15 min	**CONSENSUS MODEL DISCUSSION** Co-construct an initial model as a whole class, finding points of agreement and disagreement about how and why these animals could be different.	N	*Initial Model*, chart paper, markers
6	20 min	**OBSERVE MORE PHOTOS SHOWING OTHER VARIATIONS** Examine collections of photos of cattle and of tulips to notice variations in traits. Acknowledge the wide range of variation within groups of organisms that might have seemed the same.	O-R	*Cattle Photo Cards*, *Tulip Photo Cards*, (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**) half-sheets of copy paper, markers
7	5 min	**LIST RELATED PHENOMENA** Individually list examples of variations among otherwise-similar organisms.	S	chart paper, markers
8	5 min	**ASSIGN HOME LEARNING (OPTIONAL)** Go into the community and find an example of a living thing that has a range of differences in a feature or characteristic.	T	
				End of day 2

Part	Duration	Summary	Slide	Materials
9	13 min	**SHARE RELATED PHENOMENA** Share examples listed during class and/or from home learning of other living things that have variations in a characteristic or trait. Create a class list of related phenomena and begin to discuss possible causes.	U	artifacts or photos collected from self-documentation home learning (optional), chart paper, markers
10	5 min	**GENERATE INITIAL QUESTIONS** Consider all the experiences in class so far and write questions we have to eventually form a Driving Question Board.	V	several 3×3 sticky notes, dark-colored marker
11	17 min	**CREATE OUR DRIVING QUESTION BOARD** Share questions aloud and group them together with other similar questions to form a DQB to guide the work of the class going forward.	W	chart paper, markers
12	10 min	**CONSIDER IDEAS FOR INVESTIGATION** Generate ideas for future investigations and consider what data we would want to find or collect to help us answer some of the questions on our DQB.	X-Y	chart paper, markers

End of day 3

Lesson 1 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Initial Model* • artifacts or photos collected from self-documentation home learning (optional) • several 3×3 sticky notes • dark-colored marker	• *Cattle Photo Cards* • *Tulip Photo Cards*	• Notice and Wonder chart • markers • transparent tape • chart paper • half-sheets of copy paper

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make one copy of *Initial Model* for each student. Trim to fit into students' science notebooks.

Make and post a Discussion Norms poster near your DQB space if you haven't already. See the *Teacher Handbook* for more information about developing norms to support productive discussions.

Plan a space in your classroom to create a Driving Question Board (DQB) that students can gather around.

Online Resources

Plan space in your classroom to post the classroom consensus model as it evolves over the course of the unit. The teacher reference *Unit-Wide Lesson-by-Lesson Model Resource* is provided to help you anticipate the various updates and additions to this model.

Have transparent tape available for students to attach the *Initial Model* handout to their science notebook.

Online Resources



Gather the cattle photo cards and tulip photo cards from your materials kit. Or, if you do not have premade cards from the materials kit, see the **Online Resources Guide** for links to these items (**www.coreknowledge.org/cksci-online-resources**). Prepare them as follows:

- Print 1 color copy on cardstock of *Cattle Photo Cards* and cut the cards apart to make 1 set of 30 individual photos.
- Print 8 color copies on cardstock of *Tulip Photo Cards* and cut and organize the cards to make 8 sets of 24 photos per set. The images are numbered in each set, so each set will need tulips #1-24.
- Consider laminating both the cattle and tulip cards since you will reuse them for each class you teach and can keep them year to year.
- You will distribute the cattle cards individually to students, but groups of students will each get an entire set of tulip cards, so consider bundling those with rubber bands or binder clips so they're easier to distribute.

Note that we included names for the cattle used in this lesson and others for easy reference; some of these are simplified versions of the animals' actual names, but many were invented because the actual name was not available.

Have half-sheets of copy paper ready to add the following words to the Word Wall: **trait, variation**. Do not post these words on the wall until after your class has developed a shared understanding of their meaning.

As a reminder about supporting students with visual disabilities: This unit in general and this lesson specifically use images as data. So, you will need to make accommodations so that students with visual disabilities can access these data. Depending on your students' needs, suggested modifications include enlarging and/or brightening the provided digital versions of these photos or using alternate text descriptions. Your students' IEP or 504 case leaders should also be able to provide you with specific resources and possible modifications to use.

If you have students who are color blind, the conversations in this lesson around color variations in a group of organisms may pose a unique challenge. If you haven't already done so, take some time to talk with your student(s), familiarizing yourself with their way(s) of seeing the world, and ask how you can best support them as they investigate differences among organisms, including but not limited to their color patterns.

Lesson 1 • Where We Are Going and NOT Going

Where We Are Going

Students may come into this unit with different ideas about how animals get such big muscles. They most likely will know that diet and exercise play a large role in how big an animal's muscles get. What they might not know is that the extra-big muscles they see in the anchoring phenomenon are the result of having an allele for the MSTN gene that makes a different shape of a protein called *myostatin*. Figuring out the genetic and environmental factors that can influence musculature is the focus of the first lesson set of the unit; in the second lesson set, students will explore how genetic and environmental factors influence the variation we see in other traits in other organisms.

This unit intentionally brings out the effects of environmental factors on trait variation because this is an important scientific concept to understand that will be further built upon in high school. The trait variation we see among living things is almost never due to genetics alone. By the end of the unit, students will grasp that genes and environment are always at play in the variation we see among living things. (There is a gene and environment interaction, but this is beyond the middle school grade-band understanding).

Note that we generally refer to this phenomenon as "extra-big muscles" until Lesson 4, when we hear a farmer describe these cattle as "heavily muscled."

The teacher reference *Unit-Wide Lesson-by-Lesson Model Resource* is provided in Lesson 1 to help you see the scope of what students will figure out in the entire unit.

Where We Are NOT Going

There is no immediate need for students to connect the variation we see in animals' musculature as the result of inheritance (although they might, and that's fine, too). In fact, the next couple of lessons explore exactly what the students might predict causes these differences: environmental factors like diet and exercise. Students will realize in Lesson 4 that environmental factors alone cannot explain all the variation they see in the heavily muscled animals, which will be a natural turning point to a focus on inheritance. Therefore, it is not necessary to have questions about family or inheritance or genes on the DQB at this time.

We made a deliberate choice not to use the word "species" in this unit. Understanding this classification is beyond the scope of this unit, and the words "group" and "population" (in Lesson 4 and beyond) better fit the needs of our work in this unit.

LEARNING PLAN FOR LESSON 1

1. Observe photos of cattle with typical and significantly different musculature. 15 MIN

Materials: science notebook, Notice and Wonder chart, markers

Introduce an interesting phenomenon. Say, *I've got some pictures of interesting animals to show you. When I first saw them, I found them very surprising. I want us to take a look at them as a class.*

Set up Notice and Wonder charts in science notebooks. Display **slide A**. Say, *You'll use your science notebooks to record what you notice and wonder about the animals shown in the pictures, so let's set up a chart now so we are ready to record our thoughts.*

Science Notebook



If you haven't already set up science notebooks for this unit, direct your students to count off about 4 pages to use for a table of contents. They will also need to set aside 10-15 pages at the end of the notebook to use for the Progress Tracker (starting in Lesson 2).

Independently record noticings and wonderings about the bull photos. Say, *The photos I'm going to show you are of actual animals. These photos have not been altered to make them look like this. Take a couple of minutes to look at them carefully and record what you notice and wonder.*

Additional Guidance

If you anticipate that your students need it, give a reminder about keeping voices off so everyone can have quiet think time. You could say something like, *We want to gather as many ideas as possible, and if you say something out loud, your idea might disrupt other people's thinking and make them forget their own ideas. We will have time to share all of our thinking in just a few minutes, but for now, it's important to keep your thoughts to yourself.*

Display **slide B**. Give students about 2 minutes to work silently on the Notice and Wonder chart in their science notebook.

Turn and talk about the bull photos. After students have had some time to work on their own, display **slide C** and direct them to share their thinking with a neighbor. Remind them to refer to specific details in the photos to support their ideas.

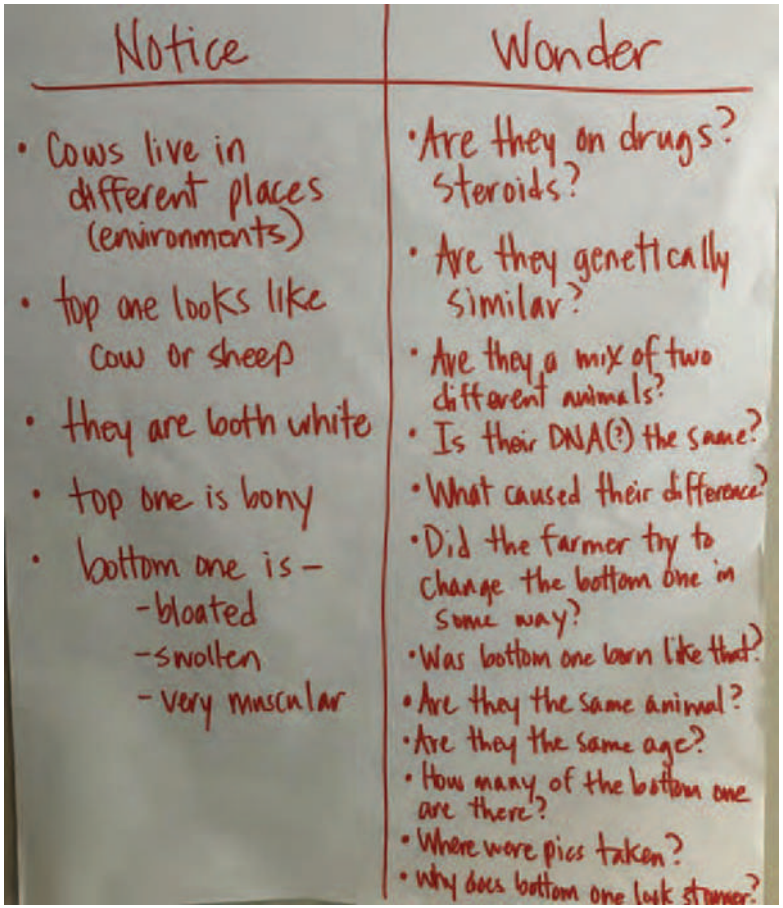
Share noticings and wonderings with the whole group in an Initial Ideas Discussion. Display **slide D** and record students' thinking on a Notice and Wonder chart as they share.

Key Ideas

Purpose of this discussion: (1) to engage students in thinking very carefully about these photos, (2) to generate a range of ideas to cultivate curiosity and uncertainty, and (3) to build student agency in science discussions. A diverse range of ideas is something to celebrate here!

Listen for these ideas:

- Accept all student answers and be careful to not evaluate them as correct or incorrect.
- While there may be differences in the posture of the bulls, the settings they're in, and so forth, we want to be sure students all see the difference in their musculature most of all.



Example Notice and Wonder chart.

Suggested prompts	Sample student responses	Follow-up questions
What did you notice about these animals?	*The bull on the bottom has huge muscles!* *The one on the bottom looks stronger than the one on top.*	*Thank you for sharing.* *What in the photo makes you think that?* *So let me see if I get what you are saying. Are you saying that . . .? (Leave space for the original student to agree, disagree, or say more.)*
What are you wondering?	*How did they get this way?* *Does this happen in other animals?*	*Who can add on to the idea that we are building?* *Can you say more about that?* *Who can repeat this idea or put it in your own words?*

Additional Guidance

Students may refer to the pictures of the bulls as "cows" or "cattle" or some other word. Whatever name they use in their initial ideas is fine. For your background knowledge, the following are definitions of the specific terms:

- *Cattle* is the plural for males and/or females.
- A *bull* is a fertile male.
- A *steer* is a sterile male.
- A *cow* is a female who has had a calf.
- A *heifer* is a female who has not had a calf.

If students ask if the images are of males or females, say, "That's a good question that we might want to find out." Add the question to the "wonder" side of the Notice and Wonder chart. We don't want the sex of the cattle to become a stumbling block. Even though the pictures of the cattle are of males, we don't want students to think that only males can develop the large musculature. In later lessons, students will see evidence that females can also have the heavily muscled phenotype.

2. Make observations about other animals that have big muscles. 5 MIN

Materials: science notebook

Observe other animals with extra-big muscles. Display **slides E through J** one at a time, allowing some time for students to notice and comment on the images. Keep this part moving, no more than 20 seconds per slide. No need for students to write down anything. The goal is to broaden out to more examples of animals that have really large muscles. The large musculature isn't just a one-time thing that happened in one animal.

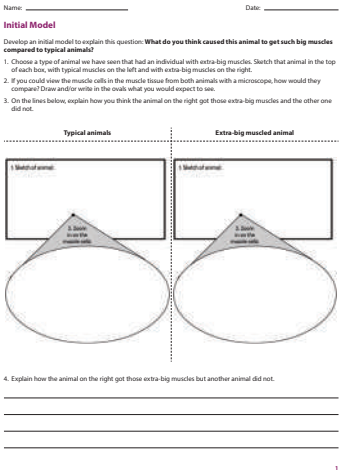
Suggested prompts	Sample student responses
What do you notice?	*There are so many different animals that have extra-big muscles!* *The black-and-white cattle have different coloration than the pictures we originally saw, but they still have big differences in the muscles.* *These animals with big muscles are all ones that humans interact with a lot, like on farms or as pets.*
What are you wondering now about these animals?	*How are these animals getting so jacked? Do they go work out at the gym?* *How does this work?* *Does this happen in the wild or just when humans are involved?*

3. Create initial models.

15 MIN

Materials: *Initial Model*, transparent tape

Create initial models. Display **slide K**. Distribute the *Initial Model* handout. Give directions for drawing quick stick animals in the boxes for step 1 so students don't spend too much time on their animal drawings. More time and effort should go into their thinking about steps 2 and 3. Allow students about 10 minutes of quiet, independent work time. While they're working, encourage students to record in their notebook any questions they have right now. Display **slide L** so students can refer to the animal examples while they work.*



Name: _____ Date: _____

Initial Model

Develop an initial model to explain this question: **What do you think caused this animal to get such big muscles compared to typical animals?**

1. Choose a type of animal we have seen that had an individual with extra-big muscles. Sketch that animal in the top of each box, with typical muscles on the left and with extra-big muscles on the right.
2. If you could view the muscle cells in the muscle tissue from both animals with a microscope, how would they compare? Draw and/or write in the ovals what you would expect to see.
3. On the lines below, explain how you think the animal on the right got those extra-big muscles and the other one did not.

Typical animals | Extra-big muscled animal

1. Sketch of animal:

2. Zoom in on the muscle cells:

1. Sketch of animal:

2. Zoom in on the muscle cells:

4. Explain how the animal on the right got those extra-big muscles but another animal did not.

***Supporting Students in Engaging in Developing and Using Models**

Remind students that we are using this model to predict and describe what we think may be causing this phenomenon, so the goal of this initial model is to get students' thinking down on paper, not to have the "correct" answer.

Additional Guidance

Initial Model asks, *If you could view the muscle cells in the muscle tissue from both animals with a microscope, how would they compare?* If your students did not participate in *Unit 6.6: How do living things heal? (Healing Unit)* and/or you know they have not had experience with microscopes, you may need to dissect the word *microscope* (*micro* meaning "small" and *scope* meaning "see") and/or rephrase this direction to something like, *If you could zoom in really closely ….*

Science Notebook



You may instruct students to tape their initial model in their science notebooks or you might want to collect the initial models as a pre-assessment (see the assessment guideline in the next part). If you do collect initial models, students can tape them into their science notebooks when you return them.

4. Compare and contrast initial models.

10 MIN

Materials: *Initial Model*, science notebook



Compare models with partners. Display **slide M** and direct students to make a T-chart in their science notebook to collect similarities and differences between their models. Briefly explain the instructions for Stand Up, Hand Up, Pair Up and give students about 8 minutes to mingle, comparing models with different partners. Students should record similarities and differences in their T-charts while they are talking with different partners. If other questions come up during their conversations, students should record those questions in their science notebooks, too.

Collaboration



"Stand Up, Hand Up, Pair Up" is a partner talk protocol that works like this: When you say "Go", students stand up with their hand up in the air (and handout, notebook, and pen in the other hand). They roam around the room to find another person whose hand is also up (the first person they make eye contact with) and go talk with that person. After they've recorded similarities and differences, they both put their hands up again to go find new partners (with someone else whose hand is also up again). Students continue mingling to find partners as they're ready (no set signal from the teacher to rotate).

While students are sharing their models, circulate the room and listen in so you can gauge the range and diversity of student ideas and be ready to surface these ideas in the Consensus Discussion on day 2. You may also choose to collect the *Initial Model* handouts so you can look more closely at students' models after class.

Assessment Opportunity

Building towards: 1.A Develop and/or use a model to predict what is causing these animals to have extra-big muscles.

What to look and listen for: These initial models provide an opportunity to learn more about the ideas your students bring to this unit, in general and about genetics specifically. Revealing these ideas early can help you be strategic in building from and leveraging student ideas throughout the unit. Look for the following possible causes of these muscle differences:

- exercise
- diet
- possibly that other animals in that individual's family might share this feature

What to do: If students are struggling to develop their initial models, remind them that we are using this model to predict and describe what we think may be causing this phenomenon, so the goal of this initial model is to get their thinking down on paper, not to have the "correct" answer. If they're having trouble thinking of ideas for possible causes, ask them to consider any background knowledge they have about muscles (not necessarily for that specific animal). Also, do not worry if students do not bring up the family connection around musculature; there will be other opportunities to raise this possible cause as the unit progresses.

Pause here for now. Say, *Thank your last partner for sharing with you, and thanks to you all for your great thinking today. Next time we're together, we will combine our ideas into our consensus model. I'm looking forward to it!*

End of day 1

5. Consensus Model Discussion

15 MIN

Materials: *Initial Model*, chart paper, markers

Scientists Circle



Your students may be familiar with the Scientists Circle from previous units. Remind students of the norms for participation and the logistics for forming and breaking down that space. A Scientists Circle includes these important features:

- students sitting so they face one another to build a sense of shared mission and a community of learners working together;
- celebrating progress toward answering students' questions and developing more-complete explanations of phenomena; and
- focusing on where students need to go next and how they might go about the next steps in their work.

It is also helpful to establish norms for whole-group and small-group science discussions. See the *Teacher Handbook* for more guidance on establishing classroom norms.

Bring students together in a Scientists Circle for a Consensus Discussion. Display **slide N**. Tell students that the goal of this discussion is to figure out areas of agreement and disagreement in our initial models. Knowing where we agree and disagree will help us figure out how we might want to proceed in figuring out how these animals got their different muscles.

Key Ideas

Purpose of this discussion: There are two goals of this discussion: (1) to generate a variety of initial ideas about what is going on in these animals and (2) to scope out the territory of what the class does and does not understand in order to problematize what the group needs to figure out. As such, it is again important to accept all student responses and to encourage students to share their ideas. Furthermore, it is important to highlight areas of disagreement and help students clearly explain their thinking in these areas. Be careful not to respond favorably to any one idea over others

so as not to "give away" the reasons for the big muscles that the class will investigate as the unit progresses.

Listen for these areas of agreement:

- the difference in size of muscles between both animals
- a possible difference between these muscles at the cellular level
- the possibility of several reasons why these animals have such different musculature

Listen for these areas of disagreement:

- how the muscle cells might be different: larger cells, more cells, or both
- the possible factors causing this muscle difference
  - what the animal eats
  - how much it exercises
  - whether its family members had or have those same muscles
  - other ideas such as steroids, genetic modification, and so forth

Represent areas of agreement and disagreement in a classroom consensus model. It is unlikely that you will have complete consensus about the possible causes of these muscle differences. Instead, students will likely propose a handful of causes that everyone can probably agree are worth investigating. Mark areas of disagreement or ideas to pursue with question marks. It is OK (preferred, even) to have several possible causes to investigate later.

Throughout the discussion, and again toward the end, remind students to record any questions they have right now in their science notebook so we do not lose those questions.



Example classroom consensus model.

6. Observe more photos showing other variations.

20 MIN

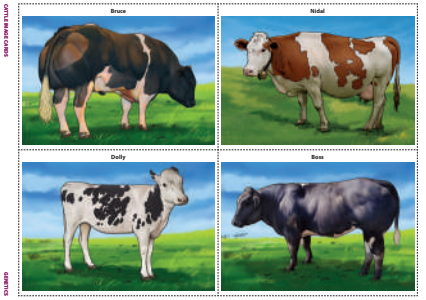
Materials: *Cattle Photo Cards*, *Tulip Photo Cards* (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**), half-sheets of copy paper, markers

Suggest a question about our classroom consensus model. Display **slide O**.

Say, *We developed a classroom consensus model to explain the differences between individuals with extra-big versus typical muscles, but as we have been talking about this, I have been thinking. Are there only two sizes of muscles that animals can have—extra big and typical—or do you think that there can be other sizes of muscles too? Turn and talk with a neighbor. Share what you think and decide if you agree with each other's ideas or not and explain why.*

Give students a minute to turn and talk with a partner.

Say, *I have some photographs of different cattle that we can use to try to find additional evidence to support or refute the initial arguments you shared with your partners.*



Observe and compare other cattle photos. Display **slide P**. Distribute all 30 individual images of cattle from the *Cattle Photo Cards*—depending on how many students are in your class, each student may get 1 or 2 photos or share a

photo with a partner. Direct students to compare the muscles of their animal to others in the class, inviting students to stand up and cluster together or form a loose line of cattle photos based on how muscled the cattle appear to be.

Additional Guidance

It is not critical to have perfectly organized groups or a continuum of cattle musculature—it is difficult to decide from these photos exactly where each animal would go, so there is no correct order. What is important here is that students figure out that there is variety in the apparent musculature of different cattle.

Ask, *What do you notice about the muscles of these cattle?*

Sample student responses

- The cattle have different amounts of muscles.
- There probably are not just two groups (extra-muscled or typical).

Say, *We focused specifically on the muscles of these cattle just now, but look at your photo and the ones around you: What other characteristics do these cattle have that we could sort or organize them by?*

Each time a student suggests a characteristic, ask, *How could we group or arrange them if we focused on that characteristic?*

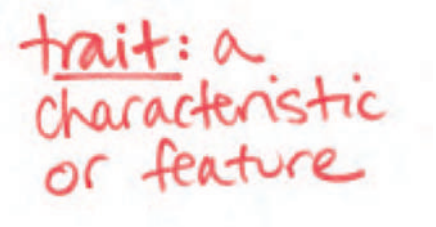
Sample student responses

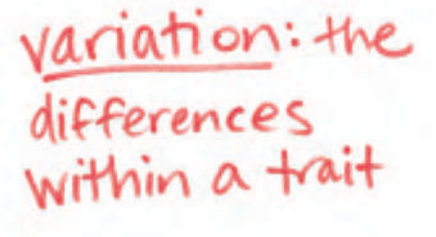
- horns (none, small, bigger, really long)
- color (black, white, brown, reddish)
- pattern (solid color, big spots, small spots)
- fur texture (smooth, short, shaggy, long)

Define *trait* and *variation*. Point out to students that scientists have specific words to use when describing the differences we've been talking about.

Say, *It can get tricky to talk about these differences, so we're going to add a few terms to our science Word Wall to help us have discussions about this. You pointed out some of the general characteristics or features that cattle have, such as color or height or horns—these are called "traits". The differences within each of those categories—such as black, white, brown, or reddish for color and none, small, bigger, and really long for horns—these are the variations within the trait. So the trait includes all the variations in that category.*

Add *trait* and *variation* to your Word Wall. Sample definitions are shown here.





Suggest exploring differences in other organisms, too. Ask, *If we looked at other living things, do you think we would see other variations in their traits, too?*

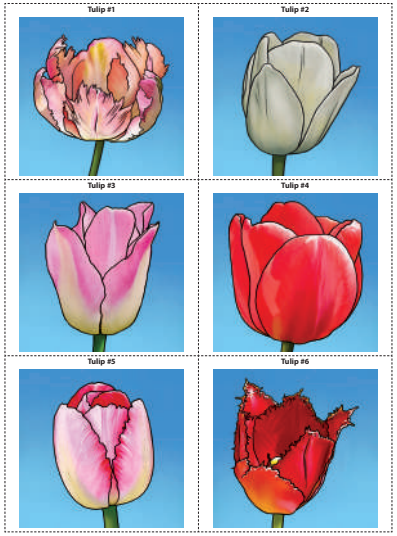
Work in small groups to observe photos of tulips and identify traits and variations. Display **slide Q**. Say, *I have some images of a type of flower called a tulip. Work with your group to observe the images and identify some traits of tulips. Choose one trait and then organize the images by variations in that trait, grouping them or lining them up to show the variations.*

Form 8 small groups of students and distribute a set of 24 images from *Tulip Photo Cards* to each group. Give students 5-7 minutes to examine their photos and sort them based on a trait of their choice. If they have time to spare, encourage groups to reorganize their tulip photos based on a different trait.

Debrief findings from these observations. Gather students together in a whole group again and display **slide R**. Have students briefly share examples of the traits and their variations. Traits students may identify (with possible variations they may sort by):

- color (white, yellow, orange, red, purple)
- color pattern (solid, center stripe, edge outline, speckled)
- petal shape (rounded, pointed, narrow, wide)
- petal edge texture (smooth, fringed, ruffled)
- number of petals (4, 5, too many to count, hard to see to count)

Remind students to jot down any questions they have about traits and variations in their science notebook so we can remember those questions next time.



7. List related phenomena.

5 MIN

Materials: science notebook, chart paper, markers

List related phenomena. Display **slide S**. Direct students to the next clean page in their science notebook and have them title it "Related Phenomena."

Say, *Like the cattle or tulips were generally the same but had differences or variations in some characteristics or traits, what other examples of living things have you seen that are basically similar but have different variations in a feature or trait?* Give students 3 minutes to create their lists, working silently and independently.

Additional Guidance

If students are struggling to come up with ideas, prompt them to think about their own pets compared to a friend's pet, plants they see on the walk to school, or even the foods they eat that are living things, such as apples or bananas.

8. Assign home learning (optional).

5 MIN

Materials: None

Assign home learning. Display **slide T**. Explain the assignment.*

Say, *Think of or find another example of a type of organism that shows differences between individuals in some characteristic or trait. Consider at least two of that type of organism. Think about where you could even see a group of these organisms in your community. The walk home from school or imagining a trip to the grocery store produce section might be good places to start. Taking photos or making drawings will help you describe the traits and variations you notice, but you*

***Attending to Equity**
At some point during this unit, your students may bring up the idea that they may (or may not) share traits with members of their families. Recall that not all your

*might just jot your ideas in your science notebook, too. We will discuss our related phenomena from class and outside school next time we meet, and the more ideas, the better!**

Home Learning Opportunity



Help support students and trusted members of their community in observing variations in living things. Encourage students to bring their observations and ideas back to class to inform and enrich the work of this unit. Inviting students to bring their family and/or community knowledge, experiences, and practices into school not only supports students in coordinating the learning they do outside school with what they do in school, but it can also help you as a teacher to expand your understanding of the strengths of the families and communities you work with.

Additional Guidance

This home learning opportunity is an example of self-documentation, an instructional routine that helps students see how the focal science ideas they are figuring out relate to everyday phenomena in their lives. This routine can be a powerful way to support students in forging connections between their identity outside of the classroom and the science ideas they engage with inside of the classroom.

Do not require that students complete this home learning and do not score it; the goal of this self-documentation is to expand students' noticings of trait variations. However, some students may not feel safe exploring their community outside school or may not have the time or resources to complete this assignment. Your discussion of related phenomena will be enriched if students do this home learning, but they should still be able to contribute to the class collection of related phenomena without having done this specific assignment.

End of day 2

students may be living with or in touch with their biological family members and therefore would not be able to compare themselves with their parents, grandparents, siblings, and so on. In order to be sensitive to these situations, you should not direct students to explore inheritance with their families. The home learning in this lesson should be focused on nonhuman examples of trait variation, although if students bring in human examples on their own, that is OK.

***Attending to Equity**
Universal Design for Learning: A key element of the Anchoring Phenomenon routine is inviting students to share their experiences with related phenomena. Connecting the anchoring phenomenon more concretely to their world can help it be more personally meaningful to each student, supporting their *engagement* with it and increasing their investment in figuring out the broader question of how living things get variations in their traits.

9. Share related phenomena. 13 MIN

Materials: science notebook, artifacts or photos collected from self-documentation home learning (optional), chart paper, markers

Share related phenomena examples. Display **slide U**. Invite students to share the examples they listed in their science notebook during the previous class and to show and tell about any photos or other artifacts and ideas they collected during the home learning. Accept all student responses, as long as they are related to differences among living things, and try to draw out a wide variety of related phenomena. Keep a public record (on chart paper or in

digital form) of the related phenomena to revisit later in the unit. You may also have students add their classmates' ideas to their own list of related phenomena in their science notebook.

Suggested prompts	Sample student responses
What other examples have you seen of living things that are basically similar but have a range of different variations in a characteristic or trait? *In your example, try to identify the trait and variations for us so we can practice using those words.*	*My dog looks very different from my neighbor's dog, and both of them look very different from another dog we know down the block. One trait could be their types of fur—the variations are that my dog is super fluffy, my neighbor's dog has tight-curly fur, and the other has flat, short fur.* *I thought about the trait of height in the flowers outside school, and the variations could be tall, medium, and short, but it's a range—it's not like every tall flower is the same exact height and every short flower is the same height either.* *When I have grapes at lunch, they're all the same reddish color, but my friend likes green grapes, and I've seen really dark purple grapes at the grocery store. So those are three variations of the trait of color of grapes.*

10. Generate initial questions.

5 MIN

Materials: science notebook, several 3x3 sticky notes, dark-colored marker

Generate questions about living things having differences even though they also seem the same. Direct students to consider all these related phenomena we just listed along with all the work we did on our initial models and with our Notice and Wonder chart (be sure these are within view). Remind students that they've been jotting ideas in their notebook these past few days, too.



Say, *So we have been thinking about all this variety among living things. Let's get ready to pool together and organize what we've been wondering. Let's take some time to write our questions so they'll be clear to others when we start building our Driving Question Board. Look back at the questions you have in your Notice and Wonder chart and those that you recorded during our modeling as well as those that you had when we looked at variations in cattle and tulips, as well.*

Display **slide V** and review instructions for writing questions on sticky notes:*

- Write one question per sticky note.
- Write in marker—big and bold.
- Put your initials in pencil on the back.

***Attending to Equity**
Supporting Emergent Multilingual Students: Asking questions in everyday language allows students to share their thinking or experiences even if they do not have the appropriate scientific vocabulary yet. This is helpful for emergent multilingual students because by not requiring scientific words at the onset you do not limit their participation in classroom discourse.

Assessment Opportunity

Building towards: 1.B Ask questions that arise from careful observation of pictures of animals with different musculature to seek information about what causes these variations in populations.

What to look and listen for: Look for "how" or "why" questions about phenomena that seek to investigate possible causes for not just these extra-big muscles but the variety of features found within living things that are otherwise generally the same.

What to do: If a student struggles with sharing, encourage them to go public with a question(s) rather than focusing specifically on forming a "how" or "why" question. Make note of any close-ended questions and use navigation time throughout the unit to have your students practice turning these kinds of questions into openended questions when they relate to the investigations underway.

If students do not ask questions at this point, remind them that questions can be added to the DQB at any point in the unit. We recommend always having sticky notes or index cards on hand to capture students' evolving questions as the unit goes on.

11. Create our Driving Question Board.

17 MIN

Materials: chart paper, markers

Begin constructing the DQB. Display **slide W**. Say, *We have a lot of really good questions about these phenomena. It is important that we hear everybody's questions, and we might find that we have questions similar to some of our classmates' questions. We are going to create a Driving Question Board to help us group and organize our questions so they can help guide our investigations into what is going on with these extra-big muscles and other differences in living things. The Driving Question Board will help us keep track of what we want to figure out.*

Gather students in a Scientists Circle and direct them to bring their questions with them. Instruct students to share their questions, one by one, with the whole group. Explain to students how you will create the DQB:

- The first student reads his or her question aloud to the class, then posts it on the DQB.
- Other students raise their hand if they have a question that relates to the question that was just read aloud.
- The first student selects the next student whose hand is raised.
- The second student reads his or her question, says why or how it relates, and posts it near the question it most relates to on the DQB.
- That student selects the next student.
- Continue until everyone has at least one question on the DQB.
- If the question doesn't fit with any questions that are already on the board, students should create a new cluster.

Sample student questions are listed below under the categories that some classes have used:*

- Diet and routines
  - Did those big-muscled animals exercise or work out?
  - Do those big-muscled cattle eat special or different foods than typical cattle?
  - Did those big-muscled animals take steroids?
  - Can chemicals make animals "mutants" (like superheros)?
  - How does having such big muscles affect those animals?

***Attending to Equity**
The first priority during the formation of the DQB is reinforcing a classroom community wherein all ideas are valued. As such, everyone should have a question on the board. Use your judgement on how to press students to form "how" and "why" questions. If a student struggles with sharing, encourage him or her to go public with their question as it is rather than focusing specifically on forming a "how" or "why" question.

- Variation
  - Why don't all cattle have big muscles?
  - How often do cattle have these extra-big muscles?
  - Do these cattle give people better meat or milk?
  - How did those tulips get so many different colors, patterns, and petal shapes?
  - Why do animals of the same kind (like dogs or cattle or squirrels) look different?
  - What causes the variation in living things' shapes, sizes, and/or colors?
  - Can humans control the variations we're seeing, like those muscles?
- Family
  - Did those animals' parents have extra-big muscles, too?
  - Are those cattle born with extra-big muscles?
  - How can things like big muscles or height or hair color "run" in a family?
  - Do genes or DNA or chromosomes have something to do with those extra-big muscles or other variations?
  - Why do some people inherit more or different traits than other members of their family?

Additional Guidance

If a student uses the word "diet" in their question(s), ask the student to clarify whether they mean it as describing the types of food an animal eats or restricting calories for weight loss. In Lesson 3, students will investigate the impacts of diet and exercise on muscle development, so you will also have a chance to clarify that in that case, "diet" means the types of foods an animal eats.

Label the questions. After all students have shared their questions, you will have several different clusters of questions on the DQB. As a class, decide on "umbrella" questions or topics for the clusters of questions and label them. Then, if you haven't already done so, draw students' attention to the scope of all the "umbrella" questions to topics that seem related to figuring out how organisms get all these differences. Propose and post this question at the top of the DQB as the driving question for all the subquestions under it: "Why are living things different from one another?"

12. Consider ideas for investigation.

10 MIN

Materials: science notebook, chart paper, markers

Generate ideas for investigation. Display **slide X**. Say, *We have so many ideas to explore! How could we start to investigate the answers to some of these questions? Make a chart in your science notebook with the title "Ideas for Future Investigations and Data We Need". Take a few minutes to write your thoughts about how we might be able to try to answer some of the questions we have on our Driving Question Board.*

Have students generate ideas in their science notebook individually for 2 minutes. Meanwhile, title chart paper with "Ideas for Future Investigations and Data We Need".

Share ideas for investigations. Display **slide Y**. Direct students to turn and talk with a neighbor to share one or two of their ideas. After a moment of partner talk, ask student pairs to share one idea with the whole class. As each pair contributes an idea, record it on the Ideas for Future Investigations and Data We Need chart for the whole class to keep as a reference. The goal is to hear a variety of ideas that we may be able to investigate over the course of the whole unit.

See the example Ideas for Future Investigations and Data We Need chart shown here.



Additional Guidance

This list of ideas for investigations will be revisited throughout the unit just like the DQB. When a future lesson involves an investigation like one the class suggested, take time to point that out. For example, in Lesson 3, students will investigate what these cattle (and typical cattle) eat and do for exercise. If your students suggest ideas that are not planned in the unit but that you feel would be productive to pursue, use your discretion and your knowledge of the storyline to decide where these additional investigations would best fit so the unit's punchlines continue to build on one another.

Say, *We have so many great ideas to investigate! We're curious about variations in a lot of living things, but we seem especially interested in how animals like those cattle got their extra-big muscles, so let's start there and see if what we figure out about that can help us make progress on understanding other variations, too.*

ADDITIONAL LESSON 1 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-Literacy.SL.8.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.

If students are reluctant to participate in whole-group discussions, check in with them during partner or small-group work time to be sure they feel prepared with ideas to share. If you find students struggling to engage with the ideas of others during discussion, revisit your classroom norms and consider posting sentence stems to support how students respond to each other during discussions.

LESSON 2

How do extra-big muscles compare to typical ones up close?

Previous Lesson

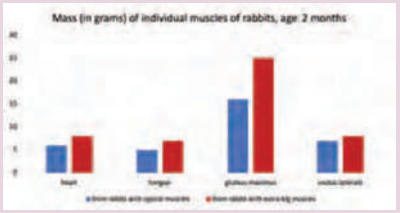
We observed a bull and other animals that have extra-big muscles. We developed initial models to explain what could be causing this phenomenon, and we identified variations in traits other than musculature in different organisms. After listing related phenomena, we developed a Driving Question Board and ideas for future investigations.

This Lesson

Investigation

1 DAY





Data Source: Lv, Q. et al. (2016). https://doi.org/10.1038/srep25029

In this lesson, we observe images of muscle tissue, video animations of muscle movement, and images of protein models with captions to figure out how muscles work. Once we understand that muscles have specific cell and protein structures to allow them to do the job of moving, we compare photos of muscle cells and graphs of muscle cell data from extra-big-muscled animals to typical ones. We discover that bigger muscles have more cells, more area, and more mass.

Next Lesson

We will evaluate information in text, images, graphs, and charts in order to determine the effect of diet and exercise on muscle growth. We will discover that exercise and a diet containing protein are essential to building larger muscles. Exercise causes microtears in muscle tissue. Muscle growth is caused by new cells being produced to repair the microtears, and protein is needed to build those cells.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5



What Students Will Do

2.A Obtain, evaluate, and communicate information about muscles in various media and visual displays, including models of complex protein structures, to describe (1) how the function of those proteins depends on their shape and (2) how the muscle cells of extra-big-muscled animals compare with those of typical animals.

What Students Will Figure Out

- Proteins are important structures in the body made of atoms.
- Muscles are composed of bundles of cells, which are made up of smaller strands.
- Muscles move by shortening (contracting) and lengthening (relaxing) these strands.
- Muscle cells contain specific proteins called actin and myosin, which help the muscles do the job of moving by grabbing onto each other and pulling so the muscle fibers contract.

- Extra-big muscles have more muscle cells than typical ones, and those cells are larger in area, as well.
- Extra-big muscles have more mass than typical muscles.

Lesson 2 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**OBSERVE AND DISCUSS MUSCLES** Feel muscles (through our own skin), observe photos of muscles, and discuss how muscle tissue can be described.	A-B	classroom consensus model from Lesson 1
2	15 min	**WATCH A VIDEO AND READ AN ARTICLE ABOUT HOW MUSCLES WORK** Discuss muscle structures after watching animations that zoom in from muscle tissue to individual cell strands. Read and discuss an article about how the proteins myosin and actin function to move muscles.	C-I	*Muscle Protein Questions*, *How Muscles Contract*, muscle contraction video at 8.5 Lesson 2 Muscle Contraction. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) 1 half sheet of paper, markers
3	5 min	**BEGIN PROGRESS TRACKERS** Students set up and use a Progress Tracker in their science notebooks to record what they have figured out so far about muscles.	J	
4	8 min	**GALLERY WALK TO COMPARE LARGE AND SMALL MUSCLE CELL IMAGES** Integrate information from photos and data sets to compare the cells in typical muscle tissue to cells in extra-big muscled ones.	K	*Comparing Muscles Gallery Walk Data* (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**), timer
5	7 min	**HOLD A BUILDING UNDERSTANDINGS DISCUSSION ABOUT MUSCLE COMPARISON** Share findings from the gallery walk in a Building Understandings Discussion.	L	*Comparing Muscles Gallery Walk Data*
6	5 min	**REVISE INITIAL MODELS INDIVIDUALLY** Complete a model independently to show today's new learning about how big muscles compare to typical ones.	M-N	*Model Update*, transparent tape

End of day 1

Lesson 2 • Materials List

	per student	per group	per class
Lesson materials Student Procedure Guide  Student Work Pages 	• *Muscle Protein Questions* • *How Muscles Contract* • science notebook • *Model Update*		• classroom consensus model from Lesson 1 • muscle contraction video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • 1 half sheet of paper • markers • *Comparing Muscles Gallery Walk Data* • timer • transparent tape

Materials preparation (20 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare the handouts:

- Make 1 copy each of *Muscle Protein Questions* and *Model Update* for each student.
- Make 1 color copy of *How Muscles Contract* for each student or have it available in the Student Edition.
- Trim *Model Update* to fit into students' science notebooks.

Have transparent tape available for students to attach *Model Update* to their science notebook.

Be sure the muscle contraction video plays correctly. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Have a half-sheet of copy paper ready to add the word *protein* to the Word Wall. Do not post this word on the wall until your class is discussing it, beginning with what they know from *Unit 7.3: How do things inside our bodies work together to make us feel the way we do? (Inside Our Bodies Unit)* and then adding examples (myosin and actin) from this lesson.

Gather the color copies of *Comparing Muscles Gallery Walk Data* from your materials kit. Or, if you do not have premade data sheets from the materials kit, prepare them as follows:

- Print a color copy on cardstock of all 8 pages of *Comparing Muscles Gallery Walk Data*. (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)
- Consider laminating these data sheets since you will reuse them for each class you teach and can keep them year to year.

Comparing Muscles Gallery Walk Data contains 2 copies each of four unique data sets. When these are posted around the classroom, there will be eight stations. Post the data sets either facedown on tables or counters where students won't be sitting or taped on the wall with the blank side facing out (or wait to have students help post them at the beginning of the gallery walk). The pages should be spread out so students do not have to huddle together to see them clearly.

Lesson 2 • Where We Are Going and NOT Going

Where We Are Going

In their initial models, students had to think about what different-sized muscles would look like up close. There were competing ideas—whether larger muscles were made up of more cells or were just larger cells of the same kind. Students will figure out the answer to that question in this lesson. Moreover, it is important for students to understand during this lesson the structure and function of proteins in muscles so they can build on that knowledge in upcoming lessons about exercise (Lesson 3) and how the myostatin protein can affect muscle size (Lesson 6).

Proteins will play an important role in this unit. In this lesson, students will reflect on what they already know about proteins, that they are important for our bodies and we get them from the food we eat. Students will then start to see specific examples of proteins, actin and myosin, that show that their structure is directly related to their function. At this point we do not have enough evidence to generalize the structure-function relationship to all proteins. Students will be able to generalize this idea when they look at another protein called myostatin as they learn in Lesson 6 the gene-to-protein relationship for extra-big muscles.

Students might have the partial understanding that large muscles are made by having bigger muscle cells or just more muscle cells. In this lesson students will build on these partial understandings, and they will have evidence that both of these causes are true. Larger muscles have more counts of cells and more mass, and the area of those cells is also larger.

At the beginning of this lesson, students connect observations of their own muscles to what they recall about muscle cells and body systems from *Unit 6.6: How do living things heal? (Healing Unit)*. If your students have not experienced these units, they will still be able to make productive observations of muscles in this lesson.

Later in this lesson, students also reference ideas they built about proteins in *Unit 7.3: How do things inside our bodies work together to make us feel the way we do? (Inside Our Bodies Unit)* and *Unit 7.4: Where does food come from, and where does it go next? (Maple Syrup Unit)*.

Where We Are NOT Going

The video, handout, and discussion of muscle structure and function, even at the protein level, have deliberately simplified the sliding filament theory of muscle contraction. Many specific terms (e.g., sarcomeres, t-tubules) have been left out, as well as the chemical processes involved (e.g., the roles of calcium or ATP). We want the students to learn enough about muscles that they can explain our anchoring phenomenon and understand the structure-function relationship of proteins but not spend so much time on muscle anatomy and movement that it detracts from the unit's focus on genetics.

The images and data in the gallery walk do compare muscles of typical animals to those with the MSTN gene mutation. However, this lesson does not yet introduce the myostatin protein or its role in muscle size, so the MSTN-mutant animals are still simply referred to as having "extra-big" muscles. Students will discover in Lesson 6 that the nonfunctional myostatin protein results in these extra-big muscles, which is how animals with this version of the myostatin allele have much larger muscles without having to exercise more than typical cattle.

LEARNING PLAN FOR LESSON 2

1. Observe and discuss muscles.

5 MIN

Materials: classroom consensus model from Lesson 1

Briefly navigate into today's work. Display **slide A**. Say, *In the previous class we came up with great questions and ideas to investigate! We worked on connecting our questions together, and we thought we might start by trying to figure out how those animals got such big muscles. We already have some ideas about muscles, but we were uncertain about what we would see if we zoomed in on the muscles of extra-big versus the more-typical individuals.* Refer to the classroom consensus model.

Suggested prompts	Sample student responses
If we could resolve that area of uncertainty by starting with an investigation into what these muscles look like up close, how would this help us make progress on our other questions?	*We will clarify the uncertainty we had in our initial models about what those cells look like.* *Figuring out what causes muscle cell differences might be closely related to what causes differences in other trait variations in other organisms, so starting with looking for muscle cell differences could be productive.*
Why might zooming in on the muscles be a productive place to start?	*We need to compare extra-big and typical muscles to establish what is different about them, then we can figure out what causes those differences.*

Say, *Let's start with considering the muscles we have on our own bodies since they're right here with us! After that, we can zoom into other animals that have those extra-big muscles. What are our muscles like?*

Feel our own muscles in our lower arms and necks. Say, *Use one hand to feel along your other arm between your wrist and elbow.* Demonstrate on your own arm.

Suggested prompts	Sample student responses
What do you think you're feeling there on your arm that might be muscle under the skin?	*Well it's not the thin skin on top, and it's not the hard bone inside … somewhere in the middle … I can feel it moving when I wiggle my fingers.*
What is that muscle even doing there in your arm when you move your arm back and forth?	*It moves! I can move my arm around because of that muscle.* *It feels tighter when I make a fist.* *The bones and muscles work together to move your arm, like we saw with the chicken wing in the Healing Unit.*

***Attending to Equity**

Students might bring up the fact that the meat people eat is muscle from animals. Leverage students' connection to meat by asking them to consider how that could help us in today's work. Does a description of meat line up with the other descriptions we're making of muscles? Be mindful of the fact that some of your students may be vegetarian, vegan, or otherwise sensitive about animal rights, and as such, discussions about this topic may be difficult for them. Remind the class to be respectful of one another's ideas, and be sure the discussion continues to focus on moving our science thinking forward.

Suggested prompt	Sample student responses
How would you describe any changes in the texture or shape of that muscle tissue as you feel along its entire length?	*The part I think is a muscle feels tight or stiff, like not as squishy or easy to push around as my skin is.* *The part I think is a muscle seems thinner in some places (closer to my wrist) and thicker in others (closer to my elbow).* *I think it's long, like it's connecting things.*

Say, *Now put your hand gently along the side of your neck, where it connects to your shoulder. Try to feel muscle there, too.* Demonstrate on the side of your own neck.

Suggested prompts	Sample student responses
What feels the same or different about your neck muscles compared to what you felt in your arm?	*I can't feel the bone as easily as I could in my arm.*
Do those neck muscles work the same way as you noticed your arm muscles working?	*Pretty much … they move, too! They help me move my head.* *I can feel them pulling tighter between my neck and shoulder when I raise my arm up.*
How would you describe the texture or shape of that muscle tissue?	*It feels like ridges, like there are tight bands connected in there.*

Talk briefly with a partner about muscles. Display **slide B**. Say, *OK, so we've been able to describe how our muscles feel. Let's consider what they look like. In the Healing Unit, we looked at different types of cells, including muscle cells. Let's take a look at these microscope images of muscle cells again to help connect to the ideas we had as we felt our muscles. Turn to a neighbor and describe what you notice about the structure of these muscle cells and how that might connect to what we observed when we felt our muscles moving.*

Additional Guidance

As needed, remind the class that the muscle tissue samples like these came from people who willingly underwent a procedure called a biopsy to remove them for study. In a biopsy, doctors cut very thin and small slices of tissue from a patient and observe it under a microscope to try to discover the presence or extent of a disease.

Share briefly what we've noticed about muscles. Bring the discussion back to the whole group so a few students can share what we've figured out and what we're wondering now.*

Suggested prompts	Sample student responses	Follow-up questions
What did your neighbor say about how the muscle cells look?	*My neighbor thought they looked striped.* *… stringy* *… like bunches of red and white ropes (or cords or cables) all pulled in the same direction*	*Can you say more about this?* *Who can add on to this idea?*
What could we do next to help us better understand the structure of these muscles?	*We want to see how these things work. What do muscles look like when they are moving?*	*How would doing that help us move our science thinking forward?*
What do you think we would see if we could watch muscles moving close-up? *Do you know anything about how muscles contract or cause your body to move?*	*I think they're stretchy like rubber bands.* *I think the cells will get short and thick when they contract and long and thin when they relax.*	*What do you think these cells might look like when they move?*

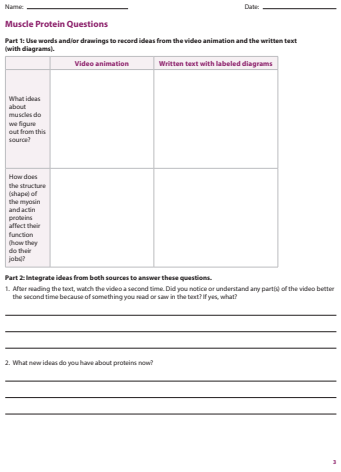
2. Watch a video and read an article about how muscles work.

15 MIN

Materials: *Muscle Protein Questions*, *How Muscles Contract*, muscle contraction video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), 1 half sheet of paper, markers

Watch a video of muscle animations. Say, *Let's zoom in even further to find out what is happening when muscles contract. I have a video of animations and an article that I think can help us figure out what's inside any muscles that allows them to move. Let's watch the video with the animations first and record what we figure out.*

Display **slide C** and distribute *Muscle Protein Questions*. Have students fill out the "Video animation" column on the chart in part 1 as they watch the video. Play the muscle contraction video. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), which includes some narration explaining the organization of muscle cells and what's happening when the muscles contract across different scales.



Name: _____ Date: _____

Muscle Protein Questions

Part 1: Use words and/or drawings to record ideas from the video animation and the written text (with diagrams).

	Video animation	Written text with labeled diagrams
What ideas about muscles do we figure out from this source?		
How does the structure (shape) of the myosin and actin proteins affect their function (how they do their jobs)?		

Part 2: Integrate ideas from both sources to answer these questions.

1. After reading the text, watch the video a second time. Did you notice or understand any part(s) of the video better the second time because of something you read or saw in the text? If yes, what?

2. What new ideas do you have about proteins now?

***Supporting Students in Engaging in Obtaining, Evaluating, and Communicating Information**

Having students watch the video a second time after reading an article will help them see how they are actively integrating multiple sources, highlighting for students ideas they may have missed by using only one source. The repetition of this detailed scientific information in various media is intended to help students clarify their understandings about how muscle structures function as well as give them an opportunity to evaluate the advantages of using various sources.

Additional Guidance

If you have extra time, play the video twice before discussing the video. The first time, play the video with the sound off so that students can focus on the different structures within muscles and see what these structures are doing as muscles contract. The second time, play the video with the sound on so that students are able to connect some of the things they observed with some of the additional details found in the narration.

Discuss take-aways from the video in an Initial Ideas Discussion. Display **slide D**.

Key Ideas

Purpose of this discussion: Summarize as a whole group the main ideas about muscle structure and function that we learned from the video.

Listen for these ideas:

- Muscles are composed of bundles of cells.
- Each muscle cell is long and made up of smaller strands.
- Muscles move by contracting and relaxing these strands.
- Muscle cells have important structures that allow for muscle contraction—myosin and actin (students may or may not be able to retell at this point how, exactly, these proteins work).

Suggested prompts	Sample student responses
What did you see or hear in the video that was something you expected or something that was familiar to you?	*The muscles are bundles of strands, like ropes or strings, like we said from the earlier image.* *It makes sense that the muscles contract and relax—we use these words all the time to describe our movements.*
What information was new or surprising to you from the video?	*The bundles of ropes (strands) keep getting smaller and thinner—it's bundles of bundles of bundles!* *I have never before heard some of those words, like myosin and actin.*
We wanted to learn from this video about what's inside muscles when we zoom in. What makes muscles move? What can you summarize about what's inside muscles to make them move?	*Muscle cell strands are like strings that can contract and relax.* *There are parts in the muscle that slide by other parts of the muscle.* *All the strands contract or relax together.*

Synthesize information from videos, images, and text. Display **slide E**. Say, *It seems like we need to understand more about the structures of these muscle parts and how they work. So I also have an article that includes still images and captions about this same topic. Work through it, and then we'll take some time to connect the ideas we watched in the video to the ideas we read in the article.*

*Supporting Students in Developing and Using Structure and Function

Using multiple sources, the video animations as well as the reading with labeled diagrams, provides multiple representations of the proteins actin and myosin during muscle contraction. Looking at the commonalities between these representations should help students focus on the actual properties of these proteins rather than the creative differences between individual models. This way students can accurately describe and discuss how the proteins' function is related to their structure. As students discuss the structure-function relationship, encourage the students to use gestures or objects to help them visualize and explain the structures that work to make our muscles move. See the "Where We Are *Not* Going" section at the beginning of this *Teacher Guide* for more information.

Distribute *How Muscles Contract* and give students about 7 minutes to work on filling out the last column on the chart in part 1 of *Muscle Protein Questions*.

Say, *When gathering information, we sometimes miss things because our knowledge changes as we continue to research. This can cause us to miss ideas from some of our initial sources that we would not have missed if we had looked at it later in our research. At this point, we first watched a video then we read an article. Let's return to the video one last time to see if there are new ideas and details we can gain by connecting what we figured out from the article.*

Play the muscle contraction video. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Then have students individually fill out part 2 and part 3 of *Muscle Protein Questions*.*



Assessment Opportunity

Building towards: 2.A.1 Obtain, evaluate, and communicate information about muscles in various media and visual displays, including models of complex protein structures, to describe how the function of those proteins depends on their shape.

What to look and listen for: See *Key for Muscle Protein Questions* for sample student responses. In general, look for responses that articulate how students' understanding improved from initially watching the video animations to watching the video animations a second time after reading printed text with labeled diagrams, specifically in regard to how integrating these different sources of information helped them understand the structure and function of the muscle cells and proteins.

What to do: If students are struggling to integrate information from different media, guide them to highlight using different colors their summary statement (in part 2) about how muscles contract. Highlight one color for ideas that came only from watching the video. Highlight with another color for ideas that came only from the article, then highlight in a third color ideas that were found in both. Students should see all three colors in their summary, showing them how they had to integrate multiple sources to deepen their understanding.

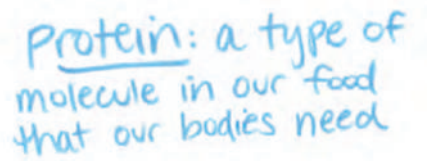
Discuss proteins, specifically the structure and function of myosin and actin, in a Building Understandings Discussion. Say, *When trying to figure out how muscles work, I noticed there was a lot of information about different types of proteins that are important for muscle contraction. Proteins aren't new to us. We figured out some ideas about proteins in Inside Our Bodies Unit and Maple Syrup Unit. Let's pause to take stock of what we already know about protein.*

Suggested prompt	Sample student response
What do you know about protein?	*Our body needs protein and gets it from the food we eat. It is in meat and in some plants, too.*

Say, *Let's pause to look at a little more data about protein to help us understand why protein might be so important to our bodies.* Display **slide F** and give students a minute to see the protein data on the slide.

Suggested prompts	Sample student responses	Follow-up questions
What are some new ideas about protein we see from looking at this graph?	*Our body needs protein and gets it from the food we eat.* *Both plants and animals have a lot of protein in them.*	
Why do we need protein?	*to help us build the muscles in our body* *We are not sure … to help our muscles move?* *We don't know.*	*What do proteins do?* *Plants don't have the same structures as humans, like muscles. Why do they need protein?*

Say, *The graph shows that our muscles are over eighty percent protein. In the Inside Our Bodies Unit we started capturing ideas about what proteins are, but it seems that in this unit we want to know more about what these proteins do inside our body. Let's add "protein" to our Word Wall with what we know already from the Inside Our Bodies Unit. As we learn more we can update it.*



Add *protein* to the Word Wall as seen in the image here.

Say, *Now let's talk about what we figured out from the video and the article.* Display **slides G-I** of images from the video and *How Muscles Contract* to support the summary of key ideas in the discussion.*

Key Ideas

Purpose of this discussion: Synthesize the main ideas about the structure and function of muscles, specifically the proteins actin and myosin that we learned about from the video, reference document images, and captions.

Listen for these ideas:

- Proteins are important structures made of atoms.
- Each muscle cell is long and made up of smaller strands.
- Muscles move by contracting and relaxing these strands.
- Muscle cells are rich in protein.
- Specific proteins called actin and myosin help muscles do the job of moving by grabbing onto each other and pulling so the muscle fiber gets shorter (contracts) and when they let go, the muscle fiber relaxes and is longer again.

- Are proteins found only in muscles, or do they have jobs in other parts of the body, too?

Suggested prompts	Sample student responses
In both of these resources we zoomed in on muscles so that we could look closer at muscle protein. We noticed that some protein seems really important in muscle contraction. How do the structures, the shapes, of these proteins involved in muscle contraction help them function and do their jobs?	*The actin has that stringy shape, and the myosin is like a thicker string but with all those bumpy head parts woven together.* *Myosin's heads grab on and exert a force or pull the actin to make the whole strand contract.* *Lots of these bundles of strands contracting together pulls the muscle tighter so you can move.*
Describe or summarize how muscles contract that leads to the body moving.	*The brain sends a signal that causes the myosin heads to start pulling on the actin, causing the strand to shorten and contract. Multiple strands contracting at the same time cause the muscle cell to contract. Multiple muscle cells contracting at the same time causes the whole muscle to contract, causing the body to move.*
As we have been working to understand muscles and how they function, what are some advantages of using multiple sources to help you deepen your understanding of this information?	*The video went really fast through the information, so having an article helped me connect the science ideas in the article to what I was observing in the video.* *The video was able to help us visualize what was happening when the proteins and filaments move, and the article was able to help explain in more detail how and why they were able to move this way.*
What ideas would we have missed about muscles and how they function if we looked at only one source?	*The video was important because it really helped us visualize and connect what was happening both within the cell and when the arm was contracting.* *The article was important because it gave us a lot more information about what was happening with the different proteins during contraction.*

Update the Word Wall card for "protein" to include the examples of proteins found in our body: actin and myosin. You may choose to include simple illustrations of these proteins to support students' understanding of how a protein's shape relates to its function.



3. Begin Progress Trackers.

5 MIN

Materials: science notebook

Begin Progress Trackers in science notebooks. Direct students to draw directly in their science notebook a T-chart as indicated on **slide J**. Explain that as we investigate what is going on with these cattle and their muscles, we are going to keep track of our new ideas and how our model changes and develops over time. To do this, we are going to use a Progress Tracker.

Science Notebook

If you haven't already, direct students to set aside 10-15 pages at the end of their notebook to use for the Progress Tracker.

Tell students, *This is a tool designed to help us keep track of ideas we figure out from each lesson. In the "What I figured out" column you can draw pictures or describe in words, with bullet points, or whatever way is most meaningful for you. Individually, take three minutes to think and record what you figured out today, using any of the work we did during today's class.*

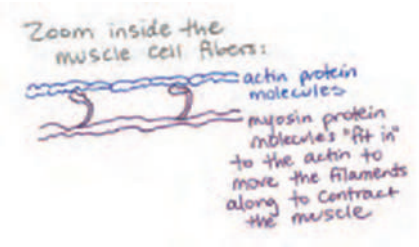
Have students individually write in their Progress Trackers what they have figured out so far about how muscles work.

Assessment Opportunity

The Progress Tracker can be a valuable tool for formative assessment, giving you a clear picture of students' thinking and allowing you to direct your instruction accordingly. However, Progress Tracker entries should not be scored or graded because doing so would invalidate their purpose—to be a safe space for students to process and record their thoughts honestly and without worry about evaluation.

Since this T-chart is a loose structure, students can take up a lot of space or a little space for each entry in their Progress Tracker. When students complete their thinking for today, they can draw a line below their work to delineate space for the next time they are instructed to write in their Tracker.*

In the example two-column Progress Tracker row for this lesson, each column has been completed with ***possible*** student ideas.

Question	What I figured out in words/pictures
What do muscles look like up close?	• Muscle cells are structured to do the job of contracting and relaxing so the muscles can move. • Muscle cells are rich in protein. • Actin and myosin are proteins that help the muscles do the job of moving by grabbing onto each other and pulling. 

***Attending to Equity**
This Tracker serves as teacher guidance for what students might say at various points throughout the unit. However, some students may write or draw more and others may say less. It is important that what the students write in the Progress Tracker reflects their own thinking at that particular moment in time.

4. Gallery walk to compare large and small muscle cell images. 8 MIN

Materials: science notebook, *Comparing Muscles Gallery Walk Data*, timer

Introduce the gallery walk of muscle cell images and data. Display **slide K.**

Say, *OK, so we have figured out that muscle cells are these bundles of fibers that can contract and relax. The fibers have these proteins in them called myosin and actin that have specific shapes so they can grab on and push along to make the muscle move. So that's how muscles work, but we still have some more figuring out to do.*

Suggested prompt	Sample student responses
I know we said we also wanted to look at the cells in the tissue of animals with extra-big muscles and of animals with typical muscles. But remind us, why did we decide we wanted to do this?	*We want to compare them to see what makes big muscles actually bigger.* *We want to see if the predictions we made in our initial models are correct!*

Say, *OK, so I do have some photos taken through a microscope of cross sections of muscle fibers from animals that have extra-big muscles, and we can compare them to images of muscles in typical animals. But while I was looking at the images, I saw that the scientists also shared some other cool data: they used box plots and a bar graph to summarize measurements they took from these samples. So we can also use these data sources to compare the muscles. We have four different sources of information—images and graphs—around the room for you to go investigate. There are two copies of each source so you can spread out and be able to see clearly. You won't go to every station. The sources are numbered one through four, so you just have to be sure to stop and look at all four different sources. You have about seven minutes to gallery walk around the room and interpret these data. Take notes in your notebook about what you notice so you'll be ready to share your thinking with the class.*

Additional Guidance

Students have already used cross-sectional images in the *Healing Unit* and *Unit 6.4: What causes Earth's surface to change? (Everest Unit)*. In the *Healing Unit* when students observed muscle cell tissue with microscopes, they looked at a longitudinal section. If students need help in this lesson making sense of what they're seeing in microscope images of cross sections of muscles, go back to the image on **slide G** as a guide to help make sense of what we're looking at.

Direct students to make a table in their science notebook as seen on **slide K** and instruct them to begin the gallery walk.* Set the timer for 7 minutes.

Additional Guidance

Post or spread out the gallery walk pages so that students aren't all clustered in one area. A gallery walk is not a move-on-a-timer activity; rather, students move from one page to the next at their own pace and in any order.

***Supporting Students in Engaging in Obtaining, Evaluating, and Communicating Information**

If students are struggling to integrate the quantitative scientific information from the graphs with the visual images of cell structures they encountered in the gallery walk, consider focusing on just the cell images and box plots of cell count from the catfish. Ask, *If you were this scientist comparing these two muscle samples, what could you do to show how different they are?* Elicit that we could count the cells in the sample to prove that there are more in one than in the other.

Discuss what the box plot shows: *Did the scientist count only the cells in this one sample?* Elicit an answer of "No, they must have used several samples because their data include a median, maximum, and so forth."

5. Hold a Building Understanding Discussion about muscle comparison. 7 MIN

Materials: science notebook, *Comparing Muscles Gallery Walk Data*

Share key take-aways from the gallery walk. When your timer goes off to signal the end of the gallery walk, have students go back to their seats. Display **slide L** and lead a Building Understandings Discussion about how extra-big muscles compare to typical ones. Prompt students to share the evidence they found to support their ideas.



Key Ideas

Purpose of this discussion: Share our findings and evidence about how extra-big muscle cells compare to typical muscle cells.

Listen for these ideas:

- Extra-big muscles have more muscle cells than typical ones (in the same amount of space).
- The area of the muscle fibers is larger in extra-big muscles (cells that are thicker or larger).
- Extra-big muscles have more mass than typical muscles.

Suggested prompts	Sample student responses
What did you discover about how the cells of extra-muscled animals compare to typical animals' muscle cells? *What evidence did you find to support your idea?*	*The extra-muscled animals have more cells in their muscle tissue.* • *The graph of catfish cells shows around 800 cells in the extra-muscled sample and around 600 in the typical sample.* • *The image of the extra-muscled catfish cells looks more crowded. I didn't count them, but you could estimate that there are more cells than in the typical cells image.* *The extra-muscled animals' cells are bigger.* • *The graph of the catfish cells shows they have a greater total area.* • *The images of the rabbit cells are definitely bigger, like thicker or wider, in the extra-muscled one than the typical one.* *The bigger muscles have more mass: the rabbit graph compares four different muscles, and all of them have more mass in the extra-muscled animals.*

Assessment Opportunity

Building towards: 2.A.3 Obtain, evaluate, and communicate information about muscles in various media and visual displays, including models of complex protein structures, to describe how the muscle cells of extra-muscled animals compare with those of typical animals.

What to look and listen for: During this discussion, listen for

- students who can integrate information to describe differences between the extra-big and typical muscle tissue photos and graphs,
- students connecting ideas from the different sources to make general claims about organisms that have typical muscles in comparison to organisms that have extra-big muscles, and
- comments that synthesize the information from the various media in this lesson to explain the structure and function of muscle cells and proteins.

What to do: If students struggle to synthesize information from the data they saw in the gallery walk, leverage the data from the graphs and images that they can use as evidence for how extra-big muscles compare to typical ones. As a class or small group, look back at each individual image set or graph and summarize what it shows. Then work as a class to put those data to use as evidence to support their claims about muscles.

6. Revise initial models individually. 5 MIN

Materials: *Model Update*, science notebook, transparent tape

Revise our initial models to check in about today's learning. Display **slide M**.

Say, *We investigated how big-muscle tissue compares to typical-muscle tissue because that was a place where we had some competing ideas in our initial model. So, now that we discovered some answers, let's take some time to update those models. Since erasing or drawing on top your first model could get messy, I have a new copy here for you to use. Also, your work on this handout will help you capture and identify what questions our class should answer next. After you finish updating your model, add it to your science notebook.*

Distribute *Model Update* and have students tape it into their science notebook after they complete it.

When everyone is done, discuss the handout's last question ("What question(s) are you still wondering about?") before the end of class. Display **slide N** and have students go public with their questions and discuss the other questions on the slide, as shown in these prompts.

Suggested prompts	Sample student responses
What question(s) are you still wondering about?	*What caused the extra-big muscles to develop?*
Where do you think the matter could be coming from to build these extra-big muscles?	*the food the animals eat*
What should we investigate next to keep figuring out why the cattle got these extra-big muscles?	*Do certain kinds of food help them build extra-big muscles?* *I think that exercise makes muscles bigger, too, so we should see if these animals have been working out.*

You may choose to add this model update to the initial classroom consensus model as shown in this example:



ADDITIONAL LESSON 2 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS ELA LITERACY RI.8.7 Evaluate the advantages and disadvantages of using different mediums (e.g., print or digital text, video, multimedia) to present a particular topic or idea.

Students will be working more deeply with SEP 8 to obtain, communicate, and evaluate information in this unit, so considering in this lesson how video compares to print materials when learning about muscle cell structures starts them out with evaluative thinking. If students need support finding advantages of either media type, you could prompt them to think about which seemed "easier" to understand, and then ask why.

Supporting Students in Making Connections in Math

Summarize and describe distributions.

CCSS.MATH.CONTENT.6.SP.B.4

Display numerical data in plots on a number line, including dot plots, histograms, and box plots.

Draw informal comparative inferences about two populations.

CCSS.MATH.CONTENT.7.SP.B.3

Informally assess the degree of visual overlap of two numerical data distributions with similar variabilities, measuring the difference between the centers by expressing it as a multiple of a measure of variability. *For example, the mean height of players on the basketball team is 10 cm greater than the mean height of players on the soccer team, about twice the variability (mean absolute deviation) on either team; on a dot plot, the separation between the two distributions of heights is noticeable.*

Both of these math goals are ones that students would have developed in prior grades in the Common Core State Standards. Understanding what a box plot represents should not be unfamiliar to students by the end of grade 6. Understanding how to compare data sets from two different populations should not be unfamiliar to students by the end of grade 7. Both of these skills are leveraged in this lesson in the interpretation of the two box plots from the two different sample sets taken from two different animals.

LESSON 3

How do diet and exercise affect muscle size?

Previous Lesson

We observed images and video animations to figure out that muscles have specific cell and protein structures to allow them to move. We compared photos and data about muscle cells from extra-big-muscled animals and typical ones, and we discovered that bigger muscles have more cells, more area, and more mass.

This Lesson

Investigation

1 DAY



We evaluate information in text, images, graphs, and charts in order to determine the effect of diet and exercise on muscle growth. We discover that exercise and a diet containing protein are essential to building larger muscles. Exercise causes microtears in muscle tissue. Muscle growth is caused by new cells being produced to repair the microtears, and protein is needed to build those cells.

Next Lesson

We will update our classroom consensus model and use it to attempt to explain the differences in musculature we see. We will listen to an interview with a farmer to learn more about these heavily muscled cattle.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5

What Students Will Do

3.A Obtain, evaluate, and communicate information to determine the effects of exercise and diet in the development of muscle tissue.

What Students Will Figure Out

- Exercise and diet play important roles in building muscles. Exercise has a large influence on musculature. Diet has a small influence on musculature.
- During exercise, tension on the muscle fibers leads to microtears, which interfere with actin and myosin. These tears are repaired, resulting in thicker and longer muscle fibers.
- Protein from food is required to build and maintain muscle.

Lesson 3 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Recall students' questions about how extra-big muscles could be developed and brainstorm ways they think muscle mass can be increased, including how athletes who race wheelchairs might have developed their larger arm muscles.	A-C	Ideas for Investigations and Data We Need chart from Lesson 1
2	13 min	**READ ABOUT THE ROLE OF DIET AND EXERCISE (COMBINED) IN MUSCLE GROWTH** Co-construct a checklist for students to use as they obtain and evaluate information in readings from a dubious source and credible sources on the role of diet and exercise on muscle growth.	D-I	*Organizer for Obtaining and Evaluating Information* (optional), *Version 1: How to Build Muscles*, *Version 1: Greek Yogurt + Resistance Training (Study 1)* (for half of the class), *Version 1: Carbs or Protein with Exercise (Study 2)* (for the other half of the class)
3	12 min	**READ ABOUT THE ROLES OF DIET AND EXERCISE (SEPARATELY) IN MUSCLE GROWTH** Read one of two articles (protein or exercise) to obtain and evaluate information. Understand through discussion that both diet and exercise contribute to muscle growth, but exercise has a greater effect.	E; J-L	*Version 1: Protein's Effect on Muscles* (half of class), *Version 1: Effect of Resistance Exercise on Muscles* (other half of class)
4	10 min	**CONNECT WHAT WE FIGURED OUT TO PROFESSIONAL ATHLETES AND TRANSFER UNDERSTANDING TO CATTLE** Confirm key ideas about how diet and exercise impact muscle growth by observing photos of professional tennis players, then transfer what they figured out from humans to cattle.	M-P	
5	5 min	**EXIT TICKET** Synthesize today's learning and ask questions for next time's work.	Q	*Exit Ticket - Role of Protein and Exercise in Building Muscle* *End of day 1*
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 3, students are ready to read Student Reader Collection 1 and then respond to the writing exercise.		Student Reader Collection 1: *Muscles and Other Traits*

Lesson 3 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Organizer for Obtaining and Evaluating Information* (optional) • *Version 1: How to Build Muscles* • *Version 1: Greek Yogurt + Resistance Training (Study 1)* (for half of the class) • *Version 1: Carbs or Protein with Exercise (Study 2)* (for the other half of the class) • *Version 1: Protein's Effect on Muscles* (half of class) • *Version 1: Effect of Resistance Exercise on Muscles* (other half of class) • *Exit Ticket - Role of Protein and Exercise in Building Muscle*		• Ideas for Investigations and Data We Need chart from Lesson 1

Materials preparation (20 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare the handouts:

- If you choose to use *Organizer for Obtaining and Evaluating Information*, make 1 copy for each student.
- Make 1 copy of *Exit Ticket - Role of Protein and Exercise in Building Muscle* for each student.
- Students will need to use the readings listed below during this lesson. Decide whether your students (as a whole class or individuals) will use the on-grade-level versions of the readings in this lesson (named "Version 1" in the titles) or the simplified versions (named "Version 2" in the titles). The content is the same, but the text complexity has been lowered in the simplified versions. If you do not have Student Editions which contain these readings, prepare them as follows:
  - Make 1 copy of *Version 1: How to Build Muscles* for each student. Alternatively, you could make one copy for each student in your largest class and then collect them after each use to be distributed in another class. Students will not need to reference this text in the future, so they do not need their own copies.
  - Make enough copies of *Version 1: Greek Yogurt + Resistance Training (Study 1)* for half the class.
  - Make enough copies of *Version 1: Carbs or Protein with Exercise (Study 2)* for half the class.
  - Make enough copies of *Version 1: Protein's Effect on Muscles* for half the class.
  - Make enough copies of *Version 1: Effect of Resistance Exercise on Muscles* for half the class.

Lesson 3 • Where We Are Going and NOT Going

Where We Are Going

In order for students to consider how genetic information and/or environmental factors play a role in muscle development and variation, it is important for students to understand the process by which exercise causes an increase in muscle tissue as well as how the amount of protein in the diet can affect muscle tissue growth. These understandings not only motivate their work in Lesson 4 but also help students explain in Lessons 15 and 16 how these environmental factors could indeed influence the muscle variation we see in cattle who do not have the allele that causes extra-big muscles.

In this lesson. students should come to the conclusion that while protein from food is important in building muscle and the amount of protein can have an effect on the amount of muscle being built, muscle size will not increase from consuming more protein alone. Exercise is a key factor in increasing muscle growth. In Lesson 4, students will figure out that cattle with extra-big muscles do not eat an especially protein-rich diet nor do they really do any exercise, but in fact they are born like that, which will motivate their investigations into pedigrees and inheritance patterns.

Where We Are NOT Going

The description of muscle tissue and the intricacies of muscle tissue growth have been simplified, as details such as myoblasts, satellite cells, and fibrosis are beyond the scope of this unit and not necessary to students' sensemaking at this point. The aim is only that students develop the understanding that microtears are formed as a result of exercise and the repair of these microtears is what ultimately leads to the development of larger muscles.

LEARNING PLAN FOR LESSON 3

1. Navigation

5 MIN

Materials: science notebook, Ideas for Investigations and Data We Need chart from Lesson 1

Navigate to the work in this lesson. Display **slide A**. Use prompts such as the following to navigate into today's work, directing students to look back at their Progress Tracker entries from Lesson 2, if needed.

Suggested prompts	Sample student responses
Who remembers where we ended last time?	*Last time, we figured out how muscles worked.* *We updated our initial models to show what's different between the cells of the extra-big muscled animals and the typical ones.*
What did we find out is the difference between the extra-big muscles and the typical ones? *What questions do you have about the muscle differences between the bigger muscles and the typical ones?*	*We've figured out that bigger muscles have more cells with more area.* *How did the bigger muscles get more cells?* *How do muscles actually get bigger?* *Are the animals with extra-big muscles working out more?*

Summarize for the class. Say something like, *We've figured out that bigger muscles have more cells with more area. Do we have any ideas for investigating how animals get more muscle mass?* Refer to the Ideas for Investigations and Data We Need chart and give students a minute to look at the chart. Listen for students to suggest investigating diet and exercise as ways for animals to increase their muscle mass.

Motivate the desire to investigate human muscle growth. Display **slide B**. Direct students to briefly turn and talk with a neighbor about their own experiences with building bigger muscles. After about 30 seconds, share ideas as a class.

Ask, *Do you have any personal experiences with increasing your own muscle mass? What are some ways you or other people have built bigger muscles?*

Sample student responses

- I can build muscle when I work out.
- I can build muscle when I play sports.
- I've heard that some people drink whey powder when they want to build muscle.

Consider the muscles of athletes who race wheelchairs. Display **slide C**. Say, *Here are some pictures of athletes working out. What do you notice about the muscles of these athletes' arms and legs?**

***Attending to Equity**

As you discuss the athletes pictured on **slide C**, be mindful of ability-diversity. Disabled students may experience exercise in different ways than their nondisabled peers, so it is important to welcome and honor all experiences. Listen for students who use language that may construe disability in a negative light, reminding students that individuals who are disabled adapt to their body's way of functioning and are able to complete the daily tasks of life, if a little differently. It is important that students understand that individuals with disabilities often take a great deal of pride in their disability and consider it a key part of their identity.

Sample student response: The athletes' arm muscles look very large and their leg muscles look very small. Ask, *How do you think these wheelchair athletes got such large muscles in their arms?*

Sample student responses

- They exercise those muscles a lot!
- Maybe they eat certain foods, too.

Say, *Sometimes we use a model organism to study another one, such as we did in Unit 6.6: How do living things heal? (Healing Unit) when we used a chicken wing to investigate how a human arm moves. There is a lot more information about the effects of diet and exercise on muscle mass in humans than in cattle, so let's start figuring this out with humans.*

Additional Guidance

If needed, clarify that when you use the word "diet" in this lesson, you mean the types of food a person or animal eats (not restricting calories for weight loss).

2. Read about the role of diet and exercise (combined) in muscle growth.

13 MIN

Materials: *Organizer for Obtaining and Evaluating Information* (optional), *Version 1: How to Build Muscles*, *Version 1: Greek Yogurt + Resistance Training (Study 1)* (for half of the class), *Version 1: Carbs or Protein with Exercise (Study 2)* (for the other half of the class)

Co-construct a checklist for obtaining and evaluating information.* Display **slide D**. Say, *I have an article for us called "How to Build Muscles." Before we take a look, let's think about our purpose as readers. We have practiced reading informational texts before, so what should we be looking for to see if a source is credible? What else do we need to pay attention to as we read?*

Listen for student ideas such as those listed here and record them on **slide E**.

- We want to look for the central idea or claim.
- We should consider whether the central claim makes sense with our ideas about muscle growth.
- We should look for evidence that supports the claim.
- We should pay attention to the sources the author(s) cites.
- We should think about the goal of the text.
- We should ask ourselves what methods the author(s) used to study and test their ideas and/or answer their questions.

Say something like, *Great, you can use this checklist as a reference and look for these ideas as you read the article.*

Obtain and evaluate information from a dubious source.* Display **slide F**. Distribute *Version 1: How to Build Muscles* to students or direct them to find it in their *Student Edition*.

***Supporting Students in Engaging in Obtaining, Evaluating, and Communicating Information**

This unit is one of the last units taught in 8th grade. At this point in the scope and sequence, students should be able to utilize the practice of "obtaining, evaluating, and communicating information" almost or completely independently. If this unit is taught out of sequence and/or you have students who are struggling with this practice, scaffolding may be appropriate here. Instead of co-constructing a checklist with students to guide their reading, you may want to distribute *Organizer for Obtaining and Evaluating Information* and have students fill it out as they read. If you choose this option, **slide E - alternate** is available to support your students, as well.

Alternate Activity

If you think that any of your students would benefit from simplified versions of the readings used in today's lesson, use the materials with "v2" in the titles, which have a lower text complexity (but the same content).

Say, *As you read to yourself, keep track by counting with your fingers whenever you find something in the reading that relates to our checklist. You don't have to hold your fingers up very high, but I'll be watching and when I see that most of you have at least one idea to share, we'll pause our reading to discuss.*

Students will likely not finish reading the article before they start indicating with their fingers that they have ideas to share. Pause the reading and start the discussion as soon as you see that everyone has at least one finger raised. Use prompts such as the following to discuss the credibility of this article.

Suggested prompts	Sample student responses
What are some of your thoughts about this article?	*We shouldn't trust it!* *It's not credible.*
What makes you think it is not credible?	*The author didn't cite any sources!* *And they were trying to sell stuff!* *They said stretching helps muscles grow. Is that true?*

Move the discussion to focus on the author's purpose.

Suggested prompts	Sample student responses
What is the author's purpose in writing this article?	*They are probably trying to sell something.* *They want to make money.* *They want to gain popularity and get a lot of views.*
Oh, interesting. So can we trust this source?	*No!*
But it matches up with some of our thinking about building muscles. Does that mean we are wrong?	*No.* *Maybe.* *I'm not sure.*
Hmmm, what should we do?	*We need to find a source we can trust with information about how muscles actually get bigger.*
What would a credible source—one we can trust—look like?	*It would have sources cited.* *It might use data from a scientific study as evidence.* *It wouldn't be selling anything.*

Say, *We're going to stop reading this article. If you are doing research and find a source to be not credible, you do not have to read the whole thing. You should skip it and move on to the next source you find.*

***Supporting Students in Engaging in Obtaining, Evaluating, and Communicating Information**

Not all communications students see in their lives are credible. This "blog post" challenges students to call into question the credibility of a source that agrees with their own claim (that diet and exercise are involved in human muscle growth), a valuable practice in and out of the classroom.

***Supporting Students in Developing and Using Cause and Effect**

The teacher instructions here assume that students have experienced *Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)* prior to completing this unit. In the *Magnets Unit*, students used this framing to establish several cause-and-effect relationships about how a speaker makes sound. If your students have not considered cause-and-effect relationships in this way, you may need to provide more support as they complete the table on **slide H**.

If students have been reading *Version 1: How to Build Muscles* in their *Student Edition*, they can just close their book. If they had it as a handout, you might collect them to use with the next class.

Obtain and evaluate information from a credible source. Display **slide G**. Say, *Even though the claim in the first article matches our ideas, the author's purpose was different from our purpose as readers. We were hoping to find credible information about how muscles grow, but the author was trying to sell some products. We need to find some information from credible sources about how muscles grow.*

Continue, *I have summaries of two studies done about the effects of diet and exercise on muscle growth.* Distribute *Version 1: Greek Yogurt + Resistance Training (Study 1)* to half the students in class and *Version 1: Carbs or Protein with Exercise (Study 2)* to the other half.

Display **slide E** (or **slide E - alternate**) again and say, *Our checklist helped us determine that the first article was not credible. Let's use the checklist again for these next articles. If it helps you track your thinking, you might choose to mark up your text about ideas related to our checklist.*

Give students 5 minutes to read and mark their papers.

After 5 minutes, ask students if they found these articles to be more credible than the blog post and why. Listen for ideas such as these:

- The article I read appears to be a scientific study. It had a controlled test.
- Data are clearly represented (e.g., tables, charts) so the reader can make sense of them.
- The authors are not trying to sell any products.
- The evidence from the study supports the article's claims.

Discuss science ideas learned from credible sources. Say, *So we have two credible articles sharing information about human muscle growth.* Use prompts such as these to elicit key ideas from both studies.

Suggested prompts	Sample student responses
What was the central claim of the study you read about?	*That diet and exercise both help muscles grow!* *The study I read said the same thing.*
Did that claim match what we were thinking?	*Yes, we thought that diet and exercise are how people grow their muscles.*
What part of people's diet did the articles mention as important for muscle growth?	*My article talked about protein.* *The article I read talked about protein and carbohydrates, but it showed that protein was more important in building muscles.*

Establish a cause-and-effect relationship.* Display **slide H**. Say, *In the Magnets Unit, we traced cause-effect relationships within the system of the speaker. Now we get to apply the same idea to living systems! Based on the articles we just read, what are the cause-effect relationships among protein in food, exercise, and muscle growth? Let's work together and use this table to articulate this relationship.*

As students suggest the responses below, you may choose to type them into the table on **slide H**.

- When we: *eat more protein and exercise more*
- we observe: *muscle growth*
- because: _____*(We're not sure yet.)*

Suggested prompts	Sample student responses
In the studies we read, what changes were made to people's habits?	*The people ate more protein.* *People exercised several times per week.*
What effect was observed?	*The people who ate more protein and exercised more had more muscle growth than those who didn't make those changes.*
How or why did those changes cause those effects?	*(Answers may vary but will be speculation or prediction.)* *We're not sure yet—these articles didn't explain why or how.*

Motivate the need to explore each factor's influence separately. Display **slide I**. Say, *So we've figured out that both diet—specifically protein—and exercise play a role in building larger muscles, but we're not yet sure about how or why.*

Suggested prompts	Sample student responses
Do we even know how much each factor—protein and exercise—influences muscle building? Do they have the same influence—fifty-fifty? Or could it be eighty-twenty? Are they both needed?	*We don't know!* *We don't have enough evidence to say yet.*
How could we figure out how important protein is for muscle growth?	*Maybe we could look at what happens to muscles if the amount of protein someone ate changes but their exercise didn't.*
Oh, so we'd need to change only the amount of protein and look at the effect on muscles?	*Yes.*
Well, then how could we figure out how important exercise is for muscle growth?	*We would need to look at just exercise. Like, maybe if someone ate the same amount of protein but exercised different amounts.*

3. Read about the roles of diet and exercise (separately) in muscle growth. 12 MIN

Materials: *Version 1: Protein's Effect on Muscles* (half of class), *Version 1: Effect of Resistance Exercise on Muscles* (other half of class)

Obtain and evaluate information about the role of diet and the role of exercise in muscle growth. Display **slide J.** Explain that you have two articles: one about protein's effect on muscle mass and the other about exercise's effect on muscle mass. Pass out *Version 1: Protein's Effect on Muscles* to one half of the students in the class and *Version 1: Effect of Resistance Exercise on Muscles* to the other half.

Say, *Half of you have an article on how diet, specifically protein, influences muscle growth. This is Team Protein. The other half of you are on Team Exercise and have an article on how exercise influences muscle growth. After you read, we'll share what you found out and discuss how much each factor influences muscle growth.*

Display **slide E** (or **slide E-alternate**) again. Say, *Remember to mark your text to help you track your thinking about ideas related to the checklist.*

Give students about 5 minutes to read and mark their article.

Establish credibility of sources and discuss science ideas from the readings. Use prompts such as the following to elicit from students that exercise plays more of a role than diet in human muscle growth.

Suggested prompts	Sample student responses
Were your articles from credible sources?	*Yes!*
How could you tell?	*There were references at the bottom that looked like scientific studies.*
	The authors weren't trying to sell anything.
	The article had data in the text that supported the claim.

As students suggest the responses below, you may choose to type them into the table on **slide K**.

- When we: *eat more protein*
- we observe: *less muscle loss*
- because: _____*(We're not sure yet.)*

Suggested prompts	Sample student responses
Team Protein, in the study you read, what changes were made to people's habits?	*No changes were made to what they did.*
	People ate like they usually do, but scientists grouped them by how much protein they ate.
What effect was observed?	*The people who ate a lot of protein lost less muscle than the people who ate only a little protein. No amount of protein by itself made muscles grow bigger, but eating a higher amount of protein helped people keep more of the muscle they already had.*
How or why did those changes cause those effects?	*(Answers may vary but will be speculation/prediction.)*
	We're not sure yet—this article didn't explain why or how.

As students suggest the responses below, you may choose to type them into the table on **slide L**.

- When we: *damage our muscles through resistance exercises*
- we observe: *muscle growth*
- because: *our bodies use the protein from our food to repair the microtears and make new muscle cells!*

Suggested prompts	Sample student responses
Team Exercise, what did your article say about what happens to muscles when people exercise?	*It said when we work out, like lifting weights, our muscles get tiny tears.*
If our muscles get damaged, how does that cause bigger muscles?	*Our body makes new cells to fix the tears, and that's the muscle growing!*
So, how do protein and exercise work together to build muscles?	*Without exercise, the muscles wouldn't grow at all.*
	Without enough protein, the muscles wouldn't be able to grow as large or at all.
	After we exercise, our body uses the protein we eat to repair and grow muscle cells.

Additional Guidance

Students may connect to previous knowledge learned in *Inside Our Bodies Unit* where they figured out that proteins are broken down into amino acids inside the digestive system, then absorbed into the bloodstream. If students bring this up, explain that those amino acids in the bloodstream are used in building the new muscle cells involved in healing microtears.

Additional Guidance

Students may connect the idea of muscle microtears from resistance exercise to previous knowledge they learned in *Unit 8.1: Why do things sometimes get damaged when they hit each other? (Collisions Unit)* where they figured out that objects bend or change shape when contact forces are applied to them.

4. Connect what we figured out to professional athletes and transfer understanding to cattle.

10 MIN

Materials: None

View images of professional tennis players to confirm our thinking. Display **slide M**. Say, *I heard you suggest that exercise plays a larger role in muscle growth than how much protein we eat. I have some photos for us to look at to see if we can confirm our thinking about that.*

Say, *These people are professional tennis players—they play tennis every day as their job. Tennis players usually use one arm more than the other to hit the ball, such as every time they serve. What do you notice about the muscles of these tennis players?*

After students point out that these players have one arm that looks bigger than the other, continue the discussion as follows.

Suggested prompts	Sample student responses
How do these images support what we just figured out about the roles of diet and exercise on muscle growth?	*Their bigger arm is getting more exercise—that's why it's bigger!*
What can we say about how their diet is impacting their muscle growth?	*Well, their whole body gets the protein from the food they eat.* *I can infer that they're eating enough protein and other healthy foods to support or maintain their muscle growth.*
Does one arm get more protein than the other? Is that why it's bigger?	*No, the amino acids from the proteins in their food are circulated in the blood to each of their arms equally.*
So which has a greater effect on muscle size: the protein people eat or the exercise they do?	*Exercise makes more of a difference—that's why their serving arm has bigger muscles than their other one.*

Additional Guidance

If students are looking for evidence that the effect they're noticing in tennis players' arms has been repeated in a scientific study, you can share this example with them: A controlled study of 9 males (humans) had them do resistance exercises with their left leg only (and not their right) two times a week for nine weeks. The mean cross-sectional area of their left quadriceps (thigh muscle) was 77 square centimeters before training, and it increased to 82 square centimeters after training. The right (untrained) quadriceps mean cross-sectional area did not change. (Source: Ploutz, L. L., Tesch, P. A., Biro, R. L., & Dudley, G. A. (1994). Effect of resistance training on muscle use during exercise. *Journal of Applied Physiology*, *76*(4), pp. 1675-1681.)

Connect what we've learned about muscle growth in humans to cattle. Display **slide N**. Say something like, *OK, we have figured out how diet and exercise can contribute to muscle growth in humans. Can we infer that the same is true for cattle?* (Expect student answers of "yes", "no", and/or "maybe".)

Say, *I have images of human muscle tissue and muscle tissue from cattle to help us consider whether they might work the same ways. What could you be looking for in images of cattle and human muscle tissue to see if they are similar?*

Sample student responses

- Do they look the same?
- Are they made of the same structures?
- Do we see similar-looking cells?

Display **slide O**. Direct students to turn and talk with a partner about the similarities (and any differences) they see between the images of human muscle tissue and cattle muscle tissue shown on the slide. After a minute of talk time, ask students to share their thinking.

Sample student responses

- They look really similar!
- They have the same bundles of cells like we saw in Lesson 2.
- They both look stringy and have strands in them with some spaces in between.

Display **slide P**. Share the information on the slide with the class: *Scientists and researchers have also claimed that muscle tissue from cattle (beef) is similar to human muscle tissue. Their evidence includes the following information:*

- *The muscles develop in similar ways.*
- *The muscle fibers are structured similarly.*
- *The muscle cells use energy from food in similar ways.*
- *The amounts of amino acids found in the muscles of cattle and humans are similar.*

Ask, *Do we agree that human muscle tissue and cattle muscle tissue are similar enough that we can apply to cattle what we've figured out about diet and exercise in humans?* Establish that, yes, we have enough evidence to think that diet and exercise would affect cattle similarly to humans.

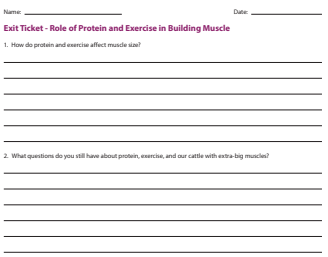
5. Exit Ticket

5 MIN

Materials: *Exit Ticket - Role of Protein and Exercise in Building Muscle*

Complete an exit ticket. Display **slide Q**. Distribute *Exit Ticket - Role of Protein and Exercise in Building Muscle* and give students about 3 minutes to answer the two questions:

- How do protein and exercise affect muscle size?
- What questions do you still have about protein, exercise, and our cattle with extra-big muscles?


Name: _____ Date: _____

Exit Ticket - Role of Protein and Exercise in Building Muscle

1. How do protein and exercise affect muscle size?

2. What questions do you still have about protein, exercise, and our cattle with extra-big muscles?

Assessment Opportunity

Building towards: 3.A Obtain, evaluate, and communicate information to determine the effects of exercise and diet in the development of muscle tissue.

What to look for: Look to see if students synthesize information presented in the lesson via images, readings, and data to identify the role of diet and exercise in building muscles. Look to see if students use specific pieces of

information to support the claim that protein consumption can positively influence muscle growth but that exercise is key in building larger muscles. Look for questions that ask about the diet of the cattle with extra-big muscles and how they exercise.

What to do

- If students need support in organizing their thoughts, recommend that they look back at the credible sources from which they obtained information today. Consider showing the images of the tennis players again to highlight the different roles of protein and exercise.
- If it would be helpful to their questioning, allow students to review the questions on the DQB that are about the diet and exercise of cattle with extra-big muscles.
- Read the students' exit tickets so you are ready to refer to them during next time's class, referencing the questions students wrote.

Close today's work. As students are turning in their exit tickets, say something like, *We have figured out so much about how muscles grow and get bigger—let's update our consensus model with that information next time and then we can investigate answers to more of our questions.*

ADDITIONAL LESSON 3 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.RI.8.8 Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient; recognize when irrelevant evidence is introduced.

Students co-construct a checklist to identify an author's central claims, the evidence used to support those claims, and whether the information is credible.

SCIENCE LITERACY: READING COLLECTION 1

Muscles and Other Traits

1 Diversity of Phenotype
2 Wellness Wonders Podcast
3 Buy Now and Bulk Up!
4 Growth in the Family Tree

Literacy Objectives

- ✓ Distinguish cause(s) and effect(s) related to human height differences.
- ✓ Organize related details about human adult heights.
- ✓ Distinguish between credible and non-credible sources.
- ✓ Translate visual/graphic representation of ideas to text.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 1–3.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare an infographic in response to the reading.

Instructional Resources

Student Reader



Collection 1

Science Literacy Student Reader, Collection 1
"Muscles and Other Traits"

Exercise Page



EP 1

Science Literacy Exercise Page
EP 1

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 1: How do organisms get their differences?
- Lesson 2: How do extra-big muscles compare to typical ones up close?
- Lesson 3: How do diet and exercise affect muscle size?

Standards and Dimensions

NGSS

Science and Engineering Practices: Analyzing and Interpreting Data; Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Cause and Effect; Structure and Function

CCSS

English Language Arts

RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

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.

Math

CCSS.MATH.CONTENT.7.SP.B.3: Informally assess the degree of visual overlap of two numerical data distributions with similar variabilities, measuring the difference between the centers by expressing it as a multiple of a measure of variability. For example, the mean height of players on the basketball team is 10 cm greater than the mean height of players on the soccer team, about twice the variability (mean absolute deviation) on either team; on a dot plot, the separation between the two distributions of heights is noticeable.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

phenotype

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

fast-twitch muscle **skeletal muscle**

slow-twitch muscle

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

Exercise Page



EP 1

Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.

- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations.

(Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Genetics unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
  - *First, you'll read a photo essay about the variety in appearance of animals' traits. By the end, you'll have a good understanding of what* phenotype *means.*
  - *Next, you'll read a transcript of a fictitious wellness podcast episode. The interviewee knows firsthand how skeletal muscles behave during exercise.*
  - *Then, you'll read some mock ads selling products to enhance muscles. Luckily, there is also a fact-checking analysis that will save consumers money they don't need to spend.*

- *Finally, you'll read a simulated blog post by a young man who presents data on variations in adult height of humans, depending on where they grew up.*

- Distribute Exercise Page 1. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to complete an infographic about phenotypes of adult human height.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
How does the phenotype of a macaw's beak differ from a hornbill's beak?	*They have different shapes. The macaw's beak is curved, and the hornbill's has a bump on it.*
What are two types of skeletal muscle fibers?	*fast-twitch and slow-twitch fibers*
What do some advertisers claim their product will do to your arm muscle phenotype?	*make your muscles look bigger*
What two factors affect phenotype?	*genetics and the environment*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
What variations in traits did you see in the photos in the first selection?	*variations in kangaroo muscle size, human height, shell and fur colors, bird beak shapes*
How did the podcast interview enhance our learning in Lesson 2 about muscle fibers?	*It explains that there are two types of muscle fibers—fast-twitch and slow-twitch.*
Which is more important in developing larger muscles, drinking shakes or exercising?	*exercising*

Exercise Page



EP 1

- Refer students to the Exercise Page 1. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to complete an infographic about the human phenotype related to mature adult height.*
  - *An infographic should have more graphics than text on it, so that means don't write too much.*
  - *In the first box, define the term. You'll find support for this step in the first reading selection.*
  - *In the next three boxes, write something about the human height phenotype that you learned from each graph. Think about what the data mean rather than merely sharing individual data points.*
  - *The important criterion for your work is that you communicate the term* phenotype *and your interpretation of the data accurately.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

4. Facilitate discussion.

(Friday)

Facilitate class discussion about the reading collection and writing exercise. Throughout this collection, students will begin to build understanding of the concept of *phenotype* so that when they reach Lesson 5, they will be ready to add the term to the class Word Wall.

Student Reader



Collection 1

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Pages 4–13 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "Diversity of Phenotype"?	*It explains what phenotypes are through many examples.*
Take a look at the photos of the polar bear and grizzly bear. How might the different phenotypes of fur color aid in their survival?	*Both colors make the bear harder to see in their environment. The polar bear's white fur matches the color of snow on the ground, and the grizzly's brown fur matches the color of tree trunks and the ground.*
How much overlap is there in the graph comparing male and female adult heights? Use numbers to answer.	*Both men and women have heights ranging from about 60 to 75 inches.*
What is the general purpose of the second selection, "Wellness Wonders Podcast"?	*It compares and contrasts fast-twitch and slow-twitch muscle fibers and explains that some people have more of one kind than the other.*
How does the second selection help you build knowledge on top of what you learned in the first selection?	*The first article reveals that observable traits, or phenotype, can differ among members of a species. The second article details how muscle potential differs among humans.*
How do slow-twitch and fast-twitch muscle fibers differ in their functions?	*Slow-twitch fibers carry more oxygen and are used for moving long distances. Fast-twitch fibers carry less oxygen and are used for sudden power movement.*
What is the general purpose of the third article, "Buy Now and Bulk Up!"?	*The first half contains ads that try to persuade people to buy products that claim they will increase their muscles. The second half fact-checks each ad to explain what they are selling and point out questionable claims.* *The purpose is to show readers how to think about claims for diet supplements.*
What are some possible problems with advertised supplements?	*They may not work.* *They may be bad for you.* *They may not contain the substances they say they do.*
Take a look at the Spot the BS box. What words in these ads trigger your BS detector?	*"magically," "get huge," "synthetic version," "safe," "effective"*
What credible sources could you use to evaluate the claims made in ads such as these?	*You could check science journals and reputable newspapers or ask an expert such as a physical therapist or doctor.*
What non-credible sources would you avoid?	*any source that makes money from the ads or by selling the supplements*

SUPPORT—Remind English learners that the consonant diagraph *ph* in the word *phenotype* make the "fff" sound. Point out other examples, such as *elephant*, *phone*, and *graph*. Then remind students of the similarity in meaning to the related word *phenomenon*, meaning an observable fact or event.

Pages 4–13 Suggested prompts	Sample student responses
What is the general purpose of the fourth article, "Growth in the Family Tree"?	*It discusses differences in height within the author's family and presents data on human adult heights related to when and where people grew up.*
How have changes in the environment affected the human height phenotype over the last 100 years?	*They mostly caused people to become taller, but in some cases, people became shorter.*
Look at the graph "Height of 18-Year-Old Men, 1914–2014." How does the trend (direction) of the line for South Korea compare to those of the other countries?	*It is a completely positive trend with no dips. It also shows the greatest change in height for all the countries.* *Unlike Egypt and Uganda, the change in height never decreased.*

5. Check for understanding.

Evaluate and Provide Feedback

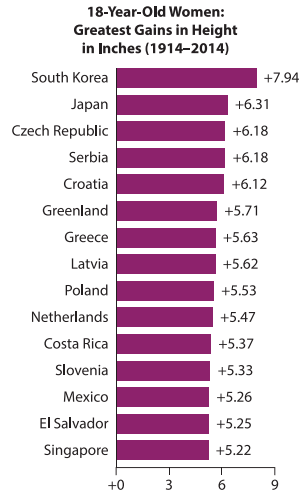
For Exercise 1, students should complete the provided infographic on the topic of phenotype. Students should interpret the graphs on phenotypes of human height in various populations and write one sentence to explain the data in each graph. A sample of a satisfactorily completed infographic is shown on the following page, with the student's writing in red.

Use the Evaluation Guidelines provided on the Exercise Page to supply feedback to each student.

EXTEND—Point students who wish to change the design of their infographics to appropriate design apps or websites. Most of these tools have templates from which to choose layouts, design text, and make color decisions and can be used with tablets or computers. Check the privacy policy of any tool to make sure it conforms with your school's internet-use policies.

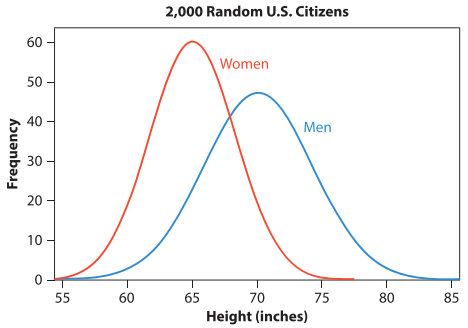
Data About Phenotype

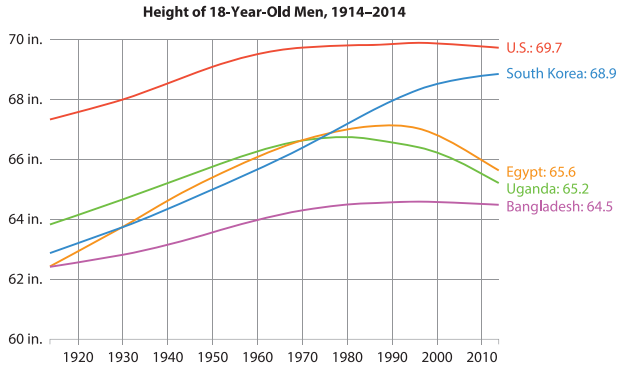
Phenotype describes . . . how an individual of a species appears and is based on genes and the environment.



In many countries around the world, women are 5 to 7 inches taller than a century ago.

In humans, the tallest adult males are taller than the tallest adult females, but the shortest male and females are about the same height.





From 1914 to 2014, South Koreans steadily increased in height.

LESSON 4

What is different about the food and exercise for cattle with extra-big muscles?

Previous Lesson

We evaluated information in text, images, graphs, and charts in order to determine the effect of diet and exercise on muscle growth. We discovered that exercise and a diet containing protein are essential to building larger muscles. Exercise causes microtears in muscle tissue. Muscle growth is caused by new cells being produced to repair the microtears, and protein is needed to build those cells.

This Lesson

Problematizing

1 DAY



We update our classroom consensus model to include our findings about the role diet and exercise play in making muscles. We attempt to apply our class model to explain how the extra-muscled cattle would have developed their muscles, but we realize the model cannot explain the differences in musculature we see. We learn more about the diet and habits of these cattle by listening to a farmer who raises cattle, and we also find out that the calves that grow up to be heavily muscled are born with more muscles than calves that don't grow up to be heavily muscled. We discuss how this information impacts our model.

Next Lesson

We will observe cattle family photos to figure out that offspring inherit musculature from parents. We will analyze an offspring's muscle cell karyotype and parental sex cells to learn that each offspring chromosome came from the parents.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5

What Students Will Do

4.A Develop and use a model to construct a scientific explanation based on evidence for how different environmental factors (cause) influence variation in a trait (effect).

What Students Will Figure Out

- Diet has a small influence on musculature for cattle with extra-big muscles.
- Exercise also has a small influence on musculature for cattle with extra-big muscles.
- Diet and exercise can't explain all the variation we see in musculature so there must be other factors involved.

Lesson 4 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**UPDATE CONSENSUS MODEL IN SCIENTISTS CIRCLE** Update the classroom consensus model to include how diet and exercise affect musculature variation.	A	classroom consensus model from Lesson 1, chart paper, markers
2	5 min	**UPDATE PROGRESS TRACKER** Update students' Progress Trackers individually to include the new ideas they figured out.	B	
3	2 min	**USE CONSENSUS MODEL TO EXPLAIN HEAVILY MUSCLED CATTLE** Apply the classroom consensus model to explain how the extra-muscled cattle have their large musculature.	C	updated classroom consensus model
4	10 min	**ASK A FARMER ABOUT EXERCISE** Listen to an interview of a farmer to better understand the daily life of these heavily muscled cattle.	D	*Exercise: Ask a Farmer Transcript*, 8.5 Lesson 4 Ask a Farmer: Exercise video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), computer and speakers to play audio
5	10 min	**LEARN ABOUT WHAT HEAVILY MUSCLED CATTLE EAT** Examine protein content of common cattle feed items. Listen to an interview of a farmer to better understand what the heavily muscled cattle eat compared to cattle that are not heavily muscled.	E-F	*Diet: Ask a Farmer Transcript*, 8.5 Lesson 4 Ask a Farmer: Diet video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), computer and speakers to play audio
6	5 min	**OBSERVE PHOTOS OF DIFFERENTLY MUSCLED CALVES** Observe photos of differently muscled calves, writing down what students notice and wonder, and then share with the class.	G	
7	3 min	**NAVIGATION** Discuss with a partner questions about the cattle being born like this, update the classroom consensus model, and connect and add the questions to the DQB.	H	classroom consensus model

End of day 1

Lesson 4 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Exercise: Ask a Farmer Transcript* • *Diet: Ask a Farmer Transcript*		• classroom consensus model from Lesson 1 • chart paper • markers • updated classroom consensus model • 8.5 Lesson 4 Ask a Farmer: Exercise video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • computer and speakers to play audio • 8.5 Lesson 4 Ask a Farmer: Diet video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • classroom consensus model

Materials preparation (20 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare the handouts:

- Make 1 copy each of *Exercise: Ask a Farmer Transcript* and *Diet: Ask a Farmer Transcript* for each student.

Have the classroom consensus model from Lesson 1 on hand.

Be sure you can access and play the two audio clips of "Ask a Farmer" 8.5 Lesson 4 Ask a Farmer: Exercise and 8.5 Lesson 4 Ask a Farmer: Diet. (See the **Online Resources Guide** for a link to these items. **www.coreknowledge.org/cksci-online-resources**)

Lesson 4 • Where We Are Going and NOT Going

Where We Are Going

It is important for students to understand that there are a number of different environmental factors that influence traits, yet the effects may be unequal. Some factors have a larger influence on a trait than other factors. Students come to these conclusions through the development of their classroom consensus model. After attempting to apply their model to the phenomenon and listening to an interview of a farmer, students come to the conclusion, by the end of the lesson, that there are other factors besides diet and exercise that are influencing musculature, and that's what they want to investigate next.

Another subtle shift that takes place in this lesson is after the farmer interview. Prior to this interview, the way students refer to these animals is by saying "cattle with extra-big muscles". From the farmer interview we learn that these cattle are referred to as "heavily muscled cattle". So, now we can use that term when referring to these animals.

Where We Are NOT Going

In this lesson, students work on understanding how different factors can influence a trait. While students are grappling with environmental factors such as diet and exercise, it is important that we aren't calling them "environmental factors" yet because the punchline of this lesson is that there is another class of factors (genetic) at play causing these cattle to be heavily muscled.

This shift from talking about "cattle with extra-big muscles" to "heavily muscled cattle" might seem trivial, however, the shift is important because it subtly introduces that this condition has a unique name. In a later lesson we will introduce the idea that a unique name and/or condition is what we call a *phenotype*, but we are not yet introducing that vocabulary here.

LEARNING PLAN FOR LESSON 4

1. Update consensus model in Scientists Circle. 10 MIN

Materials: science notebook, classroom consensus model from Lesson 1, chart paper, markers

Update classroom consensus model. Display **slide A**. Have students get into a Scientists Circle around the classroom consensus model from Lesson 1. Remind students that we have made a lot of progress since we first created this model. Facilitate a Consensus Discussion to update the model based on what we have learned so far.

Key Ideas

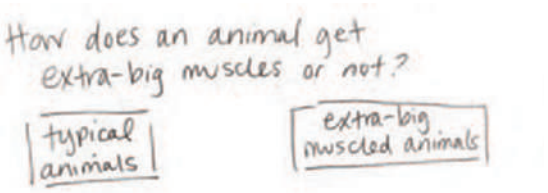
Purpose of this discussion: To use evidence from our investigations to update our classroom consensus model with the causes of different musculatures

Listen for these ideas:

- There is a range of variation of musculature. Muscles don't come in just two categories: big and typical.
- Smaller muscles have fewer and smaller cells.
- Larger muscles have more cells that are larger.
- Our model has a thicker arrow for exercise because the amount of exercise plays a greater role in muscle size than diet.
- Our model has a thinner arrow for eating more protein because the amount of protein consumed plays less of a role in muscle size than exercise.
    - However, if the animal doesn't get enough protein, then it won't be able to build muscle tissue through exercise.

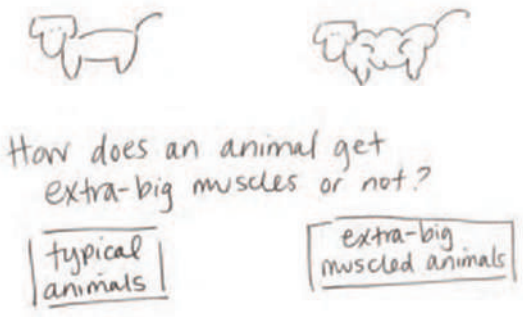
Say, *Let's revise our model to reflect the new ideas we have figured out. Since we've clarified some of the ideas we were not certain about, let's start with a new chart to give us more room.*

Title a new chart paper "How does an animal get extra-big muscles or not?" and, like before, have two headings—"Typical Animals" on the left side and "Extra-Big Muscled Animals" on the right. Draw two representative animals below the headings.



Suggested prompt	Sample student responses	Follow-up questions
What have we figured out about the difference between extra-big versus typical muscles?	*Larger muscles have more muscle cells.* *The area of the cells is larger in larger muscles.* *Larger muscles weigh more than smaller muscles.*	*How do we represent this in our model?* *What was our evidence for this idea?*

Choose another color marker to add to the model the ideas about how extra-big muscle cells look compared to typical muscle cells.

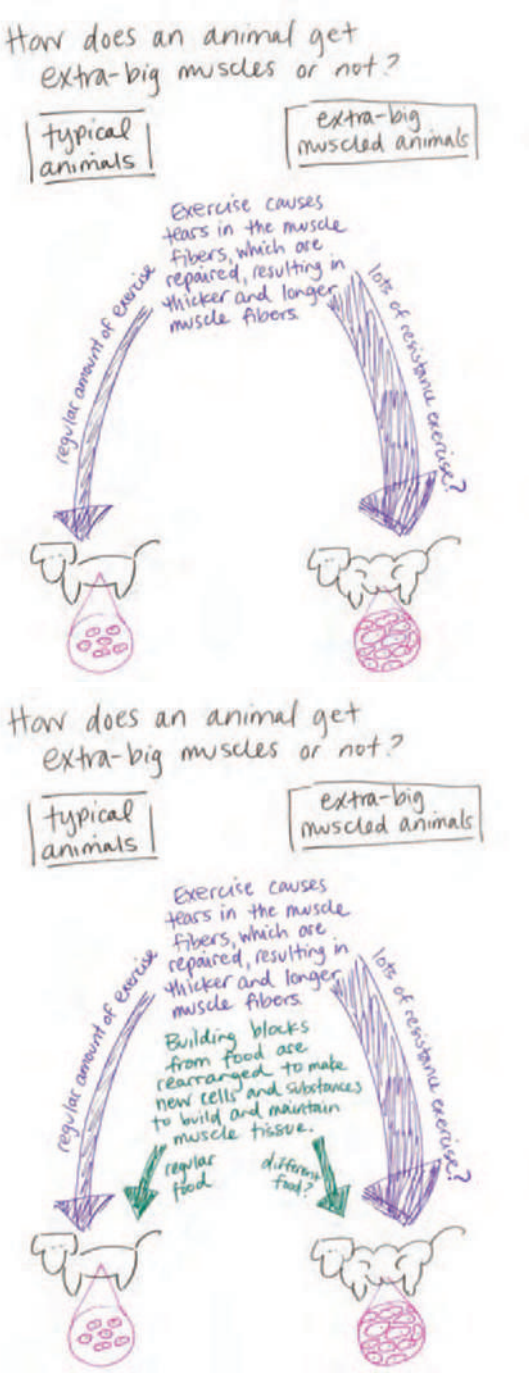


Suggested prompt	Sample student responses	Follow-up questions
What have we figured out about the role of exercise?	*Movement is necessary to build muscles. The more exercise, the bigger the muscles.* *When muscles are worked they get tears and then they are repaired.* *The muscle fibers are larger when they are repaired.*	*How do we represent this?* *Is this everything we know?* *If the mass is increasing, where would that new matter come from?*



Choose another color marker to add to the model the ideas about how exercise impacts muscle size.

Suggested prompt	Sample student responses	Follow-up questions
What have we figured out about how diet affects musculature?	*Building blocks from food are needed to make the protein in muscles.* *You break down food you eat, and then those building blocks get rearranged into new muscle fibers.* *Eating protein alone won't build muscles.* *Not eating enough protein causes organisms not to be able to make muscles.*	*What evidence do we have for this idea?* *How can we represent this in our model?* *Do you think diet affects muscles the same way exercise does?* *How should we represent this?* *Should the arrow for diet be smaller or larger than the one for exercise?* *Why do you think that?*



Choose another color marker to add to the model the ideas about how food impacts muscle size.

Additional Guidance

When co-constructing this model with the class it is important to highlight the idea that there are different factors that have an influence on a trait (in the example shown we use different-color arrows). It is also important for the model to be able to show that these different factors don't influence the trait equally (in the example shown the arrows are different sizes as students discuss whether they believe diet or exercise would have more of an effect on the different animal types). As we continue to build the model, more factors and their contributions can be added using different colors and thicknesses of arrows.

2. Update Progress Trackers.

5 MIN

Materials: science notebook

Update Progress Tracker. Display **slide B**.

Say, *By rebuilding our classroom consensus model for muscles we now have a deeper understanding about each idea and component we included. We added these ideas and components to our model because we have evidence to support their role in musculature. Let's add what we figured out so far to the Progress Tracker in our science notebooks.*

In the example Progress Tracker for this lesson, the boxes have been completed with possible student ideas.

Question	What I figured out in words and/or pictures
How do most animals get bigger muscles?	• There is variation in musculature. • The size of muscles you have depends on how much you exercise because the more exercise one does, the larger the muscles. The less exercise one does, the fewer the muscles. • Eating more protein does not significantly affect muscle size, but if you are not eating enough protein it seems to cause fewer muscles. • Exercise has a bigger influence on musculature than diet. 

Assessment Opportunity

Building towards: 4.A Develop and use a model to construct and predict a scientific explanation based on evidence for how different environmental factors (cause) influence variation in a trait (effect).

What to look and listen for: Look to see if students are able to make connections between the updates the class made to the classroom consensus model and how these updates can change or influence musculature.

What to do: If students are struggling, recommend that they first create a list of the ideas and components that were added to the model. Suggest that they use that list to decide what to include in their representation.

3. Use consensus model to explain heavily muscled cattle. 2 MIN

Materials: Updated classroom consensus model

Use the updated classroom consensus model to explain how cattle get their extra-big muscles. Display **slide C**.

Say, *Now that we have updated our model, let's look back at our cattle with extra-big muscles.*

Turn and talk with a partner about the question on the slide. Give students a minute to discuss with a partner the question on the slide. Then facilitate a whole-class discussion. Have a few pairs of students share their ideas with the whole class.

Suggested prompts	Sample student responses
What does our model predict that the cattle should be doing in order to get their extra-big muscles?	*Our model predicts that those cows must be exercising a ton!*
Do you think that's happening? Are the farmers taking their cattle to the gym? Or maybe they have workout areas at the farm?	*We do not know!* *Maybe they're pulling heavy carts around or something?*

Additional Guidance

There is a good chance students have asked questions on the Driving Question Board related to this (such as "Are those animals working out?"). If that is the case, refer to the DQB and the specific questions about whether the cattle with extra-big muscles were getting exercise.

Say, *It sounds like many of us are saying that the cattle with extra-big muscles are working out a lot more than cattle with muscles that are not extra big.*

4. Ask a farmer about exercise. 10 MIN

Materials: science notebook, *Exercise: Ask a Farmer Transcript*, 8.5 Lesson 4 Ask a Farmer: Exercise video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), computer and speakers to play audio

Listen to a clip from an interview with a farmer. Say, *I have an interview with a cattle farmer, one who raised cattle with extra-big muscles for over twenty years, talking about what her cattle do to get big muscles. What do you think we'll hear from her?*

Student predictions might include that these cattle have some kind of workout regimen or possibly that there are supplements or steroids that might make the muscles get so big.

*** Attending to Equity**

Universal Design for Learning: The *action* of marking two key points on the list of ideas they have written down allows all students to manage the information. Taking the time to do this gives students a moment to focus on their ideas and allows them to be better prepared and more confident to share their ideas with the class.

Show **slide D** and distribute the *Exercise: Ask a Farmer Transcript*. Have students individually make a T-chart in their science notebook where they can keep track of what they notice and wonder as they listen to the interview. Say, *You can read the transcript as the audio is playing. Let's listen now to learn what the farmer says her cows are doing all day.*

Play the audio interview about exercise 8.5 Lesson 4 Ask a Farmer: Exercise video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) which is also linked on **slide D**.

Lead a Building Understandings Discussion about the interview. Have students put a star next to two things that they wrote down that they feel are the most important ideas and questions. Then ask students to share these important ideas and questions with the whole class.

Key Ideas

Purpose of this discussion: To connect the new information we have from the farmer interview with what we have already figured out about these cattle

Listen for these ideas:

- The interviewer calls them "heavily muscled cattle", so we should, too.
- The heavily muscled cattle are not exercising. They behave similarly to typically muscled cattle.

Suggested prompts	Sample student responses
Was there anything surprising the farmer said about the heavily muscled cattle's day-to-day activity?	*She said they didn't exercise at all.* *She said they are really docile and lie down all day—she even could read a book lying on them!*
OK, well, how does that match the model we've created so far?	*We thought exercise was more important than diet to make big muscles, but maybe that isn't the case for these animals.*
What else do you think we need to know?	*We should find out what the cattle eat and if there is anything special about the food the cattle with extra-big muscles eat.* *We should find out what is in the food they eat.*

5. Learn about what heavily muscled cattle eat.

10 MIN

Materials: science notebook, *Diet: Ask a Farmer Transcript*, 8.5 Lesson 4 Ask a Farmer: Diet video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), computer and speakers to play audio

Examine protein amounts in typical cattle food. Say, *OK, I have some information about the amount of protein contained in some of the foods that are commonly fed to cattle. Examine the slide and prepare to share what you notice. If it's helpful, you can record notes in the T-chart in your science notebook about the amount of protein in these foods.* Display **slide E**.

Suggested prompts	Sample student responses
What do you notice about the different types of cattle feed?	*They have different amounts of digestible nutrients, but they are all still considered high quality.* *Most of the food the cattle eat has protein levels around ten percent.* *Some of the human food contains more protein than the food the cattle are eating.* *One of the human food items has a similar percentage of protein composition compared to the cattle feed.* *Oat grain is the highest quality with regard to the percent of crude protein.*
We have another clip from the interview with the farmer. What do you predict they feed the heavily muscled cattle? Do you think it is the same food the other types of cattle get?	*They probably feed them oat grain because it is the highest in protein.* *They probably don't feed all the cattle the same thing.*

Listen to another clip of the interview with a farmer and record what we notice and wonder. Display **slide F** and distribute the *Diet: Ask a Farmer Transcript*.

Say, *Let's listen to what the farmer explains about what these heavily muscled cattle are eating. You can read the transcript as the audio is playing.*

Play the audio interview about diet 8.5 Lesson 4 Ask a Farmer: Diet video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) which is also linked on **slide F**. As students listen, they should continue to record the important ideas on the Notice and Wonder chart they started earlier.

Conclude the Building Understandings Discussion about the interview. Have students put a star next to two things that they wrote down and that they feel are the most important ideas and questions. Then ask students to share these important ideas and questions with the whole class.

Key Ideas

Purpose of this discussion: To connect the new information we have from the farmer interview about what the cattle are eating with what we have already figured out about these cattle

Listen for these ideas:

- The heavily muscled cattle are not eating differently.
- We know that diet and exercise play a part in muscle size, but this does not seem to explain the heavily muscled cattle.
- The heavily muscled cattle are often born like this.

Suggested prompts	Sample student responses
Was there anything surprising the farmer said about what the heavily muscled cattle were eating?	*She talked about some of the different types of feed that were listed on the slide.* *She said she fed them corn, and that is actually lower in protein than some of the other options.* *They ate the same things that all the other cattle did.* *I thought it was neat that they eat whatever type of food is available where they live.* *They have to take supplements, like vitamins!*
So the cattle are getting some protein, but would we call it a high-protein diet?	*Not really. When you compare it to a piece of chicken, their food doesn't have much protein at all.* *According to the chart on slide E, they would be getting a "fair" amount of protein, but not "premium."* *The farmer also said they didn't get any extra food.*
OK, so if the extra-muscled cattle are eating the same amount of protein as typical cattle, maybe the protein isn't as important as we thought. Do you think animals need any protein at all?	*Yeah, I think they still need to eat protein.* *The muscles have protein in them, so they need a general amount of protein.*
Was there anything else the farmer talked about that you think is important to this discussion?	*She said they are born that way! Some of them look like that right away, and others take a few weeks to "muscle up".* *She also said some of the calves don't get the trait at all.*

Say, *We just listened to the farmer say the heavily muscled cattle were born that way. Do you think that's true? If that's true, what does that mean baby cattle would look like? Do you want to see some pictures of baby cattle?*

6. Observe photos of differently muscled calves.

5 MIN

Materials: science notebook

Observe photos of differently muscled calves. Show **slide G.** Direct students to make another T-chart in their science notebook to record what they notice and wonder about the baby calves. Have students observe the baby calves for a minute or two, recording their noticings and wonderings in their notebooks. Then have students share their ideas with the class.

Suggested prompts	Sample student responses	Follow-up questions
What are some differences we noticed in these baby calves?	*There is a large difference in musculature between these calves.*	*Can you go up to the slide and point to what you are referring to?*
How does our model explain these muscled baby calves?	*It really can't explain baby calves with extra-big muscles.*	*If you don't think it is diet or exercise making the babies heavily muscled, then what are we missing?*

7. Navigation

3 MIN

Materials: classroom consensus model

Update the consensus model. Refer to the classroom consensus model to update it with the pieces we just learned.

Suggested prompts	Sample student responses
How can we represent on the consensus model what we just learned?	*We can add arrows to represent that they were born that way.*
Based on how we were using the arrows before, with the thicker lines meaning the factor has more of an effect, how should we draw the "born this way" arrows?	*The arrow to the heavily muscled animals should be thick—it has more of an effect than either diet or exercise.*
Do you think we need to take diet and exercise off the model?	*We don't think so.* *We're not sure we've figured everything out about this, like, maybe it still could apply.* *They still seem important, just not as important as how they are born, at least for the heavily muscled cattle.*

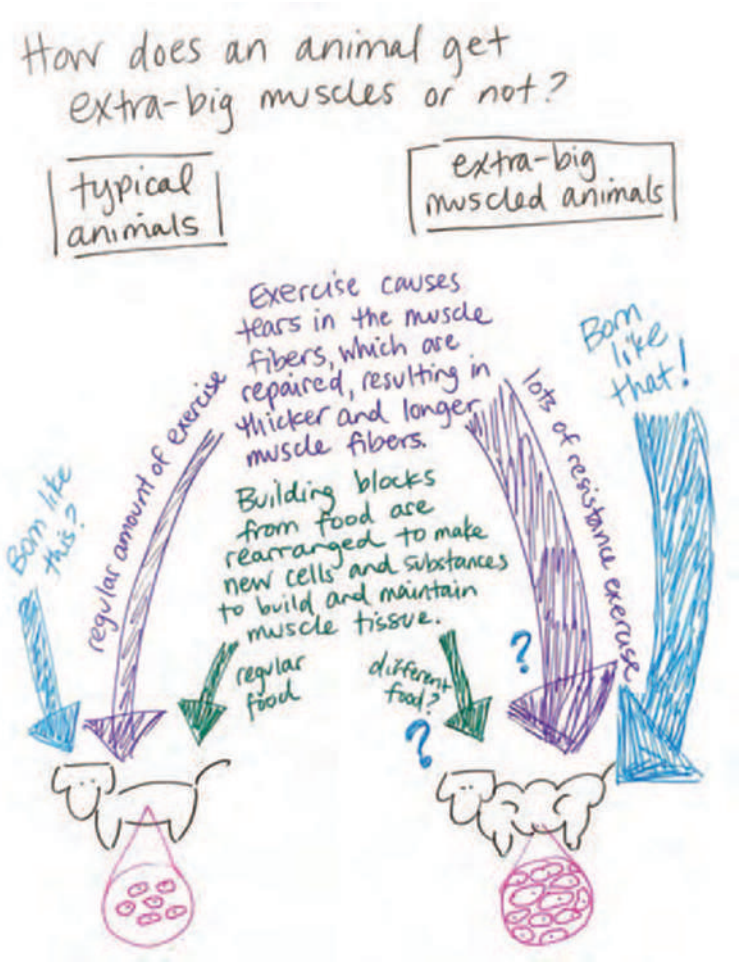
Display **slide H**. Say, *OK, so it seems like the cattle are born like this. But there doesn't appear to be anything specific in our model yet indicating what could happen before birth to cause this. What questions do we have on our DQB related to how these cattle might be born like this?*

Refer to the DQB to help decide what to investigate next. After pointing out related DQB questions, summarize these ideas by asking, *So how could this be? Why are some baby cattle born with big muscles and others aren't? What could be causing differences in what they are born with? Turn and talk with your partner for a moment about these questions.*

Additional Guidance

If a student brings up an idea about diet such as the mother cow might have been eating or drinking something different during pregnancy which resulted in the baby having bigger muscles, then refer to our classroom consensus model emphasizing the arrow thickness in regard to its influence on musculature. If the idea persists, then have the student add a question about it to the Driving Question Board.

After a minute or so of talk time, close today's work by saying something like, *We have some big ideas to investigate next time!*



LESSON 5

Where do the babies with extra-big muscles get that trait variation?

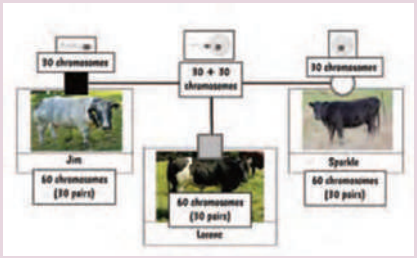
Previous Lesson

We updated our classroom consensus model and realized this model could not explain the differences in musculature we saw. We learned more from a farmer about the diet and habits of the heavily muscled cattle and also learned that the calves that grow up to be heavily muscled are born with more muscles than calves that don't grow up to be heavily muscled.

This Lesson

Investigation

2 DAYS



We observe cattle family photos to find patterns between relatedness and musculature. We wonder how muscles get from parents to offspring and zoom in to look at chromosomes inside sperm and egg cells. We then make connections between the karyotype of an offspring's muscle cell and chromosomes in sex cells of the parents. We find there are twice as many chromosomes in an individual's muscle cell as there were in parents' sex cells. These can be organized into pairs. We observe chromosomes in the karyotype that look like those in egg and sperm and figure out that each sex cell contributes one of each kind of chromosome to offspring.

Next Lesson

Students will consider the scale of chromosomes and proteins. Then students will reorganize their cattle photos with new information about each individual's chromosomes and which versions of the myostatin protein each has. Groups will construct initial models and then a classroom consensus model to explain the correlations they find. Students will read and synthesize different articles to find evidence of causal relationships among alleles, proteins, and phenotypes.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5

What Students Will Do

5.A Use a model to describe and predict the patterns in variations in traits between parents and offspring in a pedigree.

5.B Develop and use a model to describe the unobservable mechanism of fertilization, in which parents each contribute half of the chromosomes an offspring has, by discerning patterns in the number and types of chromosomes in the sex cells of parents and the body cells of offspring.

What Students Will Figure Out

- If an individual is heavily muscled, both parents have extra-big or medium muscles.

- Egg and sperm do not contain the same proteins that are found in muscle cells; therefore, parents are not directly passing on muscles or muscle proteins.
- Chromosomes are passed from parents to offspring when the sperm and egg fuse during fertilization.
- Egg and sperm each have half the number of chromosomes as the muscle cells.
- The karyotype shows that muscle cells have two of each kind of chromosome.
- One chromosome in each pair shown on the karyotype is from one parent (from the egg) and one chromosome comes from the other parent (from the sperm).

Lesson 5 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Observe photos of baby cattle with typical muscles and extra-big muscles.	A	
2	5 min	**DEVELOP CONVENTIONS FOR PEDIGREES** Discuss the best way to represent characteristics of individuals that are part of our cattle families and agree to share common symbols to do so.	B-E	
3	15 min	**BUILD PEDIGREES USING CATTLE FAMILY PHOTOS** Work in small groups to organize the pedigrees based on relatedness and transfer the observations about the phenotype and sex of each individual to a graphic organizer.	F-I	*Family Phenotype Graphic Organizer*, transparent tape, 1 family set (7 individuals) from *Cattle Family Cards*, *Key to Family Phenotype Graphic Organizers* (See the **Online Resources Guide** for link to these items. **www.coreknowledge.org/cksci-online-resources**)
4	20 min	**BUILDING UNDERSTANDINGS DISCUSSION ABOUT PHENOTYPES IN FAMILIES** Discuss patterns uncovered in students' organizers. Using the patterns, make predictions about potential offspring of a given set of parents. Develop a more-robust model as a class to represent how parents and offspring are related.	J-Q	chart paper, markers
				End of day 1
5	12 min	**INVESTIGATE WHAT IS FOUND INSIDE EGG AND SPERM CELLS** Examine components and structures in egg and sperm cells to discover that chromosomes, and not muscle cells or their parts, pass from parent to offspring when sperm fertilizes an egg.	R-T	transparent tape, *Chromosomes in Sex Cells*, scale simulations (See the **Online Resources Guide** for a link to these items. **www.coreknowledge.org/cksci-online-resources**)

Part	Duration	Summary	Slide	Materials
6	20 min	**DISCOVER PATTERNS USING KARYOTYPES** Examine the karyotype (that represents the muscle cell of an individual offspring) and compare the chromosomes organized there to the chromosomes found in the sperm and egg cells of the parents.	U-Z AA	transparent tape, *Chromosomes in Sex Cells simulation* (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), *Karyotype of Lorenc's Muscle Cell*
7	5 min	**MAKE PREDICTIONS ABOUT THE NUMBER OF CHROMOSOMES** Make predictions about the number of chromosomes in the muscle and other body cells of Jim and Sparkle and in the sex cells of Lorenc, based on the patterns observed so far.	AB-AD	
8	8 min	**NAVIGATION AND PROGRESS TRACKER UPDATE** Reflect on what we've learned about inheritance of phenotypes and chromosomes from parents. Build on this learning by thinking about what information is needed to dig deeper into understanding chromosomes.	AE-AF	

End of day 2

Lesson 5 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• *Family Phenotype Graphic Organizer* • science notebook • transparent tape • *Chromosomes in Sex Cells* • *Karyotype of Lorenc's Muscle Cell*	• 1 family set (7 individuals) from *Cattle Family Cards*	• *Key to Family Phenotype Graphic Organizers* • chart paper • markers • scale simuations (See the **Online Resources Guide** for a link to these items. **www.coreknowledge.org/cksci-online-resources**)

Materials preparation (25 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare the handouts:

- Make 1 copy each of *Family Phenotype Graphic Organizer*, *Chromosomes in Sex Cells*, and *Karyotype of Lorenc's Muscle Cell* for each student.

Gather the *Cattle Family Cards* from your materials kit. If you do not have premade cards from the materials kit, prepare them as follows:

- Print 2 color copies on cardstock of *Cattle Family Cards* and cut the cards apart to make 2 sets of each of the 5 cattle families (7 cards in each family).
- Consider laminating these cards since you will reuse them for each class you teach, in future lessons, and you can keep them year to year.
- Each group of students will get a family set, so consider bundling the sets with rubber bands or binder clips so they're easier to distribute.

Decide how to organize student groups. You will have 10 sets of cards (2 sets of each of 5 families) total, so you may choose to organize your students into 10 groups. Alternatively, you may choose to make 8 groups and give a second family set (that is not all typical) to the 2 groups that have Family #4 (since that all-typical cattle family will be quick to organize and identify phenotypes.)

Have half-sheets of copy paper ready to add the following words to the Word Wall: *phenotype*, *chromosome*, *pedigree*, *nucleus*, and *sexual reproduction*. Do not post these words on the wall until after your class has developed a shared understanding of their meaning.

Have transparent tape available for students to attach *Family Phenotype Graphic Organizer* to their science notebook.

Test the simulation to be sure it works with your computer and projector (you will view it as a whole class). If you need an alternative, a very similar scale simulation is available. (See the **Online Resources Guide** for a link to these items. **www.coreknowledge.org/cksci-online-resources**)

Lesson 5 • Where We Are Going and NOT Going

Where We Are Going

Before this lesson, students had considered the possibility that cattle developed their heavily muscled phenotype by exercise and/or diet, but they discovered that calves are born with extra-big muscles. This prompted a consideration of whether baby cattle are getting their big muscles from their parents. We develop and use pedigree models that show patterns indicating that both parents have to have the heavily muscled or medium-muscled phenotype in order for an offspring to be heavily muscled and that two parents with the typically muscled phenotype do not produce offspring that are heavily muscled. Students then wonder what is physically being passed on to offspring that would allow them to have this phenotype, and they investigate the chromosomes inside of sex cells and muscle cells to discover that the muscle cells in the body of an organism contain pairs of chromosomes. For each of these pairs, one chromosome came from the egg cell and the other from the sperm cell. It is important for students to understand this segregation so they can build on this to develop a model for probability (Lesson 9).

Work students do in this lesson to reason through how a single fertilized cell develops into a calf relies heavily on prior knowledge from *Unit 6.6: How do living things heal? (Healing Unit)*. If your students have not yet experienced the *Healing Unit*, you will need to spend more time supporting their sense-making about how cells grow and split in order to heal injuries and/or increase the organism's size (as during embryonic development).

All the cattle images in this unit are of actual animals that have the genotypes students will use in Lesson 6 and beyond. The heavily muscled cattle are full-blood American Blues, and the medium-muscled cattle are half-blood crosses of American Blues and another breed, such as Simmental, Angus, or Holstein. The typically muscled cattle are not American Blues but one of the other breeds. We invented pedigrees, using these individual animals, that show cattle with the phenotypes and the specific crosses that students need to see in order to figure out the inheritance patterns of the allele for extra-big muscles. So while some of the cattle that students see in pedigrees in this and future lessons are genetically related in real life, they are not all related or they are not related in the ways indicated on the pedigrees. In other words, these pedigrees are not records of actual breeding histories. We could not use actual pedigrees for this activity for a variety of reasons, including that breeders do not usually mate cattle in all the specific crosses we wanted students to see. If your students are experienced with cattle breeding, they may notice that trait variations other than musculature may not follow inheritance patterns they would expect. This is an artifact of the process used to create the pedigrees focused on the inheritance patterns for musculature. If knowledgeable students bring this up, feel free to share with them that the pedigrees represent the patterns of inheritance in musculature but are not records of actual breeding histories.

Note that we included names for the cattle used in this lesson and others for easy reference; some of these are simplified versions of the animals' actual names, but many were invented because the actual name was not available.

Where We Are NOT Going

In this lesson, students discuss how cattle reproduce similarly to humans in that an egg and a sperm fuse together during fertilization, resulting in a single cell that then divides to become the offspring. We identify that this is called sexual reproduction, but we do not distinguish it from asexual reproduction at this point in the unit. Students will continue to explore how sexual reproduction results in offspring with genetic variation throughout this first lesson set. In the second lesson set, specifically in Lesson 13, students will discover that while plants also reproduce using sperm and egg, they can also reproduce without them. At that point, we will specifically contrast sexual reproduction with asexual reproduction, and students will explore additional examples of asexual reproduction in Lesson 14.

Though students need to have an understanding that organisms grow by cells growing and splitting, the processes of embryonic development and cell differentiation are not topics of this lesson. Students will explore embryonic development more deeply in the upcoming *Unit 8.6: How could things living today be connected to the things that lived long ago? (Penguins Unit)*, but the processes of cell differentiation are beyond the scope of middle school.

We are not focusing on inheritance patterns per se in this lesson. Students will confirm that offspring can have extra-big muscles, medium muscles, or typical muscles. They will confirm that offspring with typical muscles come from parents with typical muscles and that offspring with extra-big muscles all have two parents with extra-big or medium muscles. However, the dominance or recessiveness of these trait variations is not a topic of this lesson. We are only confirming the idea that the heavily muscled phenotype seems to come from parents who also have extra-big or medium muscles and who pass on chromosomes to their offspring. Inheritance patterns will be the focus of upcoming lessons. In future lessons, students will uncover the idea that there are genes on chromosomes and that different versions of genes for a trait (alleles) can result in different phenotypes. However, the boundary for this lesson is that these chromosomes are the structures that are getting passed from parent to offspring, rather than proteins or specific characteristics like muscles themselves. We will not yet dive into how the chromosomes are related to the phenotype (via proteins) or even what the chromosomes are made of or that there are genes on them.

LEARNING PLAN FOR LESSON 5

1. Navigation

5 MIN

Materials: None

Look back to what we wondered about last time. Display **slide A**. Say, *So last time our classroom consensus model predicted that in order for the cattle to get* really *big muscles, they would have to be working out* a lot. *But the farmer said that the cattle just lay around most of the day. Also, we saw some baby pictures of cattle and they are* born *with these big muscles. That led us to start brainstorming some possible explanations for these two questions.*

Suggested prompts	Sample student responses
What were some of the ideas that you and your partner shared about why some baby cattle are born with big muscles and others aren't?	*One or both parents were heavily muscled too.* *They got exposed to something inside the mother cow that changed their muscles.* *The big-muscled babies were exposed to some toxin in the environment like gamma rays that made them develop really big muscles, kind of like The Hulk.*
Where do the babies with big muscles get that trait variation?	*They got their muscles from their parents.* *This musculature is something they inherited.* *The musculature is a result of something their mothers do while they're pregnant.*

*** Attending to Equity**

It is important to remember that not all students in your classroom may be living with, or even know, their biological parents. Explicitly acknowledging that human families are complex and are made up of individuals who are related to each other in many different ways—not just biologically—will allow those students to feel recognized and enable them to engage more fully with this lesson about biological relatedness and biological families.

Additional Guidance

In some classes students may also suggest that the differences in babies are due to physical structures that are passed on from one or both parents to the offspring, such as DNA, proteins, cells, and so forth.

Avoid confirming or denying whether this is correct. Acknowledge the student and ask them to jot down that idea because it suggests something is also going on at the microscopic level that we would also want to try to get some evidence for.

Summarize for the class. Say, *So it sounds like we have a variety of ideas of where these babies might get their big muscles from. One idea we're hearing is that maybe these baby cattle got their muscles from their parents.*

Most classes will also have a question (or multiple) on the DQB about getting trait variations from parents, so refer to that as part of this discussion, too. Similarly, your class may have listed something like "look at family trees" on the list of Ideas for Investigation and Data We Need from Lesson 1; if so, acknowledge that, as well.

Suggested prompts	Sample student responses
What kind of evidence would we need to decide if our ideas about the calves getting their heavily muscled trait from their parents is correct or not?	*We could just look at the parents and the babies and see if the parents all had big muscles too.* *We could look at pictures of the parents and the babies to see what their muscles look like.*
How could the pictures help answer our question about where babies with big muscles get that trait variation?	*If either parent was heavily muscled and the baby was heavily muscled, that would be a clue that the muscles were passed from their parents.* *If the baby had big muscles but the parents didn't, then that would lead us to think that the big muscles aren't inherited. Or maybe we would have to look at different family members.*

Say, *OK, when we say parents here, we mean the biological parents of that offspring or baby, right? The farmers and breeders and scientists—like us—are interested in how these extra-big muscles happen, so we are wondering about the parents that mated, or reproduced, and gave birth to that offspring. That's different than how we as human families are set up sometimes, right? There's so much awesome variety to human families whether or not we live with or even know a biological parent. Here with cattle we're just focused on biological relationships. In order for us to be thinking about the cattle muscles and whether they get them from their biological parents, let's start by looking at a few individuals together as a class.**

2. Develop conventions for pedigrees.

5 MIN

Materials: None

Discuss as a class how to represent individuals. Display **slide B**. Say, *Looking at these two cattle, we see that they are obviously different, but every image we look at of cattle might not have such obvious differences. It might be helpful to come up with some guidelines and symbols to describe the differences among individuals.*

Suggested prompts	Sample student responses
What is the trait we're interested in?	*The trait is their muscles or how muscly they are.*
If we wanted to keep track of the variations in that trait and also figure out how or which of these animals are parents of offspring, what things would we need to keep track of and record?	*We can record what they look like and if they have a lot of muscles or not.* *We should also keep track of whether they are male or female.*
How would you describe these two different animals in terms of the variation they have for muscles?	*Jim has extra-big muscles.* *Zena has typical muscles.*

*** Attending to Equity**

It is important to remember that while biological sex is genetically determined, gender is not. Gender is a social construct that refers to how individuals position themselves and are positioned by others in relation to roles as men or women. There are more gender identities than just man or woman. Gender definitions, expectations, and roles vary in different cultures, with some cultures embracing multiple gender definitions. In this unit, it is more scientifically accurate to refer to biological

Establish use of common symbols. Say, *OK, so we need a way to quickly keep track of whether they are male or female and what variation they have for the trait we are interested in.*

Show **slide C**. Say, W*hen looking at family relationships scientists usually use circle and square symbols to keep track of the sex of the animals.* A circle represents females and a square represents males, and we can shade in the shape to represent whether they show the heavily muscled variation or the typical variation.*

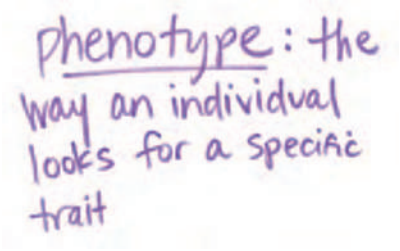
Additional Guidance

As you strive to make your classroom inclusive and accessible for all students, you'll want to consider the language you and your students use to discuss the relationships of the cattle in the pedigrees you're exploring. Use nongender terms like "parent," "offspring," and "sibling" whenever possible (note that siblings aren't introduced into our cattle pedigrees until Lesson 8). You may choose to specify "female parent" and "male parent" to keep the focus on biological relationships. For students who do not live with their biological parents the terms "father" and "male parent" may have different meanings. However, also keep in mind that using language your students choose, such as "mother" or "father" or "son" or "daughter", can encourage students to participate in the discussion. Emergent multilingual learners can share the ways in which their home language(s) mark gendered and non-gendered terms used to describe families. In this way, the teacher can explicitly support metalinguistic conversations to help the entire class make connections between English and the other home languages of students in the classroom, reinforcing that all languages are important resources for science sensemaking.

Display **slide D**. Take a moment to clarify and consolidate students' understanding of the symbols we are using since we will rely on these symbols throughout the rest of the unit.

Suggested prompts	Sample student responses
What shape are we using to refer to males?	*a square*
What shape are we using to refer to females?	*a circle*
Which variation is the filled-in shape going to represent then, based on this slide?	*The filled-in shape represents a heavily muscled animal.*
Which variation is the empty shape going to represent?	*The empty shape represents typical musculature.*

Add "phenotype" to the Word Wall. Say, *There is another common way that scientists talk about what we're investigating that we should also be using. We have been talking about these traits and variations of each trait that our individuals have. Some aspects of what our cattle look like could be from the environment and how they have grown up—for example, food and exercise—and some of what the cattle look like might be inherited or passed down from their parents. We call the way an individual looks for a specific trait or characteristic their* ***phenotype****. Scientists use this word for any organism when they refer to the way the organism looks. For example, they might say, "The phenotype of most of the puppies is brown" or "That type of*



sex rather than gender. As such, refrain from using terms like "girl" and "boy" to refer to animals; use "male" and "female" instead.

*** Attending to Equity**

Supporting Emergent Multilingual Students: When new scientific words, like *phenotype*, are introduced, it can be helpful for emergent multilingual students to see a reference to these words added to a Word Wall. Add these words to the Word Wall as they emerge in the discussion, rather than before.

*** Supporting Students in Developing and Using Patterns**

The point of this discussion is not to clarify how similar Grayboy is to either one of the others, but rather to clarify that his phenotype is visibly distinguishable as being between the heavily muscled phenotype and the typically muscled phenotype and to surface the physical details that put him in that category. Then we can decide on a way to represent an individual that appears to be in between our two original phenotypes, or has "medium muscles."

If students disagree on how to categorize Grayboy, be sure to encourage them to respectfully critique each other's ideas and to respond by asking clarifying questions and/or using evidence to support competing ideas.

*salamander tends to have a long-tailed phenotype." From now on in class, when we are referring to what an organism looks like with regard to a trait, such as how muscled it is, no matter how it got those muscles, we are going to use the word "phenotype", so we'll also post it here on the Word Wall.**

Additional Guidance

Definitions on the Word Wall can and should be modified over time. For example, when we discover in Lesson 9 that docile behavior and short gestation times are also part of the cattle's phenotype, we can add that the phenotype for a trait can also be descriptions of behavioral and physiological characteristics.

Discuss what to do about animals that are hard to categorize. Say, *When we looked at Jim and Zena, it was pretty easy to describe their phenotype for musculture and pretty straightforward in how to assign them a symbol for it. In our first lesson, though, you saw many different cattle. Let's consider another possible muscle phenotype and figure out what symbol we can use for those individuals.*

Display **slide E** and collect some ideas about how to represent the phenotype of the animal in the middle. Use the questions below to help students focus on and identify these sorts of detailed observations.

Suggested prompts	Sample student responses
How would you describe Grayboy's phenotype for musculature?	*I think he is heavily muscled.* *I think he has typical muscles.* *I think he is somewhere in between.*
*What evidence would you use to support the category in which you placed him?**	*The front and main part of his body doesn't seem to have extra muscle definition.* *Some parts of his body have extra muscles, like near the back legs, but the rest of his body looks more like it has typical muscles.*
Look at the front of Grayboy's body compared to the other two, especially around his shoulders and the top of his legs. What's different?	*His shoulders and front legs look bigger than Zena's but not as big as Jim's.* *You can see more muscles than Zena has, but they're not as clearly defined as Jim's are.*
Look at the back of Grayboy's body compared to the other two, especially around the top of his back legs and his rump. What's different?	*His rump sticks out further than Zena's but not as far as Jim's.* *The top of his back leg is more rounded than Zena's, but the muscles are not as well defined as Jim's.* *Grayboy has bigger muscles in the back of his body than Zena has, but smaller than Jim.*

Suggested prompt	Sample student response
We're using black and white colors to indicate the muscle types in Jim and Zena. How could we represent the individuals that have this medium-muscled phenotype? The ones that are in between the heavily muscled phenotype and the typical phenotype?	*We could use the same shapes but shade them in gray to indicate it is an in-between phenotype.*

Note: The slides and keys in this lesson and following lessons use gray to indicate the medium-muscled phenotype. Instead of asking, you might suggest to the class, *Is it OK with you if we use gray to represent the medium-muscled phenotype?* Or, your class may choose a different representation (such as stripes or another color), and when necessary, you can explain that your class chose a different representation than the unit developers, which is fine.

Additional Guidance

Use students' ideas as a framework for how to differentiate between the heavily muscled phenotype and the medium muscled phenotype. However, note that

- the distinguishing characteristic of ***typically muscled*** cattle, with typical muscles, is an overall smoothness to their bodies compared to the other two phenotypes. It is often possible to see the bones of the hips in typically muscled cattle.
- the distinguishing characteristics of the ***heavily muscled*** cattle, with extra-big muscles, are a much extended rump, a thick neck, and large, well-defined muscles at the top of both front and back legs.
- the distinguishing characteristics of the ***medium muscled*** cattle, with medium muscles, are a slightly extended rump, bulky muscles compared to the typical cattle, but with those muscles significantly less well-defined than the muscles of the heavily muscled cattle.

These distinctions are especially noticeable near the top of both front and back legs. Male cattle (bulls) are more muscular than female cattle (cows) in all three phenotypes. However, the distinguishing characteristics described here should be consistent in both males and females.

Help students to identify clearly how to distinguish all three phenotypes from each other.

3. Build pedigrees using cattle family photos.

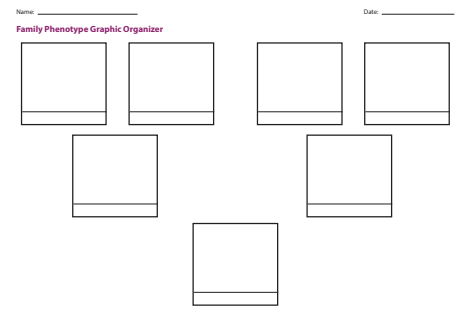
15 MIN

Materials: *Family Phenotype Graphic Organizer*, science notebook, transparent tape, 1 family set (7 individuals) from *Cattle Family Cards*, *Key to Family Phenotype Graphic Organizers*

Organize groups and materials for pedigree activity. Give all students a copy of *Family Phenotype Graphic Organizer* and ask them to open their notebooks to the next blank two-page spread. Show **slide F** and say, *Fold the graphic organizer in half and attach only the left side to the left notebook page with the crease in the center of the spread.*

*** Supporting Students in Developing and Using Patterns**
Circulate as they work in small groups to listen for students using patterns to make their decisions. If students are struggling with

Tell students, *This graphic organizer is similar to the way scientists organize and keep track of the biological relationships of parents and offspring. Scientists call this a* ***pedigree****.*



Divide students into 8 or 10 groups and give each group a family set consisting of 7 cards. You may want to give two sets to the groups that are organizing the all-typical family as this one will be quick to organize and identify phenotypes. (See the materials preparation notes for details.)

Show **slide G**. Say, *To find out which family you have, look in your cards to find one of the following names: Rob, Sasson, Conrad, Dressy, Uncanny. Use this name to title your organizer. Also write the name of this individual in the box at the bottom of the organizer as shown on the slide.*

Display **slide H** to show the addition of the key. Say, *Create a key on the side of this graphic organizer so those looking at this will know what is meant by the different symbols and shading.*

Work in small groups to build the pedigrees. Show **slide I** and review the directions listed there.

1. *Make room on your workspace so each person in your group can easily see all the cattle in the family. Work together to figure out which of the three musculature phenotypes your first individual (Rob, Sasson, Conrad, Dressy, Uncanny) has. Then agree on what symbols from your key for sex (circle or square) and for phenotype (shading) should be entered for your first individual at the bottom of the pedigree and record those in the organizer.*
2. *Then find that individual's parents, decide where they should be represented on the organizer, and add their names and the symbols for them.*
3. *Decide which symbols to enter for the grandparents, and record those as well.*
4. *When you finish recording both sets of grandparents, turn to the next blank page in your notebook and record patterns you notice in your pedigree.*

Circulate to confirm correct labeling of phenotypes. Walk around the room while groups are building their pedigrees. Use *Key to Family Phenotype Graphic Organizers* to discreetly cross-check the phenotype students are identifying for each animal. If students have labeled a different phenotype than what's indicated on the key, ask questions to help guide the group to accurately label each individual's phenotype.* (Students will use these pedigrees in the next lesson, and accurately labeled phenotypes are essential to make sense of the genotype and protein patterns they will figure out.)

If you do not have enough time to cross-check the pedigrees during class, at the end of this day's class collect one notebook from each group to check students' work.

Assessment Opportunity

5.A.1 Use a model to describe and predict the patterns in variations in traits between parents and offspring in a pedigree.

labeling the phenotypes, suggest a strategy of labeling the extremes first (typical or extra-big) and passing over any images they are not sure of. Sometimes in looking for patterns, it's easier to see a pattern when the contrast is more extreme. Then suggest that once those are labeled, students go back to assign a phenotype to the images they were unsure of during the first pass. If they are not explicitly using evidence from the pictures and the cattles' appearance to discuss patterns that are surfacing as a reason for assigning symbols, try using some of the following prompts:

- What are you noticing that determines if you are labeling it extra-big (black) or medium (gray)?
- Is it always easy to decide if it should be extra-big or medium (black or gray)?
- What specific characteristics did you use to decide which phenotypes these are?
- How are these patterns similar to or different from the other cattle in this family?

What to look and listen for

During small-group work with the *Family Phenotype Graphic Organizer*, listen for students using evidence from the images to support the assignment of phenotypes and symbols in their pedigrees. And look for the patterns to emerge that

- offspring who are heavily muscled must have two parents that are heavily muscled or medium muscled and
- offspring that are typically muscled have both parents that are typically muscled.

What to do: Have students refer to the characteristics that the class discussed to define each phenotype (heavily muscled, medium muscled, typically muscled) and focus on those patterns to assign appropriate symbols to each individual in their family as they construct the pedigree. Encourage them to focus on one set of parents and offspring at a time within their pedigree in order to pick out the patterns of phenotypes between parents and offspring in the family. Have them record the individual pattern they see in their pedigree and how many times that pattern occurs.

4. Building Understandings Discussion About Phenotypes in Families

20 MIN

Materials: science notebook, chart paper, markers

Discuss patterns each group noticed in their pedigree. Show **slide J**. Say, *Let's share and discuss what you noticed about your pedigrees.*



Suggested prompts	Sample student responses
What were some of the different musculature phenotypes in the families you studied?	*The family we looked at had a lot of heavily muscled cattle.* *Some of the cattle had obviously extra-big muscles, and others were that middle kind of phenotype—bigger muscles than typical, but not extra-big.* *Some of the cattle looked big, but you couldn't really see muscle definition, they were smooth. Those were typical muscles.*
What were some of the characteristics you used to determine which kind of muscle phenotype you said the individual had?	*You could see the lines that separated the muscles better in the extra-big muscle cattle.* *The cows looked "cut."* *The muscles by their rump stuck out way past their legs, or just a little past their legs, or not at all past their legs.* *The pictures were even taken sometimes to show their big rumps.* *If the cattle had typical muscles, their legs and rumps were in line with each other and the tail would hang straight down.*

*** Supporting Students in Engaging in Developing and Using Models**

It may seem unnecessary to ask students for their thoughts about using a particular symbol in a model when the choice seems obvious or there are useful scientific conventions, as in this model. However, students' sense of ownership of the process of modeling as a way to convey their own thinking is greatly enhanced by giving them agency over even seemingly insignificant details. In the practice of modeling, it is not about having students use the "right" symbols, but having them create meaning from symbols.

*** Attending to Equity**

Universal Design for Learning

It is likely your students will recognize the usefulness of these conventional symbols and

Move the discussion to patterns among parents and offspring. During this discussion, record general patterns on chart paper or other publicly visible space to help students keep track of what patterns have been identified. These general patterns will be referred to in the rest of this lesson and in future lessons. Use the prompts such as the following to guide the discussion.

Suggested prompts	Sample student responses
What patterns did you see between parents and offspring?	*A heavily muscled offspring can come from two heavily muscled parents and also from parents where only one is heavily muscled (if the other is medium-muscled).* *A medium-muscled offspring can come from parents when only one is heavily muscled.* *A heavily muscled offspring can come from two parents who are medium-muscled.* *If both parents are typically muscled, the offspring are typically muscled.*
Were those patterns the same in each generation in one family?	*At least one of those patterns showed up in each generation, but it wasn't always the same pattern in all the generations in each family.*
Were those patterns the same for all the families?	*All the families showed at least some of those same patterns.*
How could you describe a general pattern about where an offspring gets its muscle phenotype?	*If an offspring had any kind of big muscles—extra-big or medium—at least one parent had some big muscles.* *Sometimes extra-big-muscled offspring came from medium-muscled parents.* *If both parents had typical muscles, then the offspring did, too.* *It seems like they get the extra-big muscles from their parents, or they get the typical muscles from their parents.*

Have students record the general patterns in their science notebook. You might summarize them as follows:

- Offspring who are heavily muscled have two parents that have either extra-big or medium muscles.
- Offspring that are typically muscled have both parents that are typically muscled.

accept them easily. However, support students' differences in *representation* if they are invested in using different symbols (e.g., a different kind of line or a heart connecting the parents or an arrow pointing to the offspring) that they think are more useful. Validate their thinking and allow them to use different symbols as long as the symbols show a connection between biological parents in a particular generation and a connection between that mating of parents and the resulting offspring in a different generation. This presentation will make them familiar with the scientific conventions. If they choose different symbols, any inefficiency due to the symbols they may choose will be made up for in their investment in using their symbols for sensemaking.

*** Attending to Equity**

Some students may say genes, DNA, or chromosomes when asked what is in the egg and sperm cells. Avoid confirming that these ideas are "correct". While some students may have heard these terms, they will not likely understand what those structures actually are or how those structures are related to the phenotype.

Facilitating the discussion to encourage students to be motivated to look inside the egg and sperm will help maintain

Assessment Opportunity

5.A.2 Use a model to describe and predict the patterns in variations in traits between parents and offspring in a pedigree.

What to look and listen for

Listen for students using evidence from the images to support the assignment of phenotypes. Also listen for students to articulate the patterns that

- offspring who are heavily muscled have two parents that have either extra-big or medium muscles and
- offspring that are typically muscled have both parents that are typically muscled.

They should use those patterns in reasoning to support their prediction of what offspring of a given cross may look like.

What to do

If students struggle to articulate their reasoning, pause and ask them to clearly name the patterns that they observed and to note what those patterns have in common. Noticing that the same general patterns appear in all the pedigrees should help them identify those patterns as the ones they would predict they would see in the unknown offspring.

Develop a model to show relationships between individuals. Show **slide K**. Say, *When describing family relationships between parents and offspring, scientists usually connect the biological parents with a line straight between them, then draw a line down, like going down to the next generation, to show their offspring. Will those symbols work for us to keep track of parent-offspring relationships?*

Be sure students understand and are comfortable with these symbols before going on. Show **slide L** to demonstrate the symbols.**

Give students time to make the connections on their own organizer.

Add the word "pedigree" to the Word Wall. Students should now be using consistent symbols to represent biological inheritance. This organized representation, or model, is called a *pedigree*.

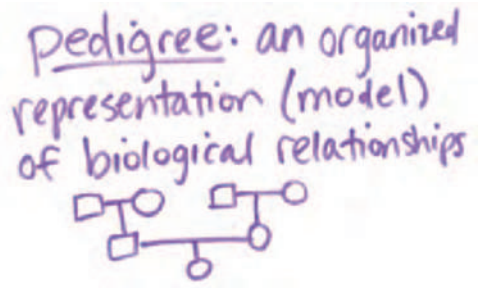
Use the model to predict biological relationships. Ask, *Do you think we could use the patterns we identified to predict whether a particular calf could be the offspring of particular parents? Shall we try it out and see?* Show **slide M**.

Add symbols to indicate the sex and phenotype to the class examples. Say, *Let's start by filling this out together the way you filled out the graphic organizers in your groups. We'll also review the symbols we're using. Start with the sex. What symbol, circle or square, would you give Jim? Sparkle? Lorenc? Cubby, Ballerina, Jalon?*

OK, how about their phenotype symbols? What would you consider Jim—heavily muscled, typically muscled, or medium? Sparkle? Lorenc? Cubby, Ballerina, Jalon?

If you are not able to annotate over the slide while you discuss the symbols, you can advance to **slide N** (where the symbols for sex and phenotype are marked for you) after the class has determined the sex and phenotype of these individuals.

interest for all students whether they have heard these terms or not. Try saying something like, "Hmm interesting, I wonder if we could find those inside the cell? Should we zoom in to these cells to see what we can figure out?" to move the investigation forward while keeping students with all levels of background knowledge involved.



Use patterns to make predictions about relatedness of example families. Ask, *Do these families fit the patterns we described?*

Use prompts such as those here and encourage students to cite specific evidence when discussing their claim about whether the offspring could have come from the parents shown.

Suggested prompts	Sample student responses
According to the patterns you saw in the families you studied, do both of these families show what you expect to see?	*We saw in our families that for the offspring to have extra-big muscles, at least one of the parents also had to have extra-big muscles.* *We also saw that if both parents had typical muscles, the offspring also had typical muscles.* *Jalon's parents both have typical muscles, so we don't think this family fits with our patterns.*
Do both of these parent-offspring relationships seem possible? Explain your thinking.	*Jalon's family relationships seem not possible because when we saw two typical-muscled parents, we only saw typical-muscled offspring.* *Lorenc's family relationships seem possible because we saw before that a medium-muscled offspring can have just one parent that has big muscles.*
What if I told you that one set of these pictures is from a farmer on a small farm who purchased a calf from a neighbor when it was a baby, and then they paired up the calf with a cow that already had another, slightly older calf so the new calf could be fed. Farmers call this fostering. Would that explain the patterns here?	*That would have to have happened in Jalon's family because neither of the parents have super-big muscles, but Jalon's muscles are huge.*
What would you expect the older calf—the biological offspring of Cubby and Ballerina—to look like?	*The older calf would probably have typical muscles.*

Additional Guidance

If your students have questions and/or comments about how cattle may be fostered compared with how human children may be fostered or adopted (or how dogs and cats from shelters are sometimes fostered or adopted), you can take this opportunity to remind students that human families are created in a variety of ways that are not just biological. Acknowledge the validity of all kinds of human (and animal) families.

Other animals (domesticated or wild) may form family groups very differently than we do, or they may not form family groups at all. In this particular case calves are sometimes raised by nursing from their individual female

parents, sometimes fostered to another milk-producing female, and are sometimes bottle fed and raised without adult animals.

Test predictions about relatedness. Display **slide O** to reveal the older calf, Jesse, that is the biological offspring of Cubby and Ballerina, to confirm student predictions.

Consider the mechanism of passing on the heavily muscled trait. Show **slide P**. Say, *OK, this is great. We're feeling pretty confident about this model, and it seems like there is definitely something to the idea that having big muscles is passed on from the parents, but how does that actually happen? What happens that allows parents to pass on big muscles to their offspring? Let's think about what happens when parents produce an offspring.*

Key Ideas

Purpose of this discussion: To help students make their reasoning with evidence public so that other students can connect with the ideas about the inheritance of phenotype, critique these ideas and build on them by motivating students to need to zoom in to look at the egg and sperm cells under a microscope so we can figure out what is getting passed on to the offspring. Students also have an opportunity to use their shared understanding to make predictions about expected phenotypes.

Listen for these ideas:

- We're wondering *how* the extra-big muscles physically get from parents to their offspring.
- We want to know what's inside egg and sperm cells.

Additional Guidance

Asking 8th grade students to discuss or reference their knowledge of sexual reproduction as part of any scientific investigation can be challenging. In this lesson, we are using only the broadest outlines and most basic definitions of sexual reproduction, but terms like egg, sperm, fertilization, mating, and reproduction are important for understanding what is actually happening with chromosomes in this lesson. They will necessarily come up in discussions.

Keep the focus of any discussion on using what we know from our academic learning to move our science thinking forward. If, as students talk with you and with their partners, you insist that they

- stick to scientific terms and
- avoid sharing any details that are not relevant and necessary for the sensemaking they are doing it will help keep their attention on the microscopic, biological processes they are trying to understand in this lesson.

Suggested prompts	Sample student responses
So how do parents produce an offspring?	*They have to mate.*
What does this line connecting both parents in the pedigree physically represent?	*It's reproduction, and both parents contribute something to make the baby.*

Suggested prompts	Sample student responses
What actually happens in reproduction with two parents?	*sex or mating*
What actually has to happen with that egg and sperm for there to be a baby calf?	*The parents contribute egg and sperm.* *The egg and sperm come together to make the baby.* *The egg needs to be fertilized by the sperm.*
OK, so we have this sperm, which is one cell, and it merges with the egg, which is also one cell. They combine—that's called fertilization—and that's how we get the baby. But then is a baby calf just one giant cell?	*No, it can't be one giant cell.* *A baby calf has bones and muscles and blood like we saw in the Unit 6.6: How do living things heal? (Healing Unit), and we know those are all made of different kinds of cells that do specific jobs—it can't be just one cell.*
So how can that single cell get to be a calf?	*We saw in the Unit 6.6: How do living things heal? (Healing Unit) that cells can grow and split to make more of themselves. That's how muscles and bones and all those tissues can grow and get bigger.*
*OK, so the baby starts with this combination of sperm and egg, and from this combination, its cells will continue to grow and split and make more of themselves. But what was in the egg and sperm that eventually made it so the baby had extra-big muscles?**	*Maybe there are some tiny parts of muscles in the egg and sperm that the baby can use to make its own big muscles.* *Maybe there are genes or something else that gets passed into the baby cell.* *We're not sure … maybe we need to look inside the egg and sperm to see.*

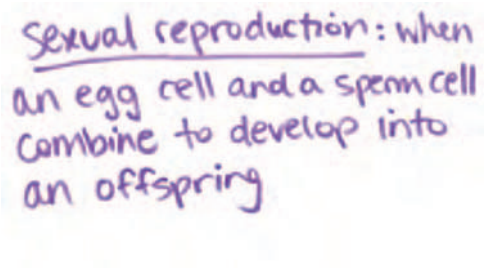
Display **slide Q** to uncover the ideas about eggs and sperm and fertilization that students have just discussed.

Additional Guidance

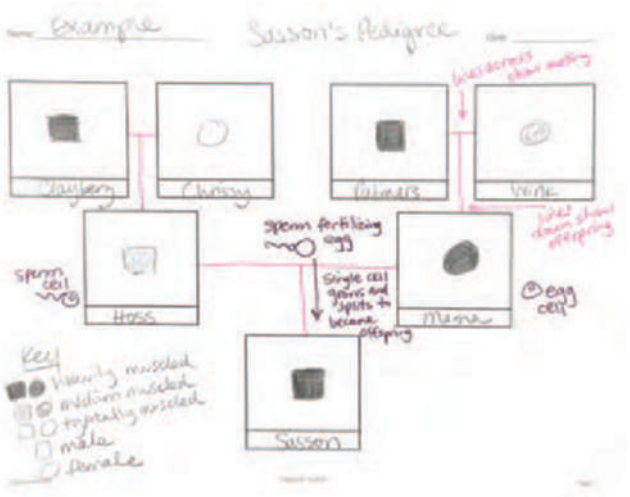
Students may bring up the idea that the fertilized egg can't have muscle cells because it is a single cell (and muscles are made of many cells). If a student does bring this up you might ask about the proteins that muscle cells are made of that students discovered in Lesson 2. Ask them if it may be worth checking to see, even if entire muscle cells are not transmitted, whether the stuff that makes up muscles can be transmitted.

Update the graphic organizer to show egg, sperm, and fertilization. Say, *It sounds like we should zoom in to the egg and sperm cells to see what they might be contributing to their offspring. We'll do that next time. First, let's record what we know on our pedigrees. Show the types of sex cells produced by the parents and show them combining for fertilization. Add any additional notes that will help you understand what is happening. For the sake of space and neatness, make these additions only to the parents and offspring, not the grandparents.*

Add "sexual reproduction" to the Word Wall. Start with the ideas you've just discussed as a class, and you may come back and add to this definition later in this lesson and again in Lessons 13 and 14. Your definition for now may be something like this: *when an egg cell and a sperm cell combine to develop into an offspring.*



Collect one notebook from each group to check phenotypes if desired. Everyone in each group should have the same information recorded, so checking just one notebook per group should be sufficient.



End of day 1

5. Investigate what is found inside egg and sperm cells.

12 MIN

Materials: science notebook, transparent tape, *Chromosomes in Sex Cells*, scale simulations (See the **Online Resources Guide** for a link to these items. **www.coreknowledge.org/cksci-online-resources**)

Redistribute notebooks. If notebooks were collected from some students to check phenotype assignments, redistribute them to those students.

Review what we want to investigate next. Have a student recall what we had decided to do at the end of the last class (look more closely at egg and sperm cells) and why we wanted to do that. Have a student clearly articulate what it is we're trying to figure out by looking more closely at egg and sperm cells:

- We're trying to figure out what gets passed on from parents—whether the offspring actually get muscles or parts of muscles from the egg and sperm or whether they get something else from the egg and sperm.

Display **slide R**. Ask students to turn in their science notebook to the next blank page and create a Notice/Wonder chart for this activity. They should write the question we're trying to answer (or what we're trying to figure out) at the top of the page in their own words.

Facilitate a conversation to share noticings and wonderings. Allow students some time to observe the information on the slide. Then, use the suggested prompts below.

Suggested prompts	Sample student responses
What do you notice about what is in the egg cells and the sperm cells compared to the muscle cells?	*There are some things they all have in common, like tubulin and histones, and they all have water and glucose, but then each cell has some components that are different.* *Sperm cells have spermosin and lysin.* *Egg cells have albumin and lysin receptor proteins.* *We learned before that muscle cells have actin and myosin, but we can see here those proteins show up in the muscle cells but not in the egg and sperm cells.*
Can pieces of the muscle cells be traveling to the offspring to give them the same types of muscles?	*No, because if there were pieces of muscle cells in the sperm and egg we would see actin and myosin in there too, but we don't see those proteins.*
What could we do to get more information?	*We could look at the egg and sperm cells under a microscope to see if we can see what is in them.*

Examine pictures of sperm and egg cells at a microscopic scale. Show **slide S**. Explain that these are the basic parts of sperm and egg cells that can be seen with a microscope. Ask, *What structures do they have in common?* Students should identify the *nucleus*, *cytoplasm*, and *cell membrane* that they are familiar with from *Unit 6.6: How do living things heal? (Healing Unit)*. Point out that

- the cytoplasm is where the glucose and water and many proteins are found in all cells
- the nucleus is also a major part of both cell types
- egg and sperm are not to scale—eggs are *much* larger than sperm!

Show students the relative size of egg and sperm using the simulation. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Students may want to add noticings and wonderings to their charts about the relative sizes of objects of interest.

Alternate Activity

If the simulation Cell Size and Scale (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) does not work for you, use the similar *The Scale of the Universe 2* instead. Note that this alternative simulation plays music in the background, so you will want to mute your computer's sound. Also, only a human egg cell is shown in the alternative simulation, so you'll want to point out to students that a human sperm cell is about 50 micrometers (including its tail), or about 2 of the "thou" markings shown in that simulation.

Note that we see a nucleus in both cell types. Say, *Let's zoom in on the nucleus of these cells*.

Examine pictures of the nuclei of egg and sperm cells. Show **slide T**. Explain that the images on the slide are taken from micrographs showing what you would see inside the nuclei of egg and sperm cells if you used a microscope to zoom way in. Ask students to take a moment to record what they notice and wonder about what is inside the egg and sperm cell nuclei.

Suggested prompt	Sample student responses
What similarities and differences do we notice between the egg and sperm nuclei?	*Both cells have squiggly structures that are all different sizes.* *Some of the squiggly things are straight and some are bent.* *It looks like they are striped or have bands that are dark and light.*

Examine chromosomes in egg and sperm cells. Give all students a copy of *Chromosomes in Sex Cells*. Ask them to work individually to continue to add to their Notice and Wonder chart now that they can work more closely with the material. Encourage them to mark up the handout as needed to compare, looking for similarities and differences.

After a minute or so, come back together as a class to share ideas.

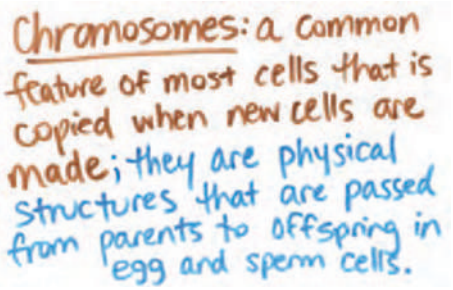
Suggested prompts	Sample student responses
What patterns did you notice now that you could look at these cells up close? What's the same and what's different about the structures you see?	*All the structures definitely looked different from each other within each cell.* *The structures also looked different than any that were in the other cell too.*
(If a count has not yet been reported) Is the number of structures in these cells the same or different?	*The same. The sperm and the egg each have thirty structures.*
What do you think happens to these structures when the sperm fertilizes the egg? What do you predict you will see in the new cell?	*We think the structures will combine together into one new cell.* *There will be a total of sixty structures in the new cell.*
Do you remember what happens to this new cell?	*It's the one that will grow and split to make new cells to make up all the cells in the baby.*

Say, *We've been referring to these things in the nucleus as "structures" or "squiggly things," and I even heard a few people mention the word "chromosome" a while back. These structures are in fact called chromosomes.*

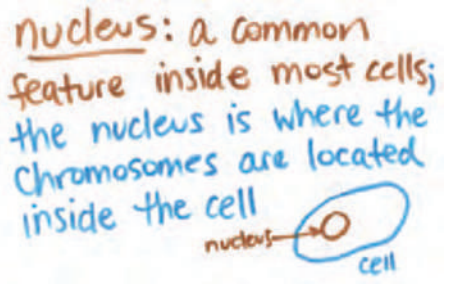
Suggested prompt	Sample student responses
Now that we have a better idea of what these structures are, do you think we can add the word "chromosome" to our Word Wall? What about these chromosomes would help us describe them?	*Chromosomes are passed from parents to offspring.* *They are found in the nucleus of egg and sperm cells.* *We think they come together during fertilization.* *There are a lot of them.* *They have different patterns on them. It looks like there are lots of different ones.*

Add "chromosome" and "nucleus" to the Word Wall. In each of these example definitions, what we know from *Healing Unit* is listed first and then the details we have just figured out.

- Chromosomes: a common feature of most cells that is copied when new cells are made (from *Healing Unit*); they are physical structures that are passed from parents to offspring in egg and sperm cells.



- Nucleus: a common feature inside most cells (from *Healing Unit*); the nucleus is where the chromosomes are located inside the cell.



Additional Guidance

If students say that these chromosomes have "genetic information" on them, include that. Otherwise, this part of the definition will come out later. Additionally, some students may want to add that there are half the number of chromosomes in egg or sperm as there are in body cells. If they want to add this now, tell them that we should confirm this for sure first (which will lead into the next activity).

6. Discover patterns using karyotypes.

20 MIN

Materials: science notebook, transparent tape, *Chromosomes in Sex Cells*, *Karyotype of Lorenc's Muscle Cell*

Make predictions about muscle cells. Show **slide U**. Say, *Check in with your elbow partner. What do you predict we would see if we were to zoom in to the nucleus of one of Lorenc's muscle cells at the same level we did for the egg and sperm cells?* Allow students to talk for a minute, then have a few students share their predictions. Ask students to share their reasoning for the predictions they are making. Accept all answers but emphasize the following predictions. If these predictions do not surface quickly, ask probing questions to help students articulate them:

- Muscle cell nuclei will have 60 chromosomes (because we think 30 chromosomes from the egg and 30 from the sperm come together to make the cells of the offspring).

*** Supporting Students in Developing and Using Patterns**
This is a challenging activity, and students may struggle to find exact matches to the chromosomes from the karyotype. The chromosomes called out are the ones with the most distinct patterns and

- Half the chromosomes in the muscle cells will be from the egg (or female parent) and half from the sperm (or male parent) because in the cell that starts the offspring in fertilization, there are an equal number from the egg and from the sperm, and those just get copied to make up all the offspring's cells.

Examine chromosomes in muscle cells. Show **slide V**. Say, *Scientists have also found chromosomes in the nuclei of muscle cells of cattle. And not just muscle cells; they also find them in skin cells, bone cells, brain cells, lung cells, and liver cells. Chromosomes can be found in the nucleus of the cells that make up the rest of the body structures too.*

Show **slide W** and say, *Can you tell if your predictions are correct? We expected to see sixty chromosomes. Did anyone confirm that there are sixty chromosomes? This is pretty messy and really tough to try to make sense of. Wouldn't it be nice to have them organized in some way? Scientists actually do this using photographs of the chromosomes they find within a body cell of an organism. They organize them in a way that's called a* karyotype.



Give each student a copy of *Karyotype of Lorenc's Muscle Cell*.

Say, *Scientists organize the chromosomes like this so they are able to see patterns. This is the karyotype of Lorenc's muscle cells. However, if we were to look at the chromosomes in any of his other body cells, they would have the same number of chromosomes and could be organized the exact same way.*

Describe patterns in the karyotype. Display **slide X**. Have students talk briefly with an elbow partner about what patterns they see in how chromosomes are organized in karyotypes. Circulate among students as they talk to listen for whether they are distinguishing the following patterns. Ask probing questions to direct their attention to patterns they might miss. It is not necessary that students notice all these patterns, only that they focus on discerning what patterns exist. They will share and consolidate the important patterns in the Building Understandings Discussion that follows.

- There are 30 different pairs of chromosomes.
- There are 60 chromosomes in total.
- They are in order from largest to smallest.
- The pairs are numbered in order.
- A lot of the patterns of the stripes on the pairs look pretty similar to each other.
- There's an X and a Y that don't seem to match.

Additional Guidance

Students will likely notice the X and Y chromosomes on the cattle karyotype. In cattle and humans, biological sex is determined by an XX/XY system. Keep in mind the difference between biological sex and gender. This unit does not address gender but deals only with biological sex.

Here is some additional information about XY chromosomes for your teacher background knowledge: A functional SRY gene on the Y chromosome, once activated, creates testosterone and anti-mullerian hormone, which typically

should be the easiest ones to find. Encourage students to focus on the major characteristics—shape, size, distinct bands—of the chromosome they are trying to locate, and to scan over both sperm and egg cells to try to find a chromosome with the exact same pattern. They may want to rotate the page with the sex cells to try to orient the chromosomes the same way as they compare them between muscle karyotype and sex cells.

As you work with students, be careful not to approach the identification with the assumption that one of each pair will be found in each sex cell. Rather, have them scan both sex cells for each member of the chromosome pair. Students should come to the conclusion themselves that one copy of each chromosome pair comes from each parent cell.

causes the development of a male reproductive system. Without a Y chromosome and functional SRY, an XX embryo develops into a female. While SRY is central, there are many other genes involved in influencing maleness. When SRY is mutated and produces a nonfunctional protein, the individual presents externally as female (and is usually raised as a female, that is, has a female gender identity) but has XY chromosomes and underdeveloped ovaries (therefore, the individual cannot bear children). There are several other systems for determining sex, some genetic (like XX/XY) and some environmental, like the effect of temperature on sex of reptiles.

Clarify the question we are trying to answer. Say, *We've seen that muscle cells have sixty chromosomes, so that's the number we predicted. What else are we trying to figure out?* Have a student clearly articulate what it is we're trying to figure out.

- We're trying to figure out where each one of Lorenc's chromosomes came from.

Ask, *How would we be able to tell where the chromosomes in Lorenc's muscle cells came from?*

Students should say we need to compare the actual chromosomes from Lorenc with those from the egg and sperm from Sparkle and Jim.

Additional Guidance

Students might not understand that one copy of a chromosome comes from the female parent and the other copy of the same chromosome comes from the male parent, even if they know that half the genetic information comes from each parent. They might think that chromosomes 1-15 come from one parent and chromosomes 16-29 (and XY) come from the other parent or any other version of dividing the chromosomes in half. The following activity should help students sort out that each parent contributes one copy of each of the chromosomes.

Observe patterns between the chromosomes from parent egg and sperm and those in the offspring muscle cell. Display **slide Y** and direct students to lay each of their handouts (*Chromosomes in Sex Cells* and *Karyotype of Lorenc's Muscle Cell*) side by side on their desks. Say, *We will be writing on these pages. After we're done with this activity, we will fold and tape these pages into our notebook to keep this record of our work.**

Have students write the question we're trying to answer (or what we're trying to figure out—Where did each of Lorenc's chromosomes come from?) at the top of the karyotype page in their own words.

Display **slide Z**. Explain the directions. Say, *Even with the chromosomes organized this way, there are still a lot of things to pay attention to. Maybe if we just focus on a few of these chromosomes at a time, it will be easier for us to make sense of how they are organized. Let's try to figure out where these chromosomes come from, but let's look at just chromosome 6 first so we're not overwhelmed. Can you find chromosomes in Sparkle's egg and/or Jim's sperm that are the same as the ones in the karyotype of Lorenc's muscle cell for just chromosome 6? Work with an elbow partner to highlight, draw circles, or use labels to show where in the egg or the sperm you found each of the chromosome 6's that are in Lorenc's muscle cell. After you find both copies of chromosome 6 in the egg and the sperm, do the same with chromosome 22 and then with chromosome 2 and chromosome 9.*

If needed, you may choose to work through finding chromosome 6 together as a class example.

Note that there is not a pattern to which chromosome (from the male parent or the female parent) comes first in the pairs on the karyotype.

Discuss what students discovered about these chromosomes in a Building Understandings Discussion. Display **slide AA**. Guide the discussion using prompts such as those that follow.



Key Ideas

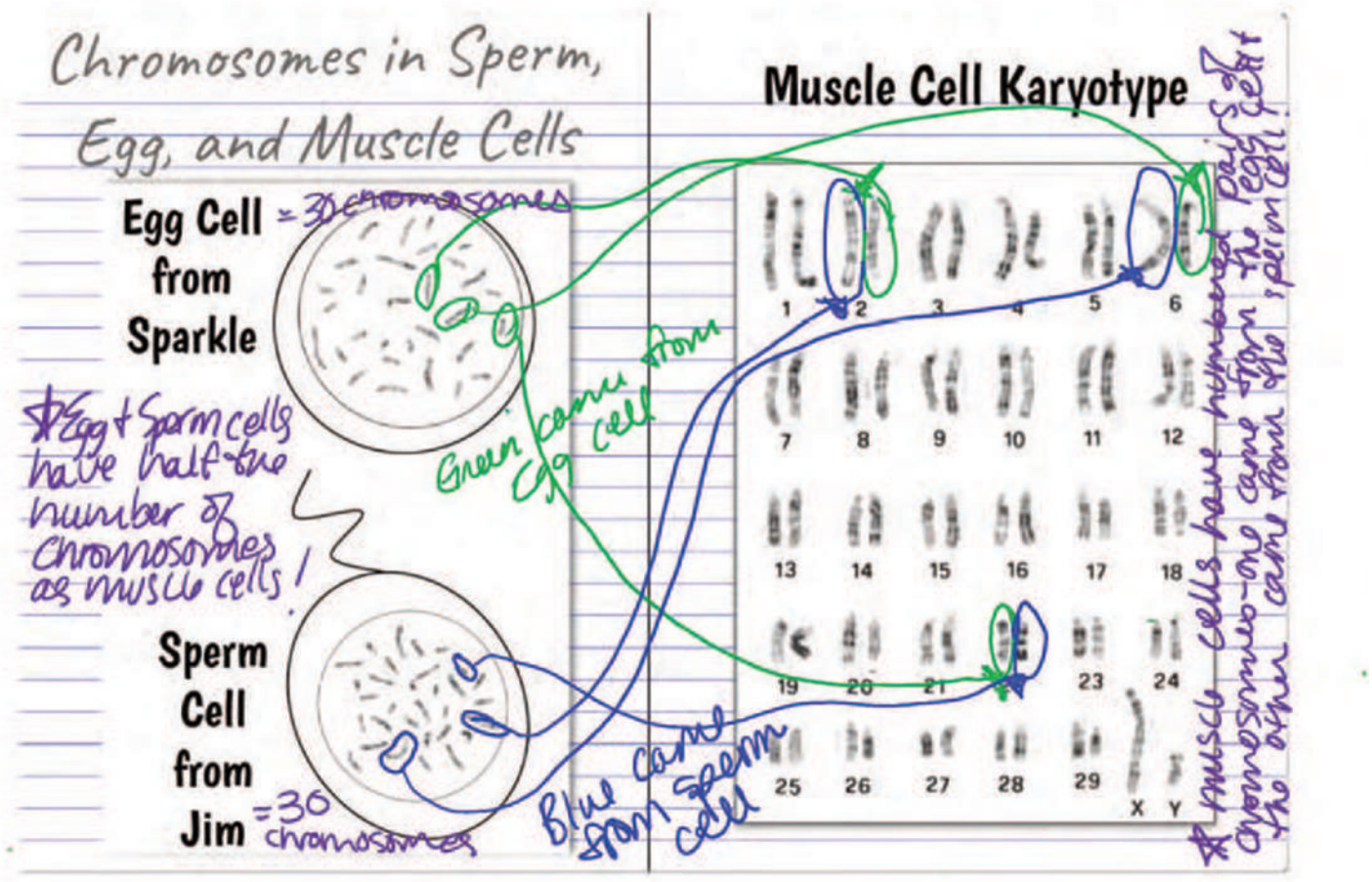
Purpose of this discussion: To help students make their reasoning with evidence public so that other students can connect with the ideas about the inheritance of chromosomes. We will also build on these ideas by motivating the need to zoom in even closer to see what is going on with these chromosomes.

Listen for these ideas:

- Chromosomes are passed from parents to offspring when the sperm and egg fuse during fertilization.
- Egg and sperm have half the number of chromosomes as the muscle cells.
- The karyotype shows that muscle cells have two of each kind of chromosome.
- By comparing the chromosomes found in the karyotype to those in the egg and the sperm, we see that one chromosome from each pair comes from one parent and one comes from the other parent.
- We're wondering HOW the chromosomes are related to our cattles' phenotype.

Suggested prompts	Sample student responses
What patterns did you see? How are these chromosomes organized?	*There are sixty total, but they are organized into thirty pairs.* *The pairs seem to be about the same size but the bands/ strips look different.*
Why do you think they are organized this way? Where did these chromosomes come from?	*Each pair seems to be organized so one came from the sperm cell and one came from the egg cell.* *The pairs on the karyotype are not always in the same order, sometimes the one from the egg is first and sometimes the one from the sperm is first.*
Can you point to specific evidence that supports your ideas?	*When I looked at chromosome 6 on the karyotype of Lorenc's muscle cell, one chromosome in the pair was shaped like a "C" so that was easy to find, and I found it in Jim's sperm cell. I started looking for the other chromosome that was part of the pair and found it in Sparkle's egg cell. We did the same for chromosomes 22, 2, and 9 as well.*
Do you think all the other chromosome pairs are organized the same way—one from the sperm and one from the egg?	*It seems like they would organize them the same way for all the chromosomes.* *Yes, it seems like for each pair of chromosomes in Lorenc, one comes from the female parent and one comes from the male parent.*

Suggested prompt	Sample student responses
Do you have any new questions about these chromosomes or about how they might help us figure out about our heavily muscled cattle?	*What is "on" the chromosomes?* *Why are some the same size but the stripes are different?* *How do these chromosomes relate to muscles? We know they are not made of actin and myosin.* *Can we look even closer at the chromosomes to see if we can learn more about them?*



Assessment Opportunity

Building towards: 5.B Develop and use a model to describe the unobservable mechanism of fertilization in which parents each contribute half of the chromosomes an offspring has, by discerning patterns in the number and types of chromosomes in the sex cells of parents and the body cells of offspring.

What to look and listen for: As they work with their partners, listen for students using evidence from the patterns of banding they see on the images of chromosomes to support the idea that one of the chromosomes that make up each pair of chromosomes in the offspring karyotype came from a parental egg, and one from a parental sperm cell. Look for annotations in the science notebook that link the parental and offspring chromosomes to each other.

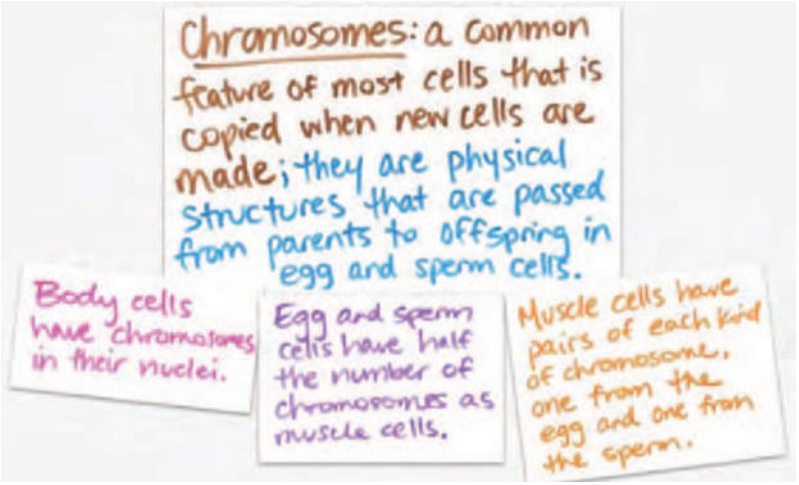
What to do: Detailed visual patterns such as the ones that distinguish the chromosomes from each other can be difficult to process. Help students to focus on the major distinguishing characteristics of the chromosomes they are looking to find (Are they bent in a particular way? Do they have a dark band at one end or the other? Do they have any uniquely shaped bands?) and then look to see whether smaller details match up. It may also be helpful for students to scan through all the chromosomes in egg and sperm cells one at a time, or in an organized way (such as from top to bottom, and then left to right) to assure that they have considered the patterns on all the chromosomes in the egg and sperm cells.

Return to the Word Wall to update our definition of *chromosome*. Say, *I feel like we've already learned a lot more about these chromosomes (and I'm sure there's still more to figure out!). Let's add to our definition of chromosomes now that we know more about them.*

Use sticky notes, index cards, or quarter-sheets of copy paper to add details such as the following to the chromosome card on your Word Wall.

- Egg and sperm cells have half the number of chromosomes as muscle cells.
- Body cells have chromosomes in their nuclei.
- Muscle cells have pairs of each kind of chromosome, one from the egg and one from the sperm.

Have students fold and tape the *Chromosomes in Sex Cells* and *Karyotype of Lorenc's Muscle Cell* handouts into their notebook to keep this record of their work.



7. Make predictions about the number of chromosomes.

5 MIN

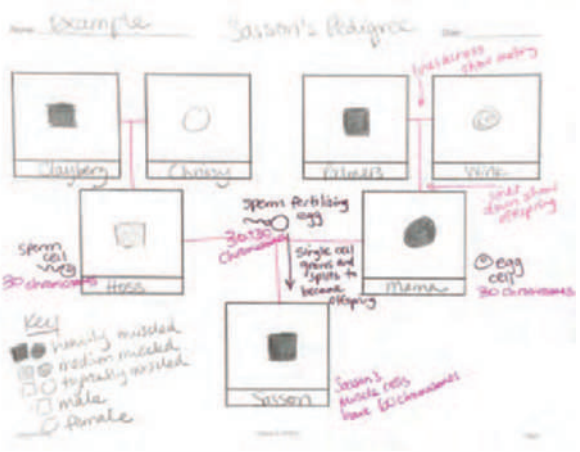
Materials: None

Update the *Family Phenotype Graphic Organizer*. Show **slide AB**. Say, *Let's go back to the page in our science notebook with our cattle pedigrees and use this new information about egg, sperm and muscle cells to add the number of chromosomes we see in each type of cell for the individuals we looked at.*

Make predictions about the number of chromosomes in the rest of the cells. Show **slide AC**. Say, *We figured out that there are thirty chromosomes in Jim's sperm cell and the same amount in Sparkle's egg cell. Then we wondered if, when*

these two met, the offspring would have sixty chromosomes in their muscle cells and other body cells, and we saw this was true, right?

Suggested prompts	Sample student responses
Let's start with Lorenc, we saw his muscle cells have thirty pairs of chromosomes to give him sixty total. How many do you think the muscle cells of Jim have? Sparkle?	*Since they are all cattle it seems like they should have the same amount.*
OK, so if they each have sixty chromosomes in their muscle cells, and made sex cells with only thirty chromosomes, how many chromosomes do you predict will be in the sperm cells that Lorenc will make?	*Lorenc will have thirty chromosomes in the sex cells he produces.*
Do you think his sperm cells will just have a randomly chosen set of thirty?	*It would make sense if one of the chromosomes from each pair was in a sex cell. Otherwise his offspring might miss a chromosome or have too many of some kind.*
What if we looked at humans? Humans have forty-six chromosomes (twenty-three pairs) in muscles and other cells that make up their bodies. How many chromosomes do you think are in the egg or sperm that humans produce?	*If the same pattern is followed, there would be twenty-three chromosomes in the egg and sperm of humans.*

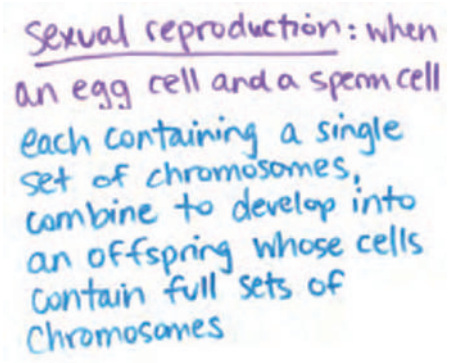


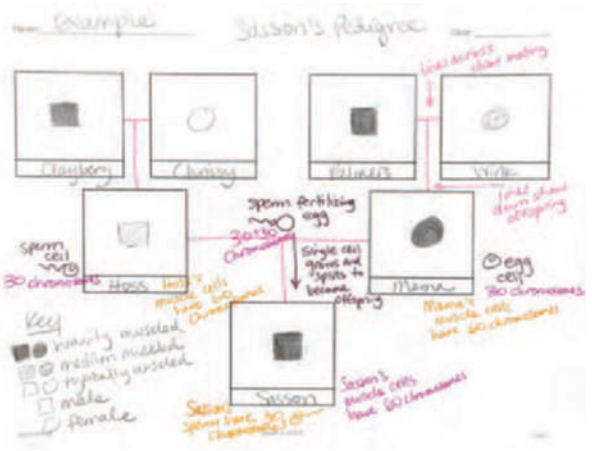
Additional Guidance

If students are struggling to think about how the chromosomes get "sorted" to divide in half to make egg and sperm, go back to the previous slide and circle one of each of the pairs that can end up in a sperm cell.

Update the pedigree to include the number of chromosomes in the other cells. Say, *OK use this new information to update the pedigrees in your science notebook one more time.* Display **slide AD** to confirm student predictions while they add the chromosome numbers to their science notebooks.

Update the Word Wall definition of ***sexual reproduction.*** Add what we have figured out about chromosomes, so the new definition is something like this: *when an egg cell and sperm cell, each containing a single set of chromosomes, combine to develop into an offspring whose cells contain full sets of chromosomes.*





8. Navigation and Progress Tracker Update

8 MIN

Materials: science notebook

Reflect on what we know and what we still need to figure out. Advance to **slide AE** and say, *OK, we made a lot of progress today, so let's record that.*

Have students open their science notebooks to their Progress Tracker pages. They should add the ideas we've figured out as well as any questions this learning has raised for them.

In the example Progress Tracker row for this lesson, each column has been completed with *possible* student ideas.

Question	What I figured out in words and/or pictures
Where do the babies with extra-big muscles get that trait variation?	*The phenotype for musculature develops in offspring who are born from one or more heavily muscled parents.* *Since there is no actin or myosin in the sperm and egg cell, parents are not passing the musculature phenotype by passing on muscle in egg and sperm.* *Chromosomes are passed from parent to offspring when the sperm and egg combine during reproduction—that is the only physical matter that's passed along (maybe a little food, but not actually myosin or actin).* *Individuals have 2 sets of chromosomes in their muscle cells, one set comes from one parent (that was in an egg cell) and the other set comes from the other parent (in a sperm cell). These two sets of chromosomes are found in all their body cells.* *Sex cells only have 1 set of chromosomes. All chromosomes in the egg and in the sperm that fertilized the egg combine to give the 2 sets found in the offspring's muscle cells.*

After a few minutes of work time, display **slide AF** and use prompts such as those shown here to navigate to next time's work.

Suggested prompt	Sample student response
So let's restep through how we're explaining how calves with extra-big muscles get that trait variation. . . We see patterns that show that extra-big muscled babies get their muscles somehow from their parents, right?	*Right.*

Suggested prompts	Sample student responses
What is it that male and female parents actually contribute physically to the baby?	*They contribute sperm and egg cells that have chromosomes in them.*
Do they contribute muscles or muscle proteins in the sperm and eggs?	*No.*
So what is in the baby's muscle cells that comes from the parents?	*Muscle cells and other body cells have chromosomes in their nuclei. Those chromosomes come from the parents.*
So how do babies get big muscles from chromosomes? What are the chromosomes actually doing?	*We need to figure that out next.* *How do chromosomes make big muscles?*

Close today's work by saying something like, *It sounds like we have a question to investigate next time.*

LESSON 6

How do chromosomes cause cattle to be born with extra-big muscles?

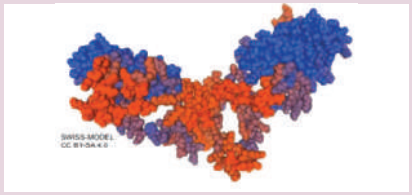
Previous Lesson

We observed cattle family photos to figure out that offspring inherit their musculature from their parents. We analyzed chromosomes from a muscle cell karyotype and from parental sex cells to learn that each parent contributes one of each type of chromosome to their offspring.

This Lesson

Investigation

2 DAYS



Waterhouse, A., Bertoni, M., Bienert, S., Studer, G., Tauriello, G., Gumienny, R., Heer, F.T., de Beer, T.A.P., Rempfer, C., Bordoli, L., Lepore, R., Schwede, T. SWISS-MODEL: homology modelling of protein structures and complexes. Nucleic Acids Res. 46, W296-W303 (2018).

In this lesson, students observe images of chromosomes to support discussions of these super-small yet hugely complex molecules. As such, the chromosome data students use in this lesson are simplified into colored geometric shapes symbolizing different alleles. Students reorganize their cattle photos with added information about each individual's chromosomes and the versions of the myostatin protein each has. Each group constructs an initial model to explain the connections they found, and then the class works to build a consensus model showing correlation. Finally, students read and synthesize two articles to find evidence of causal relationships among alleles, proteins, and phenotypes.

Next Lesson

We will update our classroom consensus model and revise our initial models to include our recent findings about the roles of genes, alleles, and the myostatin protein in development of the typically, medium-, and heavily muscled phenotypes. Using our model, we will predict that a sibling's phenotype will be the same, but we see examples of cattle siblings with different phenotypes, so we will need to figure out more about that next time.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5

What Students Will Do

6.A Develop and use a model to describe correlational relationships among chromosome pairs containing two variants, specific proteins, and the trait of musculature.

6.B Critically read scientific texts to obtain evidence that a distinct gene is the cause for the production of a specific protein related to the trait of musculature.

What Students Will Figure Out

- Chromosomes have specific regions called genes, and the different possible forms of the genes are called alleles.
- The different alleles of the genes (the genotype) determine the protein(s) that gets made.

- Different forms of a protein, like myostatin, can lead to variations, like extra-big or typical muscles.
- Scientists changed the shape of a gene in mice to figure out that a different allele causes the different-looking myostatin protein, which results in the heavily muscled phenotype.
- Animals that are heavily muscled have two copies of the allele that causes the partial myostatin protein.
- Myostatin is a protein. Its function is to fit into a receptor on a cell. When it fits in correctly, muscles develop typically. When it doesn't fit correctly, the result is extra-big muscles.

Lesson 6 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** Discuss what was figured out in the previous lesson about chromosomes and consider zooming in to look closer at them.	A	
2	10 min	**USE SYMBOLS TO SUPPORT WORK AT THIS SCALE** Zoom in on chromosomes and discuss their small scale. Plan how we can investigate something so small yet so complex.	B-G	
3	7 min	**REVISIT PROTEINS AND INTRODUCE A NEW PROTEIN** Recall what we know about proteins, explore the scale of proteins compared to chromosomes, and look at a new protein.	H-J	scale simulations (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
4	10 min	**ORGANIZE CATTLE BY NEW INFORMATION TO LOOK FOR PATTERNS** Work in groups to look for patterns in the new chromosome and protein data about our cattle.	K-N	*Guiding Questions for Chromosome and Protein Data*, transparent tape, *Protein and Chromosome Data Cards* (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)
5	15 min	**DEVELOP INITIAL MODELS IN SMALL GROUPS** Construct initial models in groups explaining the connections they found with the musculature of their cattle and their chromosome and protein data.	O	chart paper, markers
				End of day 1
6	5 min	**GALLERY WALK THROUGH INITIAL MODELS** Circulate individually among the groups' different initial models to look for similarities and differences.	P	initial models from day 1

Part	Duration	Summary	Slide	Materials
7	8 min	**DEVELOP A CONSENSUS MODEL FOR CORRELATIONS** Co-construct a classroom consensus model summarizing correlations among the cattle's muscle phenotype, chromosome information, and myostatin proteins.	Q	initial models from day 1, chart paper, markers
8	12 min	**READ ARTICLES FOR EVIDENCE SUPPORTING CAUSATION** Read and then use a jigsaw strategy with a partner to summarize ideas that provide supporting evidence of the cause-effect relationships among chromosomes, the myostatin protein, and the phenotype of musculature.	R-U	*Version 1: New Protein Linked to the Heavily Muscled Phenotype* for half the class, *Version 1: Function of the Myostatin Protein* for half the class
9	15 min	**CONSENSUS DISCUSSION ABOUT CAUSES OF THE HEAVILY MUSCLED PHENOTYPE** Come to consensus about the terms *gene*, *allele*, *genotype*, and *phenotype* and about how scientists were able to support causation of the heavily muscled phenotype.	V-X	*Version 1: New Protein Linked to the Heavily Muscled Phenotype* for half the class, *Version 1: Function of the Myostatin Protein* for half the class
10	5 min	**UPDATE PROGRESS TRACKERS** Record in the Progress Tracker what we have figured out about the relationship among the heavily muscled phenotype, chromosomes, and the myostatin protein.	Y	
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 6, students are ready to read Student Reader Collection 2 and then respond to the writing exercise.		Student Reader Collection 2 : *Born or Built*

Lesson 6 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Guiding Questions for Chromosome and Protein Data* • transparent tape • *Version 1: New Protein Linked to the Heavily Muscled Phenotype* for half the class • *Version 1: Function of the Myostatin Protein* for half the class	• *Protein and Chromosome Data Cards* • chart paper • markers • initial models from day 1	• Cell size scale simulation found at (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • initial models from day 1 • chart paper • markers

Materials preparation (20 minutes)

Online Resources



Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make a copy of *Guiding Questions for Chromosome and Protein Data* for each student. Trim the copies to fit in student notebooks.

Have half-sheets of copy paper ready to add the following words to the Word Wall: *gene, alleles, genotype*. Do not post these words on the wall until after your class has developed a shared understanding of their meaning.

Prepare the texts students will read. Half the class will need *Version 1: New Protein Linked to the Heavily Muscled Phenotype* or *Version 2: New Protein Linked to the Heavily Muscled Phenotype* and the other half of the class will need *Version 1: Function of the Myostatin Protein* or *Version 2: Function of the Myostatin Protein*. These articles can all be found in the *Student Edition* or copied as handouts. Consider intentionally assigning certain students different versions of these articles based on what you know about them as readers.

- *Version 1: New Protein Linked to the Heavily Muscled Phenotype* summarizes a very complicated scientific study, and as such even this text adapted for classroom use is relatively complex.
- *Version 1: Function of the Myostatin Protein* is a bit longer but is less complex and supported by diagrams (still fitting for readers at the end of 8th grade).
- *Version 2: New Protein Linked to the Heavily Muscled Phenotype* and *Version 2: Function of the Myostatin Protein* are the same articles as the first two readings but have both been further modified to make the text less complex.

If you anticipate that your students will struggle to understand these texts when reading independently, it is perfectly acceptable for you to have students work with a partner to complete that task and then create a group of four for sharing the ideas from both articles.

Test the cell size scale simulation to be sure it works with your computer and projector (you will view it as a whole class). If you need an alternative, a very similar scale simulation *The Scale of the Universe 2*. (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)

Gather the *Protein and Chromosome Data Cards* from your materials kit. If you do not have premade cards from the materials kit, see the **Online Resources Guide** for links to these items (**www.coreknowledge.org/cksci-online-resources**), and prepare them as follows:

- Print 2 color copies on cardstock of *Protein and Chromosome Data Cards* and cut the cards apart to make 70 individual cards (2 sets of 35).
- In this lesson, you will only use one card per student. Be sure to collect these cards because students will reuse them in Lesson 8 in their family pedigree groups.
- Consider laminating these cards since you will reuse them for each class you teach and can keep them year to year.

There are a total of 35 different cattle used in Lessons 5 and 6. Eighteen of them have "extra-big" muscles, 7 of them have "medium" muscles, and 10 of them have "typical" muscles. With fewer than 35 students in your class, leave out some of the heavily muscled cattle (and possibly a few with typical muscles) when you're distributing the *Protein and Chromosome Data Cards* so that all cattle phenotypes are evenly represented in this investigation.

Lesson 6 • Where We Are Going and NOT Going

Where We Are Going

When students are considering the structure and composition of chromosomes at the beginning of this lesson, they recall seeing atoms and molecules in living things from *Unit 7.3: How do things inside our bodies work together to make us feel the way we do? (Inside Our Bodies Unit)* and *Unit 7.4: Where does food come from, and where does it go next? (Maple Syrup Unit)*.

In this lesson, students figure out that the partial myostatin protein is related to the heavily muscled phenotype (they see correlation first and then read evidence of causation). They also find out how myostatin works to influence musculature, including the derivation of the name "myostatin." This lesson also names "gene," "allele," and "genotype" to help students use scientific terms as they discuss the patterns they're seeing.

Where We Are NOT Going

In this lesson, students read a summary of the study that linked the myostatin protein to the heavily muscled phenotype in mice. The study authors called the protein GDF-8 at the time, but it was later named myostatin, and, outside of the readings, we refer to it only as myostatin in this unit to avoid confusion. The summary does not go into detail about the gene-targeting process the scientists used. Additionally, the details of how they bred the mice to get the genotypes they wanted to study is not mentioned in the summary because students do not learn about inheritance patterns until Lesson 9 of this unit. DNA, transcription, and translation are out of the scope of the middle school grade band, so when students discover that a specific allele is the cause of a differently shaped protein, they connect it to differently shaped genetic material but not to the details of how the protein is produced.

When your class adds "genotype" to the Word Wall, you will likely define it as "the combination of alleles an animal has for a certain gene" because students haven't yet had evidence of genetic material in organisms other than animals or genes other than the one related to myostatin and musculature. You will update this definition later in the unit as the class has more examples to draw from.

LEARNING PLAN FOR LESSON 6

1. Navigation

3 MIN

Materials: None

Navigate to today's work from the last class. Display **slide A**.

Say, *Last time we were together, we started talking about chromosomes, but let's take a minute to make sure we remember where we left off.*

Suggested prompts	Sample student responses
What did we figure out last time about chromosomes?	*We know that chromosomes are what gets passed along from parents to offspring in the sperm and egg cells.* *Yeah, those chromosomes are pretty much the only thing that parents give to the babies to start growing!*
What patterns did we find between chromosomes and the extra-big muscles we're investigating?	*We saw patterns in the parents and offspring who had extra-big muscles.* *Each individual that had extra-big muscles also had at least one parent with extra-big muscles or both parents with medium muscles.* *But the muscle cells are not in the sperm and eggs!*
What did we decide we still need to figure out?	*Those chromosomes have something to do with that pattern of passing along the extra-big muscles. And we are trying to find out what chromosomes do because we're not sure!* *How do the chromosomes cause the extra-big muscles?*
In the last lesson we zoomed in on the sperm and egg cells to see what was inside them. If we also zoom in on chromosomes, how could that help us figure out what they do?	*Maybe there are other details about chromosomes that we are missing.* *If we zoom in we can observe them.*

2. Use symbols to support work at this scale.

10 MIN

Materials: None

Observe the molecular structure of chromosomes. Show **slide B**. Have students analyze the images on the slide and then move into a whole-class Initial Ideas Discussion.

Key Ideas

Purpose of this discussion: The purpose of this discussion is (1) for students to see that chromosomes have 3-D structure and (2) to demystify that chromosomes are some kind of magical structure they may have heard about in the news or be familiar with from their background knowledge. Instead, they are really, really long molecules made up of a few types of atoms that students have seen in living things before.

Listen for these ideas:

- Chromosomes have 3-D structure.
- The chromosomes kind of look like ropes, but they are actually made up of the same atoms we've seen before in living things in *Inside Our Bodies Unit* and *Maple Syrup Unit*.
- The scale of chromosomes is *really* small. It might be really hard to compare these structures.

Suggested prompts	Sample student responses
Compare the images on the slide. What do you notice about the structure of the molecular model of chromosomes?	*The chromosomes are made of lots of tiny subparts.* *They look like a twisted rope.* *They are made up of atoms.*
We've seen chromosomes represented in the karyotypes from inside cells, but these molecular models are a different type of representation. Do chromosomes look flat—2-D—or three-dimensional? What makes you think that?	*I think chromosomes looked flat in the karyotypes, but those seemed more like photos or x-rays, not like these models.* *Here they look 3-D. I think that because the structure of atoms looks like they are organized in a rope-like structure.* *The molecules look overlapping, which makes me think they have depth, like a 3-D structure.*
Which atoms make up chromosomes?	*hydrogen, oxygen, nitrogen, carbon, and phosphorus*
How do these types of atoms compare to those you've encountered in previous work in the Inside Our Bodies Unit and the Maple Syrup Unit?	*These are the same atoms we saw in food molecules in those units.* *Living things need these atoms. They get them from food.*

Problematize needing to use symbols to work at a scale too small to see. Display **slide C**.

Suggested prompt	Sample student responses
So now we have some different scales we could use to try to compare these chromosomes. We could stick with looking at karyotypes, or we could zoom in further and try to compare the atoms that form the chromosomes.	*The scale of chromosomes is so tiny, so it's too hard to compare something we cannot see with our eyes.* *There are thousands or maybe millions of atoms that make up chromosomes. We can't keep track of all those. It's not like a smaller molecule with three atoms like carbon dioxide.*

Suggested prompt	Sample student response
In either case, what kind of challenges will we face when we try to compare these structures at such small scales?	*Even those karyotypes didn't appear as zoomed in as the images on the slide, like, we couldn't see the atoms that make them.*

Say, *In either case, these chromosomes and the atoms that make them up are really small and have quite complicated structures. When we recognize this complexity in the structures that make up a system, it can be useful to switch to using symbols or more-simplified models to represent those structural differences. Simplified models can help us more quickly keep track of what we notice and make comparisons, rather than having to work with the complex images of the entire chromosome or a model of all the atoms that make up the entire molecular structure. Let's establish symbols to use to keep track of important patterns we are noticing in the structure of the chromosomes.*

Discuss how symbols can help us investigate chromosomes. Display **slide D**.

Suggested prompts	Sample student responses
This is an image of chromosome pair 2 from one individual cow. Colors have been added to show where three pairs of corresponding dark bands are found on each chromosome in this pair.	*It's easier to see what's the same and what's different with the colors rather than just the darker and lighter gray bands (or stripes) on the chromosomes themselves.*
What additional patterns does this show in the chromosomes?	*It helps us see that one of the bands—the blue one—has a different length in one chromosome versus the other.*

Display **slide E**.

Suggested prompts	Sample student responses
Now we have symbols added to help keep track of these patterns.	*The color helps us identify which band is the corresponding section on each chromosome.*
What do the colors of the shapes represent?	*Locations on the chromosome that we're looking at to compare.*
What do the shapes represent?	*The shapes help us keep track of whether they have a similar-length band at that location or a different-length band.*

Display **slide F**. Say, *We want to figure out what these chromosomes are doing to cause babies to be born with extra-big muscles. We're going to need to compare several different sets of chromosomes to find patterns that can help us. So, let's plan on using colors and symbols to represent the structures of the different chromosomes rather than the images or 3-D models of the chromosomes themselves.* Point to the representation on the right side of the slide and ask students to explain what it represents.

Suggested prompts	Sample student responses
Someone please remind us: What do these lines, colors, and symbols represent?	*The line represents an entire chromosome.* *There are two lines with symbols on each for the two halves of chromosome 2 because that cow had one of this pair from one parent and one from the other parent. So each side or stack shows us that part that came from each parent.* *The colors represent locations on the chromosome, and they help us see the corresponding section in each chromosome.* *The different shapes represent a slightly different structure or shape of the chromosome at that certain location.*
What does it mean that the blue shapes are different from each other?	*The structures of the chromosomes are different at that section or in that location.* *The atoms in the molecule are arranged differently there.*
What questions do you have about those different shapes?	*Which one came from which parent?* *Why are those sections different, but the others are the same?* *Are those differences connected with getting big muscles? If so, how?*

Motivate looking at more chromosomes from more cattle. Display **slide G**. Say, *If we are looking at only one cow's chromosome, we can't really make much progress on answering our question about how the different chromosome structures might be related to cattle being born with extra-big muscles. How could looking at more cattle's chromosomes help us?*

Sample student responses

- We would be able to see patterns better.
- If we could see the cattle who have the different chromosomes, we could figure out which structures are related to which kind of muscles.

3. Revisit proteins and introduce a new protein.

7 MIN

Materials: scale simulation (See the **Online Resources Guide** for a link to these items. **www.coreknowledge.org/cksci-online-resources**)

Set a purpose for working with cattle photos again, including chromosome and protein data. Say, *OK, since we were already working with cattle photos and pedigrees last time, let's use those to help us figure out what's going on at this new, very small scale. I have chromosome information for the same cattle we worked with last time. You'll have the image but*

also those symbol stacks showing you the information about chromosome 2 for each animal. In addition to the chromosome information, you will also see molecular representations of another protein found in and around the body cells of all these cattle. Before I show you that new protein, let's review what we know about the two other proteins that we already found in muscle cells.

Revisit what we know about proteins. Display **slide H**. Refer students to the word "protein" on the Word Wall (added in Lesson 2). Use prompts such as the following to discuss these proteins.

Suggested prompts	Sample student responses
We saw these two proteins, myosin and actin, in muscles already. Remind us: What do myosin and actin do?	*They make the muscles move, stretch, or contract.* *Myosin grabs onto the actin and pulls along to make muscle move.*
Remind us: What are these proteins made out of?	*Those little spheres are atoms. These are big molecules made of lots of atoms.* *We eat food, and our bodies rearrange those building blocks—the atoms—to make proteins or molecules like this.*
How does their structure help them do their job?	*The myosin has the right shape to grab onto the actin.* *They're each bundled together like strings so they can pull and stretch together.*

Say, *So we already figured out that the structures of the actin and myosin proteins are really important to the job they do. Understanding the structure of these proteins helps us understand how muscles work. In a few minutes we are going to be looking for patterns with the chromosomes and proteins in our cattle. But just so we don't get confused by the information we see on those cards, let's check on the relative sizes of chromosomes and proteins. In the last lesson we used a simulation to compare the sizes of sperm and egg cells. We can use that same simulation to see how the sizes of chromosomes and proteins compare.*

Use a simulation to see the relative sizes of chromosomes and proteins. Display **slide I**. Explain that the simulation does not include the specific muscle proteins we already know or that we will look at today. Instead, students should look for two other examples of proteins: an antibody and hemoglobin. Students should think about the questions on the slide while you observe the simulation as a class.

- Are chromosomes bigger or smaller than proteins?*
- How would you describe the size of proteins and chromosomes?

Open the cell size and scale simulation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) so it's projected on a screen for the whole class to view. Slide the bar until students can find the chromosome, antibody, and hemoglobin. Then discuss the questions as follows.

***Supporting Students in Developing and Using Scale, Proportion, and Quantity**
Students need a sense of how very small both chromosomes and proteins are, but also that they are both important molecules that can help explain phenotypic variation at the scale of a whole organism. Having students make sense of patterns at a molecular scale will help them connect patterns they observe when they reorganize the cattle photos with the additional information.

Alternate Activity

If the simulation does not work for you, an alternative is available. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Note that this alternative simulation plays music in the background, so you will want to mute your computer's sound. Also, antibodies and hemoglobin are not specifically shown in the alternative simulation, so you will need to compare chromosomes to other molecules shown.

Suggested prompts	Sample student responses
Are chromosomes bigger or smaller than proteins?	*The chromosomes are bigger than the proteins.* *The proteins are way smaller than the chromosomes.*
How would you describe the size of proteins and chromosomes?	*The proteins are tiny—smaller than viruses and bacteria and mitochondria!* *The proteins looked pretty big when we were seeing how many atoms make up those molecules, but they're really super tiny. There must be way more atoms making up the chromosomes.* *The chromosomes are almost as big as red blood cells, and we could see those with a regular microscope, so they're pretty big.*

Introduce the myostatin protein. Display **slide J**. Say, *You'll see a different type of protein on the cards with your cattle photos. It's not myosin or actin, but a different protein. This different protein, which is called myostatin, has a different structure. It comes in two versions, like you see here on the slide. Myostatin is not found in sperm or egg cells, but it can be found inside and outside the body cells of baby and adult cattle.*

Additional Guidance

If students want to confirm that myostatin is not found in sperm or egg cells, you can refer back to **slide R** in Lesson 5 that listed the proteins found in those cells.

4. Organize cattle by new information to look for patterns. 10 MIN

Materials: science notebook, *Guiding Questions for Chromosome and Protein Data*, transparent tape, *Protein and Chromosome Data Cards*

Distribute cattle photos with new data and prepare to look for patterns. Display **slide K**. Ask, *When we have multiple cattle photos along with their added chromosome and protein information, what is our goal? What are we trying to figure out?*

Sample student responses

- What are the chromosomes doing? How are they related to the extra-big muscles?
- How are the new protein and the chromosomes related?
- What patterns do we see that might connect the chromosomes or proteins to the extra-big muscles?

Pass out one card from *Protein and Chromosome Data Cards* to each student. Allow students to become familiar with the information on their card. Then say, *Your job is to look for patterns in both chromosomes and proteins of the cattle we have here from last time. Our goal is to see if there are any connections with the extra-big muscles.*

Additional Guidance

There are a total of 35 different cattle used in Lessons 5 and 6. Eighteen of them have "extra-big" muscles, 7 of them have "medium" muscles, and 10 of them have "typical" muscles. With fewer than 35 students in your class, leave out some of the heavily muscled cattle (and possibly a few with typical muscles) when you're distributing cards so that all cattle phenotypes are evenly represented in this investigation.

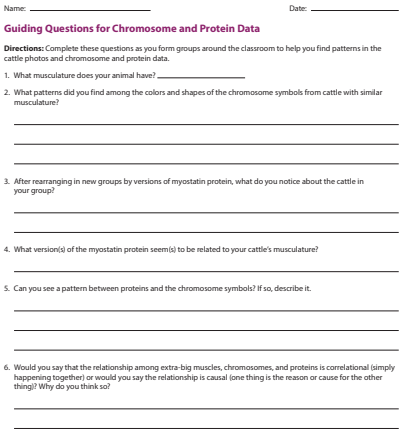
Use prompts such as the following to continue planning how to organize these data.

Suggested prompts	Sample student responses
Last class we organized these cattles by pedigrees, their family trees. If we are trying to see patterns about how chromosomes connect to an individual having extra-big muscles, then should we organize them the same way? Why or why not?	*Pedigrees help us see how the animals are related, but not all the related cattle had extra-big muscles.*
	If we're trying to find patterns about the extra-muscled cattle, we should probably put them together. We should organize the cattle by their muscles.
To help us find patterns, what are the different ways we could organize or group these cattle?	*We could organize the cattle by different phenotypes.*
	We could organize the cattle by similar chromosome structures or symbols.
	We could organize the cattle by the proteins they have.

Distribute *Guiding Questions for Chromosome and Protein Data* and give directions for organizing the cattle. Display **slide L**. Have students add *Guiding Questions for Chromosome and Protein Data* to their notebook.

Direct students to record the phenotype of their cattle at #1 on the handout. Then, point out three locations in the classroom: one place for heavily muscled cattle, a different spot for medium-muscled cattle, and a third location for cattle with typical muscles. Tell students to move to one of these places based on the phenotype of the animal they have. Once they're all sorted into those three groups, have students in each group work together to compare chromosome data for their cattle and record on #2 on the handout the patterns they find.

When most students have recorded ideas on #2, move to the next step.



Name: _____ Date: _____

Guiding Questions for Chromosome and Protein Data

Directions: Complete these questions as you form groups around the classroom to help you find patterns in the cattle photos and chromosome and protein data.

1. What musculature does your animal have? _____
2. What patterns did you find among the colors and shapes of the chromosome symbols from cattle with similar musculature?
3. After rearranging in new groups by versions of myostatin protein, what do you notice about the cattle in your group?
4. What version(s) of the myostatin protein seem(s) to be related to your cattle's musculature?
5. Can you see a pattern between proteins and the chromosome symbols? If so, describe it.
6. Would you say that the relationship among extra-big muscles, chromosomes, and proteins is correlational (simply happening together) or would you say the relationship is causal (one thing is the reason or cause for the other thing)? Why do you think so?

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Direct students to regroup in a new location based on proteins. Display **slide M**. Say, *We also wanted to try organizing our cattle by myostatin protein to see if we notice patterns there. We saw that the myostatin protein comes in two versions, and you each have two proteins represented with your cattle. So, you'll move to these locations when I say "go":*

- *If both of the myostatin proteins for your animal are full, with no holes, you will move to _____*
- *If both of the myostatin proteins for your animal are partial, or have holes in them, you will move to _____*
- *If your animal has one of each version of the myostatin protein, you will move to _____*

Say, *When you're in your new location, work with your group to find patterns about how the protein might be related to the chromosomes or phenotypes. Record your thinking on #3 of the handout. Go.*

Students should notice pretty quickly that they are still with the same people and cattle. You may choose to comment on this, saying something like, *It's interesting that these groups are the same again. I wonder what that means for the patterns we're finding.*

Additional Guidance

Regrouping into groups where the cattle and students remain the same is intentional and helpful for the following reasons:

- It reinforces the patterns students are seeing about their cattle.
- It confirms that students are sharing all the information on their cards.
- It gives students some common language in describing the proteins (full or partial, holey or not).
- It allows students to wonder what is different for the other two groups and possibly predict patterns for the other phenotypes.

Display **slide N**. Direct students to complete the remaining questions on *Guiding Questions for Chromosome and Protein Data* while they're gathered in these groups.

5. Develop initial models in small groups.

15 MIN

Materials: chart paper, markers

Develop initial models in small groups for relationships they've found. Display **slide O**. As groups finish recording their patterns on *Guiding Questions for Chromosome and Protein Data*, call everyone's attention back for the next direction.



Within each group of same-phenotype cattle, arrange smaller groups of about 3 students. Distribute a piece of chart paper to each group. Direct these small groups to develop a model that captures the patterns they found among their cattle phenotype, proteins, and chromosomes.*

***Supporting Students in Developing and Using Cause and Effect**

At this point, the allele, protein, and phenotype are correlated, but we do *not* yet see causation. If students aren't identifying correlation, help them realize that we do not know what causes what, but we do see a pattern linking them (correlation).

Assessment Opportunity

Building towards: 6.A Develop and use a model to describe correlational relationships among chromosome pairs containing two variants, specific proteins, and the trait of musculature.

What to look and listen for: Students should identify these relationships as correlational:

- The partial (or holey) myostatin protein, the blue star chromosome symbol, and the heavily muscled phenotype are related.
- The full myostatin protein, the blue circle chromosome symbol, and the typical-muscled phenotype are related.
- One of each version of the myostatin protein and one of each blue chromosome symbol (circle and star) are related to the medium-muscled phenotype.

In all these cases, just because they appear together does not necessarily mean one of these components is causing the other(s). Students' models may predict which component in the pattern is "first," "next," or "last," but question marks or other indicators should show that this thinking has not been supported.

What to do: If students propose a causal relationship, refer to the cause-effect framing that we recalled from *Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)* and used in Lesson 3 of this unit: When we __[change to the system]__, we observe __[effect]___ because __[how/why]__. Ask if they can fill in those blanks for this situation yet. *Have we seen evidence of a cause-effect relationship yet?* Not yet. If students respond with something like, "because the heavily muscled cattle always have that," offer them another situation to consider: *I've noticed here at school that many of the teachers have cars. Are they teachers because they have cars? Do they have cars because they are teachers? Just because two things happen together doesn't mean I can assume one is the reason for the other.* Note which group(s) or student(s) has struggled to identify correlation or causation here so you can be sure to support them during the upcoming discussion.

Additional Guidance

While groups work on their initial models, circulate through the classroom and look for representations of key ideas that you want included in the consensus model. Specifically, look for indications of a correlational relationship between gene and protein, gene and phenotype, and phenotype and protein. These relationships may be indicated with double arrows or lines with question marks as students are confident about the pattern but don't have evidence for a causal relationship (which would likely be represented as a single directional arrow). Make note of the examples you see and consider asking the members of that group if they would be willing to explain that part of their model to the class during discussion.

As groups finish and leave the classroom for the day, be sure to collect their models for a gallery walk next time. To facilitate easy distribution next time, keep a separate stack or roll of models for each of your classes.

End of day 1

6. Gallery walk through initial models.

5 MIN

Materials: science notebook, initial models from day 1

Consider similarities and differences among initial models. Display **slide P**. As they come into the classroom, direct students to find their group's initial model from the stack you collected last time. They should then put it out on their desk or table for others to see (or have students hang them on the walls around the room). Have students create

a T-chart in their science notebook titled "Initial Models of Phenotypes, Chromosomes, and Proteins: Similarities/Differences" to record their thinking as they silently and independently walk around to compare and contrast the models created by all the groups. Allow a few minutes for the gallery walk.

7. Develop a consensus model for correlations. 8 MIN

Materials: science notebook, initial models from day 1, chart paper, markers

Meet in a Scientists Circle to develop a classroom consensus model. Display **slide Q**. Be sure the groups' initial models are within view of the circle. Gather everyone with notebooks in hand, ready to share their ideas while you record the students' thinking on a new piece of chart paper.

Key Ideas

Purpose of this discussion: Come to consensus about the patterns we saw in the grouping of the cattle and represent these ideas in a classroom consensus model of the correlations among the chromosome information, the myostatin proteins, and muscle phenotypes.

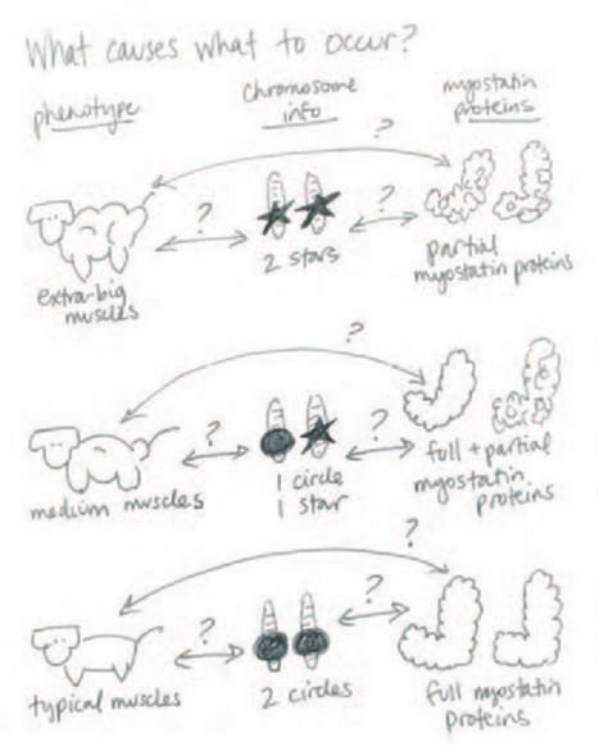
Listen for these ideas:

- We've noticed correlations but cannot yet confirm causation, so our model is composed of double-ended arrows and/or lines with question marks.
- The blue star chromosome symbol is related to the myostatin protein with holes (which we will call "partial") and the heavily muscled phenotype.
- The blue circle chromosome symbol is related to the full myostatin and the typical phenotype (eventually, we will call this version of myostatin "typical").
- When an animal has one blue star and one blue circle, they also have one of each version of the protein and medium muscles.
- We can establish that chromosomes come first in the sequence of components because we know they are transferred to offspring in the sperm and egg, whereas muscles and the myostatin protein are not.

Suggested prompt	Sample student responses
What patterns did you find and show in your models?	*The heavily muscled cattle all had the myostatin protein with holes in it—the partial one that looked incomplete, like it's not all there.* *The cattle with medium muscles had both shapes of the protein.* *It was just blue shapes that were connected to the myostatin proteins. The other colors (orange and green) didn't matter with which myostatin proteins the animal had.* *The typical cattle had two of the full myostatin protein.*

Suggested prompts	Sample student responses
Was there a pattern between a specific blue shape and those myostatin proteins?	*Yes, the specific blue shapes were related to proteins.* *If the cattle had the blue star and the blue circle, they had both kinds of protein.* *Two copies of the blue star meant they had only the partial myostatin protein.* *Two blue circles meant they had only the full protein.*
What similarities did you find in how groups modeled these ideas?	*Many groups used arrows between the parts of the model to show how they are connected or related.* *There are lots of question marks on our models still. Even though we see these patterns, we're not sure what is causing what.* *Some models have arrows on both ends of the lines and/or question marks next to those lines to show that we don't know what is causing the other, just that they're related.*

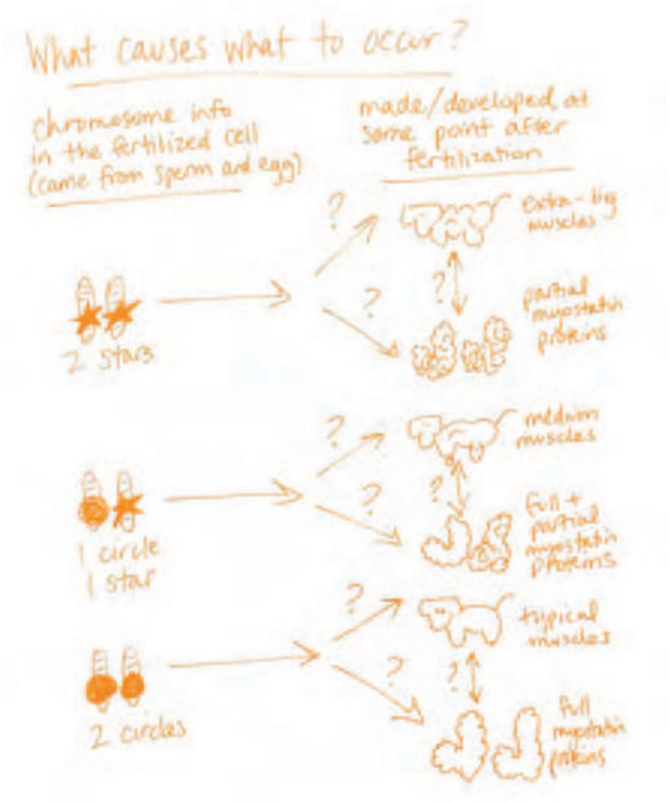
At this point, your classroom consensus model may look like the example shown here, highlighting this idea of correlation (not causation). However, your class may have already established that the first step is with chromosomes, as discussed next. If so, see the example model that follows.



Continue the discussion to establish that chromosomes are the first step. Discuss which component in our model comes first, based on evidence we already have.

Suggested prompts	Sample student responses
We've seen there is a pattern here: the heavily muscled phenotype is correlated to the chromosome's shape in that blue region and the partial, differently shaped myostatin protein. If we want to figure out causes rather than just correlations, can we at least decide which comes first? Which of these components is the starting point?	*Offspring are only getting chromosomes from their parents. There weren't myostatin or other muscle proteins in the egg and sperm cells.* *It has to start with the chromosomes because that's what was in the sperm and egg cells.*
How can we represent this idea on our model?	*Draw the chromosome first, then arrows to the other two pieces.* *But we still don't know which of those comes next in the order, so we still need double arrows and/or question marks between those.*

This example of a classroom consensus model shows chromosomes first with uncertainty around the cause of the protein and phenotype.



8. Read articles for evidence supporting causation.

12 MIN

Materials: *Version 1: New Protein Linked to the Heavily Muscled Phenotype* for half the class, *Version 1: Function of the Myostatin Protein* for half the class

Turn and talk about how scientists could support a cause-effect relationship. Display **slide R**.

Say, *OK, we've established that this relationship starts with the chromosome. And we know these proteins and the entire multicellular organism with its muscles don't appear until well after fertilization. But we still don't know whether it's the chromosome that causes the proteins or the phenotype. We should look into both of these ideas, and we can use cause-effect relationship statements to help us. If we had all the lab equipment and technology we needed, what could we try to change about one of those components (chromosome, protein, or phenotype) to observe an effect on another component (chromosome, phenotype, or protein)?* What kind of investigation would you plan to collect evidence to support the hypotheses shown on the slide? Turn and talk to a partner about that.*

After about 1 minute, bring the discussion back to the whole group.

Suggested prompts	Sample student responses
Let's start with the pattern we noticed correlating the chromosomes to the proteins and phenotype of musculature. What could we try to change to investigate those cause-effect relationships?	*We would want to get to the chromosomes. Can we get at them to change them?* *Could we take a chromosome out or take out just that section with the blue star or circle to see what we observe about the animal's muscles?* *If we could make it so the animal didn't have that blue star chromosome structure, then would we observe no extra-big muscles?* *If we could change the chromosome structure and then we observed a change to the protein, we'd know the chromosome was causing the protein.*
What about if muscles cause the protein? What could we try to change and observe to investigate that relationship?	*How could we change something so the muscles would be there without the protein and then see if the protein develops? Like, maybe if an animal has an injury and we're watching carefully while the muscle heals. Is the muscle there first or the protein?* *Aren't the muscles made of proteins, though? Could they make other proteins, too? Can we observe what this protein does, and maybe that would give us a clue?*

***Supporting Students in Developing and Using Cause and Effect**

Once again (as in Lesson 3), we are applying the cause-effect scaffold students used in *Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)*. In that unit, students used this tool to plan investigations they could carry out to test their hypotheses about forces and motion. In this lesson, this familiar tool is supporting students in planning biological investigations, even hypothetical ones they won't be able to carry out in the classroom.

***Supporting Students in Engaging in Obtaining, Evaluating, and Communicating Information**

Your class may have generated their own checklist in Lesson 3 of what to pay attention to when obtaining and evaluating information from a text. If so, refer students to that list or copy and paste those ideas from **slide E** of Lesson 3 onto **slide S** for their reference in this lesson.

Suggested prompt	Sample student responses
What about testing our theory of the protein causing the muscles? What could we try to change to investigate that cause-effect relationship?	*Could we change the myostatin protein in an animal's body and observe whether the muscles changed?* *Is it possible to take out the partial myostatins and give an animal full proteins and then see if the muscles shrink to typical size?* *Or if we could add the partial ones to a typical animal, would it get extra-big muscles?*

Say something like, *I think these ideas would help us find evidence for the cause-effect relationships we're considering. In scientific research large mammals like cattle are sometimes tricky to work with for these types of experiments, both because of their size and because of how long it takes for a baby to develop. Cattle don't fit very easily in a lab, and they take 283 days to carry a baby to birth, which is almost as long as a human. When scientists want to study how these sorts of relationships work in mammals like humans or cattle, they often switch to doing investigations with smaller mammals that reproduce much quicker. What are some examples of much-smaller mammals that reproduce more quickly than cattle?* Listen for examples that include mice and rabbits.

Say, *Mice are one of these examples that scientists use to investigate these kinds of questions.*

Prepare to read articles about chromosomes and myostatin. Display **slide S**. Explain that you have two articles about work scientists did to figure out the cause-effect relationships among chromosomes, musculature, and the myostatin protein. Half the class will read one article, and half the class will read the other, and then students will pair up to discuss what they found out. Remind students that they may want to mark up the text to help them obtain and evaluate information.*

Distribute *Version 1: New Protein Linked to the Heavily Muscled Phenotype* to half the class and *Version 1: Function of the Myostatin Protein* to the other half and direct students to begin reading independently.

Additional Guidance

Consider intentionally assigning certain students different versions of these articles based on what you know about them as readers.

- *Version 1: New Protein Linked to the Heavily Muscled Phenotype* summarizes a very complicated scientific study, and as such even this adapted text is relatively complex.
- *Version 1: Function of the Myostatin Protein* is a bit longer but is less complex and supported by diagrams (still fitting for readers at the end of 8th grade).
- *Version 2: New Protein Linked to the Heavily Muscled Phenotype* and *Version 2: Function of the Myostatin Protein* are the same articles as the first two readings but have been further modified to make the text less complex.

If you anticipate that your students will struggle to understand these texts when reading independently, it is perfectly acceptable for you to have students work with a partner to complete that task and then create a group of four for sharing the ideas from both articles.

Share with a partner what students learned from the articles. Display **slide T** and create partnerships of students who read different articles. Direct students to share their evaluation of their article and some of the new information they obtained by discussing these questions:



- Did the authors have evidence to support their claims?
- Did they cite reliable sources and/or their own scientific tests?
- Did you find any new words while you read?
- Did you have any questions about the text?

Display **slide U** to focus the partner talk to cause-effect relationships. Prompt students to share with their partner the evidence they found for cause-effect relationships by orally completing the chart on the slide. Circulate around the room to listen to students' ideas.

Assessment Opportunity

Building towards: 6.B Obtain, evaluate, and communicate information by synthesizing different adapted scientific texts in order to obtain evidence to support the idea that a distinct gene is the cause for the production of a specific protein related to the trait of musculature.

What to listen for: Students should give reasons supporting their evaluation of both articles as credible sources. They should indicate vocabulary that is new to them (specifically, *gene*, *allele*, *genotype*, and *receptor*), including definitions from context. Students' questions about the text should be relevant and show their comprehension, even partially, of the text. When focusing on cause-effect relationships, students should make cause-effect statements such as the following:

- When scientists changed the gene in the mice cells they observed differently shaped myostatin proteins.
- When scientists raised mice whose chromosomes had the changed gene (different allele) on both of their chromosomes, they observed mice with the heavily muscled phenotype.
- When scientists didn't change the mice's chromosomes (genes or alleles), they observed the usual myostatin proteins and typical muscles.
- When typical myostatin proteins fit into cells' receptors, we observe typical muscles.
- When partial myostatin proteins do not fit into cells' receptors, we observe extra-big muscles.

What to do: In order to support students who are struggling to make sense of the text, you might annotate a copy of the text, marking key words, support for cause-effect relationships, and citations. Then provide that copy of the text to students and ask them to explain why those annotations are helpful to obtaining information and evaluating the text. To support students who are struggling with identifying cause-effect relationships, you might have them create a table like that shown on **slide U** in their notebooks so they can complete it on paper.

9. Consensus Discussion About Causes of the Heavily Muscled Phenotype

15 MIN

Materials: *Version 1: New Protein Linked to the Heavily Muscled Phenotype* for half the class, *Version 1: Function of the Myostatin Protein* for half the class

Hold a Consensus Discussion about what we figured out from the articles. Display **slide V**. Have students bring their copy of *Version 1: New Protein Linked to the Heavily Muscled Phenotype* or *Version 1: Function of the Myostatin Protein* and gather in a Scientists Circle. Use prompts such as those that follow to facilitate a Consensus Discussion.

Key Ideas

Purpose of this discussion: Establish the cause-effect relationship among these alleles, myostatin proteins, and phenotypes of musculature.

Listen for these ideas:

- Specific regions of the chromosomes are called *genes;* they control how a specific protein is made.
- Different versions of a gene are called *alleles*.
- An animal's genotype is the combination of alleles that it has.
- The genotype determines the protein(s) that gets produced, which leads to the phenotype we see.
- Scientists changed the structure of a gene to figure out that a different allele causes the different-shaped myostatin protein, which resulted in those animals having the heavily muscled phenotype.
- The myostatin protein usually fits into a receptor on a cell and sends a message which results in typical muscles.
- The partial myostatin protein does not fit into receptors on cells, so no message is sent, which results in extra-big muscles.

Suggested prompt	Sample student responses
Let's start our discussion of these new ideas with some new words. I heard a lot of talk about "genes." What is a gene?	*A "gene" is a certain region of the chromosome.* *The gene is the part of the chromosome that's responsible for a certain protein. In the study, the scientists changed the shape of the gene and that resulted in a differently shaped protein.* *The scientists had already predicted that that specific gene was connected with musculature and would be related to that trait.* *The other article called it the MSTN gene and said that animals who have the changed version of it get extra-big muscles.*

***Supporting Students in Developing and Using Structure and Function**

It may be helpful to display the molecular models of myostatin from *Protein and Chromosome Data Cards* or **slide J** and the diagrams from the article *Version 1: Function of the Myostatin Protein* while the class is discussing the structure and function of this protein. You might also ask students to point out exactly how the partial myostatin protein's structure is different from the typical one and have them consider how that different structure could impact its function (or lack thereof).

Suggested prompts	Sample student responses
*Let's remind ourselves what scale we're at. Remember the images we saw on **slides B and C** last time? The chromosomes are huge, complicated molecules, and the genes are specific regions of those molecules, like the shaded bands we saw on the chromosome images. So we're saying that the shape of a specific region on a chromosome—called a gene—is causing a certain-shaped protein, which is a much-smaller molecule than the chromosomes. Why weren't we looking at the actual shapes of the genes when we organized our cattle to look for patterns?*	*The differences are happening at too tiny a scale for us to work with.* *They're super complicated.* *Stars and circles and pentagons were easier for us to compare to find patterns.*
Wait, but you all know the genes aren't actually shaped like stars and circles, right?	*Right. There are not really star shapes on chromosomes.*
When we say "change shape" about a gene, what's actually changing shape?	*The actual changes are happening in the molecule, those atoms of hydrogen and nitrogen and so forth—their structure would be changing.*
So what is that called, when there is a different shape of a gene or a different version of a gene?	*Different versions of genes are called alleles.* *Different alleles of the same gene would make similar proteins, but they would be differently shaped, like in the study.*
So different individuals can have different combinations of alleles. What's that called?	*The combination of alleles of a certain gene that an animal has is its genotype.*
What's the difference between genotype and phenotype, then?	*The genotype is which alleles an animal has, which version or versions of that particular gene.* *The phenotype is how the animal looks.* *They're both "types"—the type of the gene and the type of the … in this case, it's muscles we see. But what does "pheno" mean?*
What new ideas did we figure out about proteins that we should add to our Word Wall?	*We need to add that proteins have a specific structure that allows them to function or do a specific job.*
*That's interesting, because I'm remembering other proteins we know about in muscles: myosin and actin. They had different shapes than myostatin has. Why would this be?**	*The myosin has to be able to grab on to the actin and pull it along, so it has to have that grabber head to do its job.* *The actin and myosin are stringy because they are making the muscle pull along and contract or stretch—that's their job.* *Myostatin's job is to send a message, so it's shaped to fit into that receptor. Myosin and actin are what the muscle is actually built out of, and they make it move, so they have a different shape because their job is different.*

Supporting Students in Making Connections in ELA

The "pheno" root is from the Greek and means "to show" or "to appear" (literally, "to bring to light").

Continue the discussion to establish cause-effect relationships.

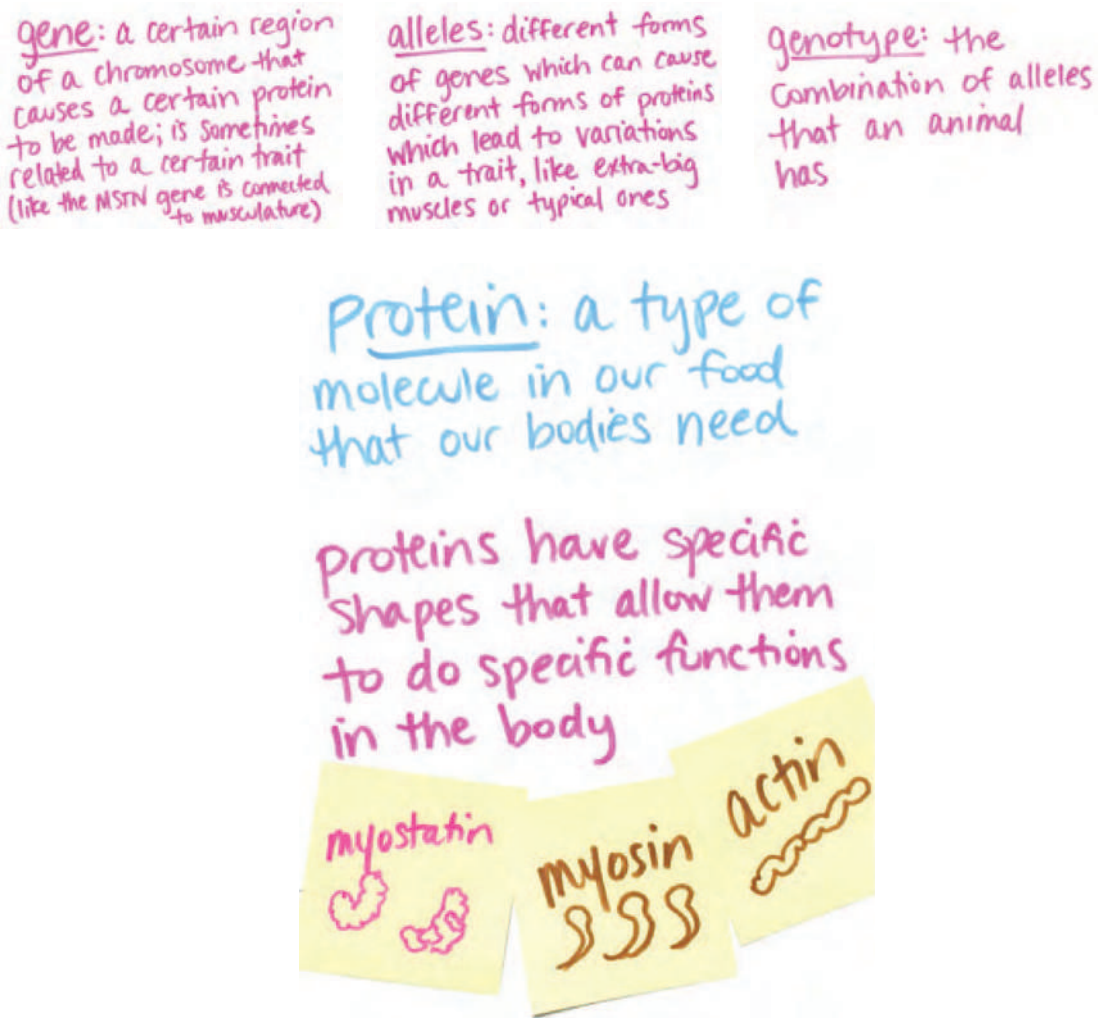
Suggested prompts	Sample student responses
Remember that our goal was to find some evidence that shows a cause-effect relationship among chromosomes and/or the myostatin protein and the heavily muscled phenotype. What evidence did you find?	*The article I read was about the scientists who changed the genes in some mice cells. They found the different myostatin protein in the cells that had the changed allele. So the chromosomes are causing the protein.* *The scientists raised mice with that different genotype—the changed alleles—and the mice had extra-big muscles.* *The article I read explained how the myostatin protein fits or doesn't fit into a receptor on cells and sends a message or not, depending on whether it is the full or the partial protein. If the messages get sent, then that animal has typical muscles. If the messages do not get sent because the protein doesn't fit in the receptor correctly, the animal has extra-big muscles. So the type of muscles results from the type of myostatin protein.*
How are genotype and phenotype related?	*The genotype determines the protein, and then the protein leads to the phenotype. It's like they're connected by the protein.*
How was using both articles important in helping us find evidence to support a cause-effect relationship among chromosomes, proteins, and phenotypes?	*The mice study article gave us more information about how the different alleles cause the different proteins.* *The myostatin article gave us more details (with diagrams!) about how the myostatin protein's structure helps it do its job, and that leads to the muscles we see.* *We can use information from both articles to help us understand how the structure of the allele affects the protein's shape, which then affects the phenotype.*

Additional Guidance

If or when your students ask about genetically modified organisms (GMOs), you can respond by saying something like, *To modify something means to change it. So yes, when scientists alter or change the shape of a specific region on an organism's chromosome, that's genetic modification.*

Add to and update the Word Wall. Add the following words and updates to your Word Wall (example definitions are included, as well).

- gene (a certain region of a chromosome that causes a certain protein to be made; is sometimes related to a certain trait, like the MSTN gene is connected to musculature)
- alleles (different forms of genes which can cause different forms of proteins which lead to variations in a trait, like extra-big muscles or typical ones)
- genotype (the combination of alleles that an animal has)
- protein (Update your existing definition to include that proteins have specific shapes that allow them to do specific functions in the body. Add "myostatin" with myosin and actin as another example protein.)



Display **slides W** and **X** to show examples of other animals scientists have studied in regard to the heavily muscled phenotype.

Say, *Scientists have been so interested in seeing how this gene to protein to phenotype works with extra-big muscles that they've investigated this pattern with other animals, too.*

10. Update Progress Trackers.

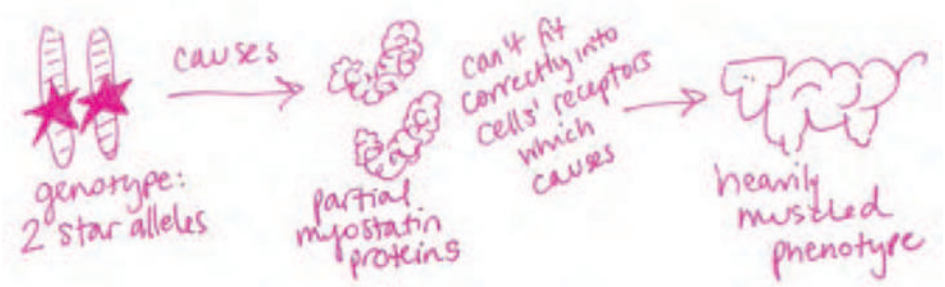
5 MIN

Materials: science notebook

Update Progress Trackers in science notebooks. Using **slide Y**, direct students to add to their Progress Tracker in their science notebook.

Say, *Let's record our new understandings about the relationships among chromosomes, genes, alleles, proteins, and phenotypes. Also, the thinking we do here and now will give us a starting point for our next lesson so we can update our classroom consensus model and determine what we need to figure out next.*

The example two-column Progress Tracker below has been completed with ***possible*** student ideas.

Question	What I figured out in words and/or pictures
How do chromosomes cause cattle to be born with extra-big muscles?	• Chromosomes have specific regions called genes, and the different possible forms of the genes are called alleles. • The different alleles of the genes (the genotype) determine the protein(s) that gets made. • Different forms of a protein, like myostatin, can lead to variations, like extra big or typical muscles. • Animals that are heavily muscled have two copies of the allele for the partial myostatin protein. • The partial myostatin protein does not fit correctly into cells' receptors, so it does not send a message (like the typical protein does), and that results in extra-big muscles. 

ADDITIONAL LESSON 6 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.RI.8.10

By the end of the year, read and comprehend literary nonfiction at the high end of the grades 6-8 text complexity band independently and proficiently.

CCSS.ELA-LITERACY.SL.8.1.A

Come to discussions prepared, having read or researched material under study; explicitly draw on that preparation by referring to evidence on the topic, text, or issue to probe and reflect on ideas under discussion.

CCSS.ELA-LITERACY.RI.8.4

Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings; analyze the impact of specific word choices on meaning and tone, including analogies or allusions to other texts.

This lesson requires students to read and comprehend articles written at the high end of the grades 6-8 text complexity band. Then, they must refer to information they read as evidence during a discussion, supporting their ideas about what causes the heavily muscled phenotype in animals. Students are also introduced to several specific new science words when they read the articles. They must use the definitions provided in the context of the reading as well as the knowledge they've built in the unit thus far to make sense of these words and then use them in the class discussion and their Progress Tracker entries. If desired, the teacher may choose to discuss with the class how the scientific vocabulary present in these texts impacts the tone of the writing, in addition to its meaning.

SCIENCE LITERACY: READING COLLECTION 2

Born or Built

1 **Doing It Right vs. Overdoing It**
2 **Essential Amino Acids and Protein Needs**
3 **Big-Screen Genes**
4 **Coins and Chromosomes**
5 **The Brothers of Bogotá**

Literacy Objectives

- ✓ Summarize key points related to traits, genetics, and the environment.
- ✓ Distinguish cause(s) and effect(s) related to changes to or stability in human traits.
- ✓ Distinguish between credible and non-credible sources.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 4–6.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a summarizing outline in response to the reading.

Instructional Resources

Student Reader



Collection 2

Science Literacy Student Reader, Collection 2
"Born or Built"

Exercise Page



EP 2

Science Literacy Exercise Page
EP 2

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 4: What is different about the food and exercise for cattle with extra-big muscles?
- Lesson 5: Where do the babies with extra-big muscles get that trait variation?
- Lesson 6: How do chromosomes cause cattle to be born with extra-big muscles?

Standards and Dimensions

NGSS

Disciplinary Core Idea LS1.B: Growth and Development of Organisms: Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (secondary to MS-LS3-2) Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. (MS-LS3-2)

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Cause and Effect; Structure and Function

CCSS

English Language Arts

RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

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.

Math

CONTENT.8.EE.A.1: Know and apply the properties of integer exponents to generate equivalent numerical expressions. For example, $3^2 \times 3^{-5} = 3^{-3} = 1/3^3 = 1/27$.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

gamete **zygote**

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

DNA bases **essential amino acids**
fraternal twins **genetic mutation**
identical twins **karyotype**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

Exercise Page



EP 2

2. Preview the assignment and set expectations.

(Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Genetics unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
  - *First, you'll read the fictitious journals of high school students preparing themselves for basketball team tryouts. As you do, think about the saying "No pain, no gain."*
  - *Next, you'll take a close look at the recommended intake data for amino acids and proteins. To make sense of it all, be sure to check the units of the measurements.*

- *Then, an article about some popular movies analyzes the genetic science concepts behind their storylines. Several of the science ideas discussed are ones we explored in our class discussions and activities.*
- *Finally, you'll read a true story from the news about twins accidentally switched at birth that will make you think about which is a greater influence on human traits: genetics or the environment.*

- Distribute Exercise Page 2. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to reflect on your reading and generate an "I used to think. . . Now I think. . ." graphic organizer.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What structural change has happened to muscles where they feel sore?	*The muscle fibers have been torn and are being repaired.*
What units were used to identify the required daily amounts needed for each amino acid?	*mg/kg body weight*
What is a karyotype?	*It's a microscopic picture (or drawing) of a person's chromosomes.*
How can there be 70 trillion different versions of you?	*because there are at least 70 trillion different ways that chromosomes from two parents can be combined*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
What can you tell the authors of the diaries about their needs for eating protein?	*True, you do need protein to make new muscle fibers, but eating protein doesn't make your muscles bigger.*
If movie X-Men get their unusual traits from gene mutations, were they once "X-Babies"? Explain.	*Yes, because a mutation is passed from parents to offspring. However, it is possible that a mutation happened after childhood.*
How do you think the genotype of a pair of identical twins compares to the genotype of a pair of fraternal twins?	*Identical twins have (nearly) identical genotypes, but fraternal twins differ in genotype as much as any two more common siblings.*

- Refer students to Exercise Page 2. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
- *The writing expectation for this assignment is to draw an "I used to think . . . Now I think . . ." graphic organizer.*
  - *That means you'll have to be honest with yourself about your understanding of genetics and the environment.*
  - *Don't worry about revealing your past thinking. You don't have to share your organizer if you don't wish to.*
  - *As you read, think about how what you are reading relates to your own experiences. Then you might reflect on how new understanding will affect you in the future.*
  - *The important criteria for your work are that you compare your past ideas to current ideas and communicate them clearly enough that when you look at the organizer in the future, you will understand your own thinking.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page



EP 2

4. Facilitate discussion. (Friday)

Facilitate class discussion about the reading collection and writing exercise. The collection begins with workout diaries written by two high school students who show different approaches to getting their muscles in shape for basketball team tryouts.

Pages 14–23 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "Doing It Right vs. Overdoing It"?	*It describes the ups and downs of training to try out for a high school basketball team.*
You've likely heard the saying "No pain, no gain." What does it mean in the context of this reading?	*It means that if you don't strain muscle fibers, making small tears, they cannot rebuild to form larger, stronger muscles.*
Take a look at the Dig into Data box. What pattern can you identify in the graph?	*The author started out with small (+10) increases each night but then changed to bigger increases (+50).*

Student Reader



Collection 2

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Pages 14–23 Suggested prompts	Sample student responses
What is the general purpose of the second selection, "Essential Amino Acids and Protein Needs"?	*It identifies the amino acids people need to get in their diet, how much of each, and how much protein in general they need to consume.*
How does the second selection help you build knowledge on top of what you learned in the first selection?	*The first article reveals that it is important to eat foods with protein to repair muscle fibers. The second article has a table that details how much protein to eat by body weight.*
Let's say you weigh about 45 kg (100 pounds). How can you determine if you are getting enough of each amino acid by eating one 170-g serving of soybeans a day?	*Using the first table, you multiply the number in the first column by 45 and compare it to the total in the last column. If your value is equal to or greater than the number in the right column, you are getting enough of that amino acid.*
What is the general purpose of the third article, "Big-Screen Genes"?	*It describes some of the genetics behind science fiction movies such as* Jurassic Park *and* X-Men.
The article mentions the "bases found in DNA." What credible sources could you use to find out what this means? What kinds of sources would you avoid?	*Credible sources could be a science teacher, websites related to science museums or universities, or an encyclopedia at the library.* *Non-credible sources might include friends on social media or movie-fan websites.*
At least one writer commenting on the X-Men stories has said, "We're all mutants." What does this mean?	*It means every human body has some mutated genes, whether we are aware of them or not.*
What is the general purpose of the fourth article, "Coins and Chromosomes"?	*It explains how scientists know the number of chromosome combinations there can be in humans.*
How do gametes and zygotes compare in their chromosome counts?	*A gamete has half the number of chromosomes as a zygote. The zygote results from the fusion of two gametes. In plants and animals, that means egg and sperm cells.*
How can you use the multiplication key on a calculator to check the value of 2^{23}?	*Multiply 2 x 2, then multiply the product by 2. Repeat 20 more times.*
Take a look at the Dig into Data box. Why is 70 trillion the minimum number of versions of you that there could have been?	*because it's all the combination of chromosomes that can happen when each parent contributes their own set of chromosomes*
What is the general purpose of the fifth article, "The Brothers of Bogotá"?	*It is a summary of a news story about two sets of identical twin brothers who were separated at birth.*

EXTEND—Since your students are likely to know a peer with Down syndrome, show students videos that explain the causes of some traits of individuals with Down syndrome and build empathy, understanding, and kindness.

Pages 14–23 Suggested prompts	Sample student responses
What does the article imply about the importance of genetics versus the environment in determining traits?	*It implies that genetics could be more important than the environment—at least in this case.*
Would identical twins have as many traits in common with their parents as with each other? Explain.	*No. They have nearly identical genes and share only half their genes with each of their parents.*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 2, students should use the template provided to express how their thinking has changed as a result of reading Collection 2. A sample student response is shown on the following page, but the range of responses will be very great.

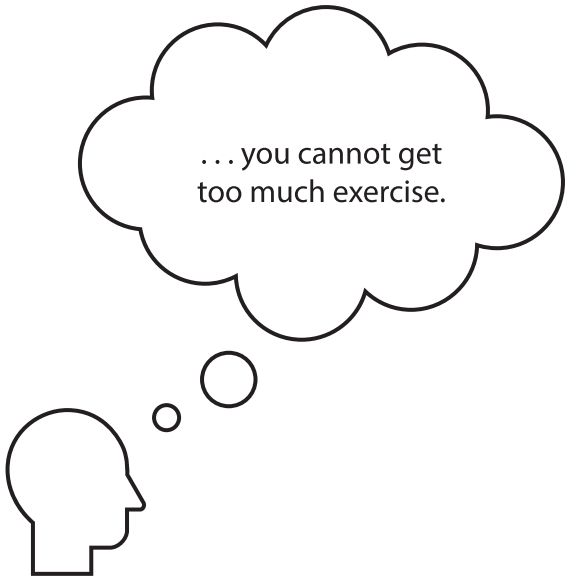
Students may reflect on understanding a narrow concept or definition of a term, or they may respond more holistically to the topic of genetics and the environment.

Since students may be reluctant to admit that their thinking had to change, remind them that you will not share their organizers without their permission.

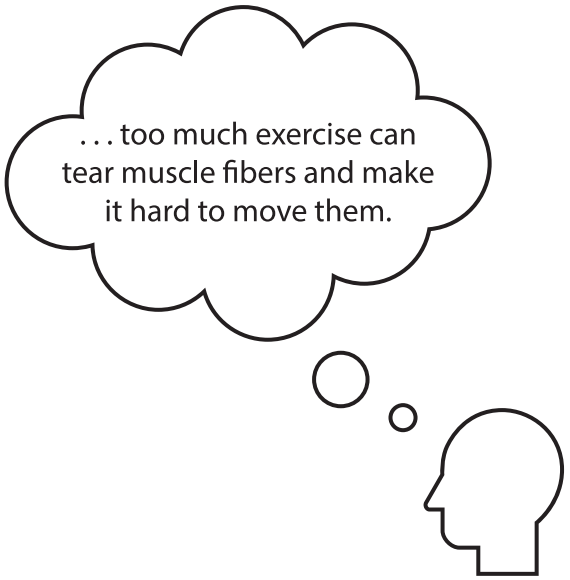
Use the rubric provided on the Exercise Page to supply feedback to each student.

SUPPORT—For students who are struggling to use the "I used to think . . . Now I think" routine, explain that their change in thinking can be specific or broad. To be specific, suggest that they identify one idea in each selection that changed their thinking and then choose one to highlight. To reflect more broadly, suggest that they think about the collection title and how their attitude toward learning about the topic has changed.

I used to think . . .



Now I think . . .



LESSON 7

How does an animal get extra-big muscles?

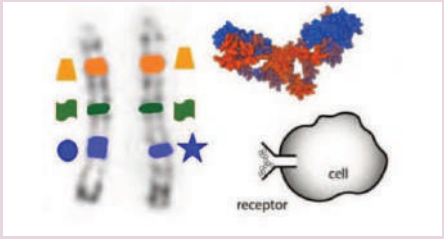
Previous Lesson

After considering the scale of chromosomes and proteins, students reorganized the cattle photos with added information about each individual's chromosomes and which versions of the myostatin protein each has. Groups constructed initial models and then a classroom consensus model to explain the correlations they found. Finally, students read and synthesized different articles to find evidence of causal relationships among alleles, proteins, and phenotypes.

This Lesson

Problematizing

2 DAYS



Waterhouse, A., Bertoni, M., Bienert, S., Studer, G., Tauriello, G., Gumienny, R., Heer, F.T., de Beer, T.A.P., Rempfer, C., Bordoli, L., Lepore, R., Schwede, T. SWISS-MODEL: homology modelling of protein structures and complexes. Nucleic Acids Res. 46, W296-W303 (2018).

In this lesson we update our classroom consensus model to include our recent findings about the roles of genes, alleles, and the myostatin protein in development of the typically, medium-, and heavily muscled phenotypes. After updating our Progress Tracker with a partner, we individually revise our initial model to explain how a heavily muscled animal and a typically muscled animal developed those phenotypes. In order to practice a little more with our model, we use it to predict what a sibling (who got sperm and egg from the same parents) would look like. While our model predicts that siblings would look the same, we see examples of cattle siblings with different phenotypes (and we know from our own experiences that siblings do not all look the same). So we have more to figure out!

Next Lesson

Students will investigate the inheritance patterns of the myostatin gene by comparing the proportion of different genotypes collected from pedigrees that show the results of known crosses. They will use simple mathematical models to help us predict the outcome of known genetic crosses and will consider the nature of mutations.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5

What Students Will Do

7.A Develop a model to show how genetic factors influence (cause) variation in a trait (effect) by controlling the production of specific proteins.

What Students Will Figure Out

- The alleles an animal gets from the sperm and egg of its parents (its genotype) determine the myostatin protein(s) that animal produces, which influences the musculature (phenotype) we see.
- Our model predicts that siblings will look the same, but that's not the case in real life for cattle (or other examples we know).

Lesson 7 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**MAP TODAY'S WORK TO OUR CLASSROOM CONSENSUS MODEL** Update the classroom consensus model to include the idea of genotype contributing to the musculature we've seen in cattle.	A	classroom consensus model, chart paper, markers
2	5 min	**DRAFT A GOTTA-HAVE-IT CHECKLIST** Work in pairs to brainstorm a list of components and interactions that will help the class develop a model to explain how cattle get extra-big muscles.	B	*Gotta-Have-It Checklist*, transparent tape
3	25 min	**DEVELOP OUR CLASSROOM CONSENSUS MODEL FOR HOW GENOTYPE INFLUENCES PHENOTYPE** Gather in a Scientists Circle and hold a Consensus Discussion to develop a model to explain how musculature can be influenced by genotype.	C-K	*Gotta-Have-It Checklist*, 9-10 large sticky notes, markers, classroom consensus model, several half-sheets of copy paper for Word Wall
4	10 min	**UPDATE PROGRESS TRACKERS AND GOTTA-HAVE-IT CHECKLIST** Update the Progress Tracker and Gotta-Have-It Checklist in pairs, adding components and ideas that were important from the classroom consensus model.	L	*Gotta-Have-It Checklist*, classroom consensus model
				End of day 1
5	20 min	**REVISE INITIAL MODEL AND CREATE AN EXPLANATION** Revise initial model individually to explain what causes the heavily muscled phenotype in an organism other than cattle.	M	*Gotta-Have-It Checklist*, *Revise Your Model*
6	15 min	**USE OUR MODEL TO PREDICT THE PHENOTYPE OF A SIBLING** Work with a partner to predict the phenotype of a sibling from the same parents using the recently added genotype section of our classroom consensus model.	N-P	classroom consensus model
7	10 min	**ANALYZE PHOTOS OF CATTLE SIBLINGS** Compare our predictions to what we notice about the musculature of cattle siblings.	Q-S	
				End of day 2

Lesson 7 • Materials List

	per student	per group	per class
Lesson materials Student Procedure Guide  Student Work Pages 	• science notebook • *Gotta-Have-It Checklist* • transparent tape • *Revise Your Model*		• classroom consensus model • chart paper • markers • 9-10 large sticky notes • several half-sheets of copy paper for Word Wall

Materials preparation (20 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare the handouts:

- Make 1 copy of *Gotta-Have-It Checklist* for each student and trim them to fit inside notebooks.
- Make 1 copy of *Revise Your Model* for each student.

Have several half-sheets of copy paper ready to add the following words to the Word Wall: **genetic material**, **genetic information**, **homozygous**, **heterozygous**. You will also update your definition of "chromosome." Do not post these words on the wall until after your class has developed a shared understanding of their meaning.

You'll use 9-10 (depending on the exact words your class chooses) large sticky notes (such as the 5" × 7" size) for the Gotta-Have-It-Checklist conversation. If large sticky notes are not available, tape and large index cards or half-sheets of copy paper will suffice.

Lesson 7 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students put the pieces together to model and explain how an organism's genotype affects its phenotype. Like in Lesson 6, we are focusing on only individual animals with the heavily muscled, medium-, and typically muscled phenotypes; this work will motivate the need to once again collect data from pedigrees in Lesson 8.

During co-construction of the model for how genotype influences phenotype, students recall work they did in *Unit 7.3: How do things inside our bodies work together to make us feel the way we do? (Inside Our Bodies Unit)* that we (and other animals) get "building blocks" from food. In this case, we're showing how those "building blocks" are rearranged in a body to make proteins like myostatin. In the *Inside Our Bodies Unit* students used square shapes to represent those blocks, but since we've been looking at molecular models of actin, myosin, and myostatin and we want to try to represent the shape of the myostatin protein in this model, we decide to use circles instead of squares. Take a moment to acknowledge with students that a limitation of our model is that we cannot draw as many circles as are shown in the molecular model of myostatin—we just need a representation of it for the purposes of this model.

Also in this lesson, students will revisit a scaffold for describing a cause-effect chain that they used in *Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)*. This time, in addition to describing a cause-effect chain in biology rather than physics, students will modify the chain to show multiple causes at play in the resulting phenotype we see.

Where We Are NOT Going

This lesson focuses on the genetic factors that influence variation in a trait, and other than referencing them in the classroom consensus model to recall that diet and exercise do play a role in muscle variation, environmental factors are not considered in this lesson. In the second lesson set, students will continue to build their understanding of the varying degrees of influence genetic and environmental factors have on trait variations when they consider populations of organisms.

In this lesson, students model how the sperm and egg from parents carry the genetic information (alleles) to create the genotype of the offspring. Stopping the model at that point (with the sperm and egg but not identifying the specific genotype(s) of the parents) will allow room for the uncertainty that motivates students' work in the next lesson. Students will want to further investigate the genotypes of parents (in the next lesson) after they consider in this lesson that siblings don't all look the same even though they're getting sperm and eggs from the same parents.

LEARNING PLAN FOR LESSON 7

1. Map today's work to our consensus model.

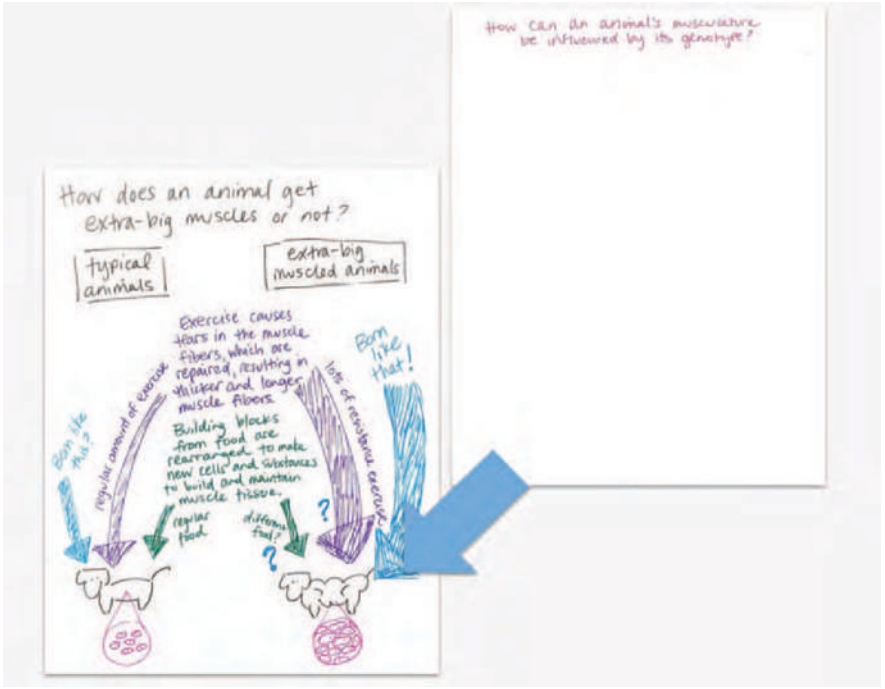
5 MIN

Materials: classroom consensus model, chart paper, markers

Revisit our classroom consensus model. Display **slide A**. Refer to the classroom consensus model. Say, *We have figured out a lot of new science ideas since we last updated our consensus model. Let's take some time today to make sense of how all these new ideas fit together. What do you think we should add to our model for how cattle get different sizes of muscles?*

Listen for the idea of genotype contributing to animals' musculature. You might choose to relabel the "born like that" arrow on the model as "genotype." Say, *We've figured out a lot of ideas about how an animal's genotype can influence its phenotype. Let's give ourselves plenty of room to organize all those ideas on our model. I'll start another poster here next to the model so we can show all the details of how an animal's phenotype can be influenced by its genes.*

Title a new piece of chart paper "How can an animal's musculature be influenced by its genotype?" and post it next to the classroom consensus model as an addition to that model (see the example shown here).



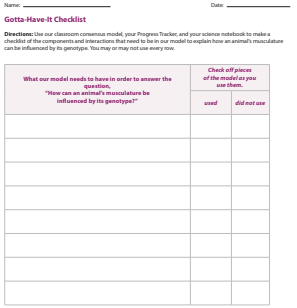
2. Draft a Gotta-Have-It Checklist. 5 MIN

Materials: science notebook, *Gotta-Have-It Checklist*, transparent tape

Draft a Gotta-Have-It Checklist. Display **slide B**. Pass out a copy of the *Gotta-Have-It Checklist* to each student and direct them to add it to their notebook.

Say, *If we are going to make a detailed model to explain how cattle's musculature can be influenced by their genotype, we need to know what things we have learned that are essential in explaining this phenomenon. Work with a partner and go through your science notebook and other resources around the room. List the components and interactions you think we'll need in our model in the first column of your Gotta-Have-It Checklist.*

Pair up students and make sure they are working on only the first column. Let them know the other parts of the table will be used later.



Name: _____ Date: _____

Gotta-Have-It Checklist

Directions: Use our classroom consensus model, your Progress Tracker, and your science notebook to make a checklist of the components and interactions that need to be in our model to explain how an animal's musculature can be influenced by its genotype. You may or may not use every row.

What our model needs to have in order to answer the question, "How can an animal's musculature be influenced by its genotype?"	Check off pieces of the model as you use them.	
	used	did not use

3. Develop our classroom consensus model for how genotype influences phenotype. 25 MIN

Materials: science notebook, *Gotta-Have-It Checklist*, 9-10 large sticky notes, markers, classroom consensus model, several half-sheets of copy paper for Word Wall

Gather in a Scientists Circle. Display **slide C**. Have students bring their science notebook including their filled-out *Gotta-Have-It Checklist* into a Scientists Circle.

Ask, *What components from your Gotta-Have-It Checklist are essential to helping us model how an animal's musculature can be influenced by its genotype?*

As students share their ideas, have them write one component or interaction per sticky note and add them to the new page you have titled "How can an animal's musculature be influenced by its genotype?" (the arrangement of these sticky notes can be totally random at this point).

Key Ideas

Purpose of this discussion: To help students to identify the components and interactions that are essential to the causal relationship of how an animal's musculature is influenced by its genotype

These key ideas need to make it onto sticky notes on the chart paper:

- sex cells (sperm and egg) from parents
- chromosomes
- gene
- alleles
- genotype

***Attending to Equity**

Often when learning genetics, there is an overemphasis on comparing physical characteristics of organisms and contrasting differences. While this overemphasis is sometimes unavoidable, intentionally look for opportunities, like here, to emphasize the process of gene influencing protein influencing trait variation more than the resulting appearance.

***Supporting Students in Developing and Using Systems and System Models**

Models can be used to represent systems and the matter flows in systems. If it's helpful, have your students picture a building block set that comes with directions for how to assemble the bricks.

- baby or offspring
- phenotype
- protein
- protein's job or function

See the example here of how your class might name and post these ideas.



Review the meanings of these terms. Display **slide D**. Say, *We have collected many important pieces of our model here! Some of these terms and ideas are still pretty new to us, so let's be sure we understand what they are.*

Help students make connections among chromosomes, genes, alleles, and genotype by discussing questions such as the following. During the discussion, invite students to the whiteboard or extra chart paper and have them draw the relationships they're describing.

Suggested prompts	Sample student responses
How are chromosomes and genes related?	*Each gene has a specific place on the chromosome.*
How are genes and alleles related?	*Alleles are different versions of genes.*
How are genes and proteins related?	*Each gene gives directions to make a certain category of protein, like the myostatin protein.*
How are alleles and proteins related?	*Alleles are different variations of a gene, which give directions to make a different variation of a protein.* *For example, one allele gives directions for the typical myostatin protein (it's complete, no holes) and a different allele gives directions for a partial myostatin protein (which has holes and gaps in it).*
How are alleles and genotype related?	*The alleles make the genotype.* *The specific combination of the two alleles that an organism has for a certain gene is its genotype.*
How are alleles and phenotype related?	*Since different alleles make different versions of a protein, the way the protein works or does not work can influence the phenotype, so we have different versions of the phenotype, too.* *A different allele means a different genotype, and the genotype leads to the phenotype.*

After your creation has been constructed, you can take the bricks apart so you have the individual, smaller pieces again. Then you can rearrange them using different instructions to build something new.

***Supporting Students in Engaging in Developing and Using Models**

We make trade-offs so that our models communicate certain interactions and relationships. A limitation of the model we're making now is that it will not represent so closely the shapes of the actual myostatin proteins, but we're willing to make that trade-off to show how they fit into the whole process of genes influencing proteins influencing traits.

***Supporting Students in Developing and Using Scale, Proportion, and Quantity**

Acknowledging the different scales in this model helps students make sense of the process of how genes affect an organism's visible phenotype through the production of molecules they cannot see directly.

If students do not right away volunteer the idea that we are looking at multiple scales in this model, from organism to cell to even smaller, ask them to recall what they figured out about the organization of an organism from

Suggested prompt	Sample student responses
Where are chromosomes found? Genes?	*They're all in the nucleus of the cells.* *The alleles and genes are on the chromosomes. They are smaller parts of the chromosomes.*

Additional Guidance

Your students might find an analogy helpful at this point. If so, consider relating the gene-allele-protein phenomenon to cooking. (Feel free to substitute a recipe that your students suggest or could better relate to.)

- The recipe for the food we're making (let's say mashed potatoes) is like the gene.
- Different versions of the recipe are like alleles.
- The food that results from following that recipe is like the protein (depending on the version of the recipe we followed, the mashed potatoes might be whipped with butter and cream or smashed skin-on with garlic).

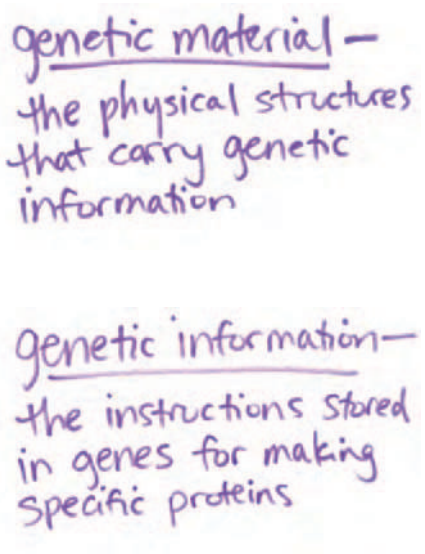
Add "genetic material" and "genetic information" to the Word Wall. While discussing the words *chromosomes*, *gene*, and *allele*, take a moment to point out that these physical structures can be referred to together as *genetic material*.

Ask, *What do these structures—chromosomes, genes, and alleles—have in common?* Sample student responses

- They're molecules made of atoms.
- They pass trait variations from parents to offspring.

Say, *Let's record that idea about the information that this genetic material carries. We can call that "genetic information"—the instructions these structures carry for making the various proteins that influence traits.*

Make cards for *genetic material* and *genetic information* for your Word Wall to capture these ideas. Consider arranging the cards for *chromosomes*, *gene*, and *allele* under or near them to show how they are related. Sample definitions are shown here.



Additional Guidance

While DNA specifically is beyond the scope of the middle school grade band, it is likely that students have heard that term and you may have questions on your DQB that mention it. Therefore, you may choose to point out to students that *DNA* is the scientific name for genetic material. It stands for "deoxyribonucleic acid", which is the name of the long molecule that winds up to form the chromosome.

the *Inside Our Bodies Unit*: organism = system > subsystem > organ > tissue > cell.

***Supporting Students in Developing and Using Cause and Effect**

Even if your students are not familiar with the cause-effect chain graphic from the *Magnets Unit*, they can use it to support their sensemaking. Not only do we have a chain of causes resulting in the genotype's effect on the phenotype, the additional causes of diet and exercise are still at play, too.

***Supporting Students in Developing and Using Cause And Effect**

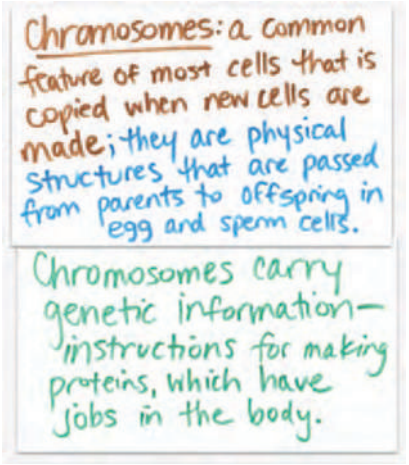
Sometimes the word "cause" seems to imply a singular and direct effect that is inevitable. Encouraging students to consider the nuance of the words they choose can help them describe situations where a chain of causes and/or multiple causes combine to produce a particular effect. We do not want students to walk away thinking that a particular allele directly and certainly causes a particular phenotype, because, in fact, traits that are influenced so heavily by a single gene and basically unaffected by environment are quite rare. Students will continue to work with the idea of multiple causes of trait variation in the second lesson set.

Add to our definition of chromosome. Say, *As we were talking about genetic material and genetic information, I realized that we know more about chromosomes now than we did when we first put that word on the Word Wall. What details can we add about the function of chromosomes?*

Sample student response

- They carry genetic information—instructions for making proteins, which have jobs in the body.

Update your class definition of *chromosome* accordingly. See the example shown here.



Alternate Activity

If you think your class would benefit from additional practice with these terms and ideas, take another round through them as you're organizing the sticky notes in the next step. As you review each word or phrase on a sticky note, ask students to recall its meaning in various ways. Mix it up! Call volunteers up to describe the images on **slide D**. For some terms you might ask a volunteer to read the Word Wall definition and then restate that in their own words. For others you might ask students to turn and tell a neighbor what that word means. If time and space allow, have students add illustrations to the sticky notes and explain why they drew what they did.

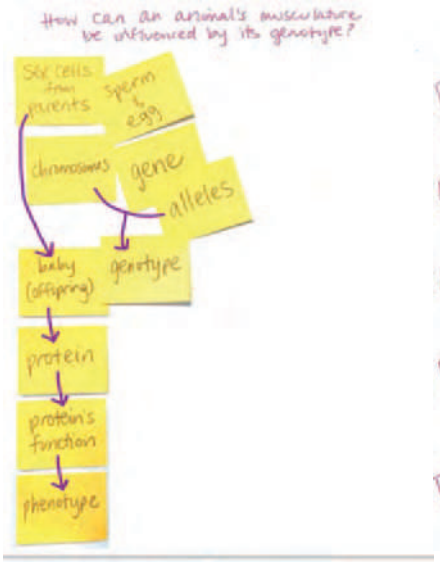
Arrange these components to support developing our model. Display **slide E**. Say, *How might we organize these ideas we collected to help us best explain how musculature can be influenced by genotype?* Facilitate students in arranging the components in a vertical list and connect the ideas with arrows to show the causal chain.

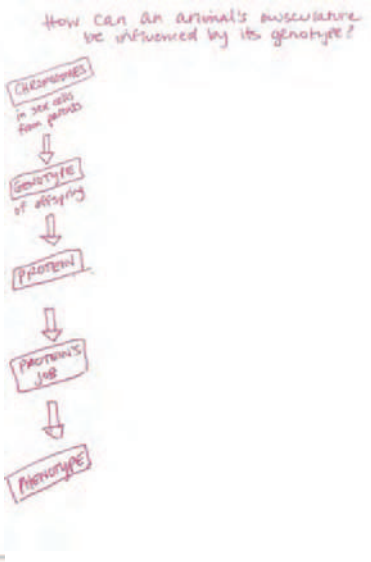
If needed, you might refer to the original classroom consensus model and say something like, *We're trying to explain what happens to cause this phenotype, to see how we end up with cattle with extra-big muscles, so let's end our list with "phenotype" here at the bottom of our new poster because we're explaining this specific part of our consensus model. So, how would we work backward from the phenotype?*

Begin building the model with students. Say, *If we are going to explain why some cattle have extra-big muscles, we should also model and compare the process to cattle with typical and medium muscles, too.**

You may choose to keep the sticky note terms on your model, or rewrite them along the side of the paper as shown in the example here. Draw representations for each of the three muscle phenotypes (typically, medium-, and heavily muscled) at the bottom of the new chart paper.

Work backwards up the paper from each phenotype and ask for each component of the list, *What function did the proteins have to result in an individual with this phenotype? And what was the same or different to cause the other phenotypes?*







Discuss the source of the building blocks for proteins. Pause when the class is considering how the myostatin protein is made (it gets instructions from the specific genotype). Say, *The genotype is the instructions on how to build a protein. But a protein can only be made if there are building blocks of matter available. If the genotype is just the specific alleles an animal has which give genetic information or directions to make a type of protein, then where do the building blocks for making the proteins come from? Let's think through that.*

Suggested prompts	Sample student responses
We've talked about protein in this unit already. What do you know about proteins?	*They're big molecules that are made of atoms.* *They have special shapes to do their jobs in the body.* *Inside our muscle cells there are lots of proteins—myosin and actin—working so we can move.* *We eat protein, too.* *Animals need to eat protein to be able to build and maintain their muscles.* *I remember from the Inside Our Bodies Unit that proteins are made of amino acids.*
As we also learned in the Inside Our Bodies Unit, when an animal like a human eats protein, what happens in the body so it can use that protein?	*The food gets broken down into little, smaller pieces.* *Those little pieces get absorbed so they can move around in the body.*
*So the body is getting these little pieces from food. How can those pieces get rebuilt into new, different proteins?**	*The body uses instructions—genetic information—for how to arrange the pieces into whatever proteins it needs.*

Say, *So the building blocks that bodies use to make these new proteins come from food.* Discuss how to represent these "building blocks" using prompts such as the following.

Suggested prompts	Sample student responses
In the Inside Our Bodies Unit, you used squares to represent the smaller, building block pieces that the body got from breaking down food. I'd like to propose that we use circles here since the molecular models of proteins we've been seeing in this unit are made of little spheres. Will we be able to draw a sphere or circle for every atom in those molecules, though?	*No!* *We would be drawing circles for a long time.*
*I agree that we don't need to try to draw all the pieces that make up the myostatin protein—that's not the purpose of this model. What is important to represent with our circles-as-building-blocks?**	*We should say that they come from food.* *We should show them making the myostatin protein that comes from that genotype.* *The myostatin protein doesn't have to be exactly the images we saw of it. We can't draw that detail, but we should show its shape.* *We want to be able to tell the difference between the typical and the partial myostatin shapes.*
Why is it important that we represent the different shapes of the typical and the partial myostatin proteins?	*The shape of the typical one allows it to do its job, and the partial one doesn't do that job because it doesn't have the same shape.* *Their structure is related to their function or nonfunction, so we need to show that in our model.*

Add "building blocks from food rearranged" to the model next to "protein" and represent the different proteins. See example on next page.

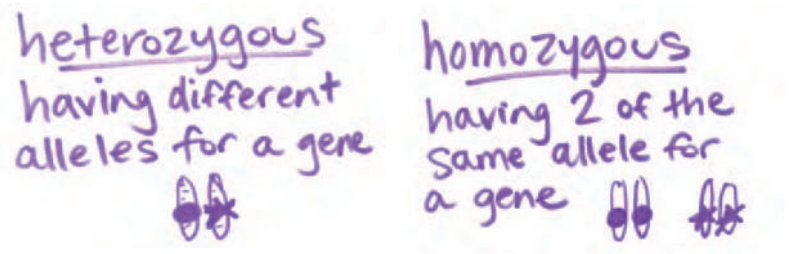
Continue to build the model as a class. Have students articulate how each component should look and provide the evidence for each representation in the model as you work your way up the chart paper. Discuss and develop each component until you arrive at the idea of the offspring getting their chromosomes in sperm and egg from the parents. At this point, it is not necessary to identify the genotypes of the parents (that will be the focus of Lesson 8). See examples below for adding the building blocks, the completed addition to the model, and how it is connected to the original classroom consensus model.







Define *homozygous* and *heterozygous*. Say something like, *When we were talking about the genotypes that lead to each of these phenotypes, we kept saying "two of the same alleles" or "one of each allele" for the gene we're talking about. It may be easier to talk about which genotype we mean if we use the words that scientists have for each of these combinations.*



Explain that having two of the same allele of a gene is called *homozygous* and having two different alleles of a gene is called *heterozygous*. If you have space on your paper, work with the class to add these labels near the genotypes for the three animals in your model.

Add these words to your Word Wall using definitions and images such as those shown here.*

Supporting Students in Making Connections in ELA

You might choose to ask students if they notice familiar Greek roots in these words that can help them determine and recall their meanings. If students don't already know the Greek roots for *hetero* (different) and *homo* (same), you could introduce them now.

Connect the scale of this new part of our consensus model to what we already know. Display **slide F**. Ask, *What scale are we looking at? What scale or scales are represented here in our model?**

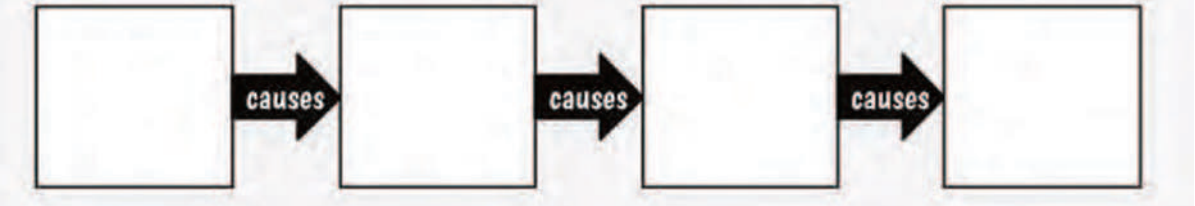
Discuss the various scales in the model using prompts such as these.

Suggested prompts	Sample student responses	Follow-up questions
What scale or scales are we representing in our model?	*There isn't just one scale here.* *The phenotype of the offspring or individual is at the organism or system level.* *Lots of muscle cells make up muscle tissue, but we're thinking about individual muscle cells here.*	*What led you to say _____? Are there other areas that support this too?* *Show us an example of where this is happening.*
What other scales do we need to add to this list of how an organism is organized?	*When we're talking about the chromosomes and genes and alleles and proteins, those are on an even smaller scale.*	*Where would each of those components fit on the scale list we have here?*
Which of these scales or components can we see? Which can we not see?	*Obviously we can see organisms, organs, and tissues with our own eyes.* *We can see cells and their nuclei with a microscope, and we've seen chromosomes in microscope photos and videos, too.* *But we cannot see the atoms that make up the chromosome molecule; we can't see the different gene regions or alleles.* *And proteins were smaller than the chromosomes, too. We can't see those, either!*	*Let's be sure we have these components on our list.*

Display **slide G** which shows this progression of larger to smaller scales with empty lines at the bottom to fill in smaller-than-cellular scales.

Work with the class to fill in the blanks in the scale list on the slide after "cell" as follows: nucleus > chromosome > gene, allele, protein. Alternatively, display **slide H**, which shows the completed list.

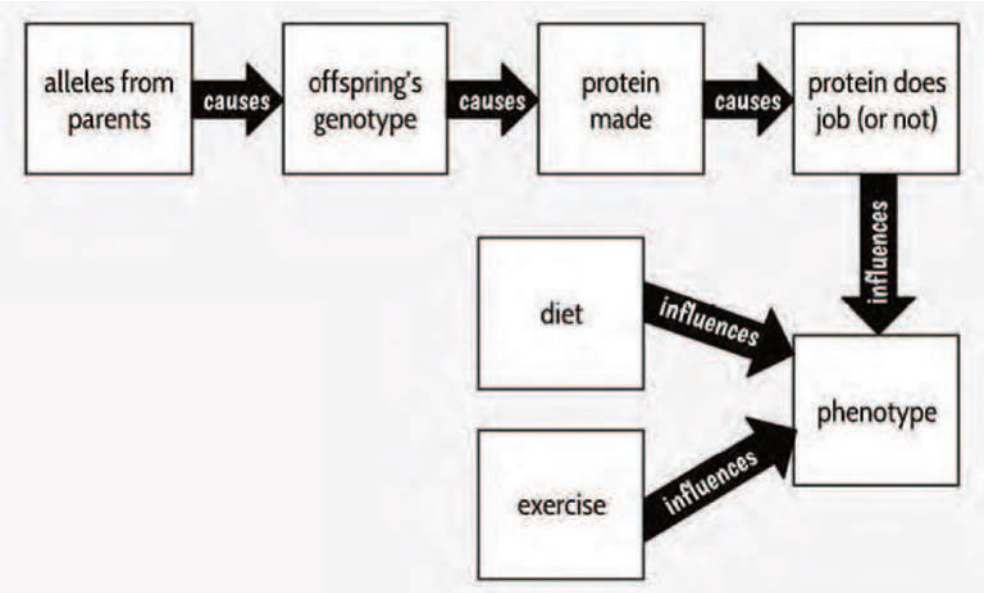
Build a cause-effect chain.* Display **slide I**. Say, *We've been modeling several cause-and-effect relationships today, and we already had others on our classroom consensus model. In the Magnets Unit when you had multiple cause-effect relationships that happened in a sequence, from turning on the music player to hearing the music, you represented them in a chain like this. This graphic can also help us visualize the cause-effect relationships that influence an animal's phenotype. But, the final result of an animal's phenotype isn't quite as simple as this graphic.*



Use prompts such as the following while you capture students' thinking on a whiteboard or chart paper or by rearranging and typing into the boxes on **slide J**.

Suggested prompts	Sample student responses	Follow-up questions
How can we change this graphic so we can use it to explain the cause-and-effect relationships that lead to the phenotype we see?	*We need more boxes for and arrows for causes. There are more steps in how the genotype influences the phenotype.*	*Let's start filling in the boxes and see how many we end up using.*
Is genotype the only thing causing an animal's musculature? Or are there other factors at play?	*Even though diet didn't make a huge difference, if an animal wasn't getting enough food or protein, it wouldn't be able to really have muscles at all, so we would see that effect.* *We've heard that these heavily muscled cattle don't need to work out to build big muscles, but for other cattle or even other animals, if they were exercising by pulling heavy loads or something, their muscles would get bigger and we could see that.*	*How can we show diet and exercise as other causes?*
*Are there synonyms for "causes" that we'd like to consider using instead?**	*We've been saying "influences" a lot today.* *Sometimes we say "leads to" or "results in".*	*Do any of those options seem to fit better here?*

See the example completed cause-effect chain shown here and on **slide K**.



Alternate Activity

If time is very short or you do not think co-constructing this cause-effect chain graphic is a good fit for your students' needs, you might choose to show **slide K** and ask students to identify its complexities by asking, *How is the cause-effect chain for an animal's phenotype different from other cause-effect chains you've worked with?*

Review the model in terms of cause and effect. Say, *Who can, in your own words, walk us through the chain of cause-and-effect relationships that result in each phenotype?*

Sample student responses

- If an individual gets sperm and egg from its parents which both have the allele (homozygous) for extra-big muscles on the chromosomes, those alleles both cause the body to make partial myostatin proteins, which don't fit correctly into the cells' receptors, which leads to extra-big muscles. So that's how the individual's genotype causes the heavily muscled phenotype. But if the animal didn't get enough food or protein, we might not see such big muscles.
- If an individual gets sperm and egg from its parents which both have the allele (homozygous) for typical muscles on those chromosomes, those alleles both cause the body to make typical myostatin proteins, which do fit correctly into the cells' receptors, which leads to typical muscles. So that's how the individual's genotype causes the typically muscled phenotype. But if that animal did lots of exercise, we might see somewhat bigger muscles.
- If an individual gets sperm and egg from its parents which have different alleles (heterozygous)—one for typical muscles and one for extra-big muscles—on those chromosomes, those alleles cause both typical and partial myostatin proteins to be formed. Some will fit correctly into the cells' receptors and some will not, which leads to medium muscles. That animal might still have slightly bigger or smaller muscles depending on diet or exercise.

4. Update Progress Trackers and Gotta-Have-It Checklist. 10 MIN

Materials: science notebook, *Gotta-Have-It Checklist*, classroom consensus model

Update Progress Tracker and Gotta-Have-It Checklist. Display **slide L**. Pair students up and direct them to work together to use the classroom consensus model we've been adding to today, in addition to the resources in their science notebooks, to both update their *Gotta-Have-It Checklist* and create a 3-box Progress Tracker entry summarizing today's work.

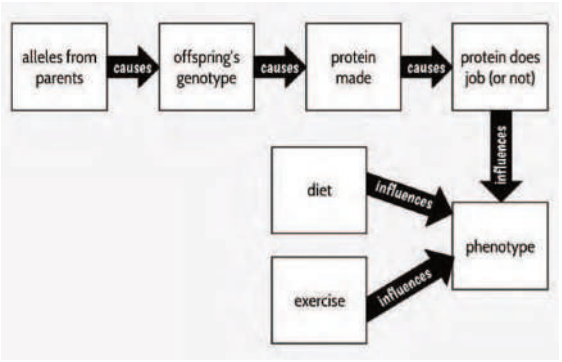
See *Key for Gotta-Have-It Checklist* for sample responses to the *Gotta-Have-It Checklist*. The example three-box Progress Tracker has been completed with *possible* student ideas. Students will likely not include both drawings.

Question	Sources of evidence
How does an animal get extra-big muscles?	• Protein and chromosome data along with photos of cattle who have different phenotypes • The study by McPherron, Lawler, and Lee that showed that an allele of a certain gene can cause an animal's body to produce a differently shaped myostatin protein, which causes the heavily muscled phenotype • The information obtained from the reading explaining how the myostatin protein fits into a receptor on a cell (or not) and sends a message (or not) which results in typical muscles (or not)

What I figured out in words and/or pictures



We put lots of pieces together so we can explain what causes the different phenotypes of musculature in cattle. For example, if an individual gets sperm and egg from its parents which both have the allele (homozygous) for extra-big muscles on the chromosomes, those alleles both cause partial myostatin proteins, which don't fit correctly into cells' receptors, which leads to extra-big muscles. So that's how the individual's genotype influences the heavily muscled phenotype.



End of day 1

5. Revise initial model and create an explanation.

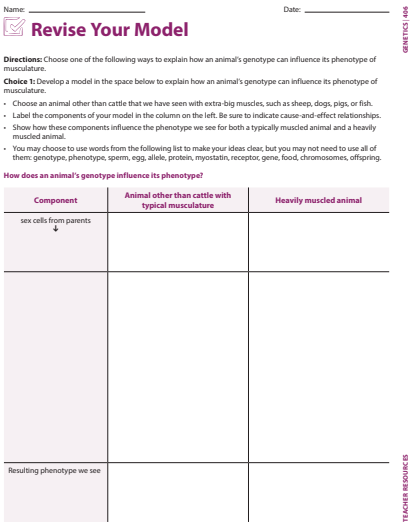
20 MIN

Materials: science notebook, *Gotta-Have-It Checklist*, *Revise Your Model*

Briefly review initial models. Cover or move the classroom consensus model (both pages) so it's out of students' view and display **slide M**. Have students open their science notebook to their initial model from Lesson 1. Ask a few students to share how their thinking has changed from then to now.

Revise initial models. Say, *Let's individually create a revised version of your initial model that will better explain how the organism you're modeling gets extra-big muscles. If you had modeled cattle in your initial model, choose a different organism to model now since we have already modeled cattle as a class.*

Remind students to use their Progress Tracker and *Gotta-Have-It Checklist* to make sure they include all the necessary components to explain this phenomenon. Distribute *Revise Your Model* and allow students time to create and explain their model on the handout.



Name: _____ Date: _____

Revise Your Model

Directions: Choose one of the following ways to explain how an animal's genotype can influence its phenotype of musculature.

Choice 1: Develop a model in the space below to explain how an animal's genotype can influence its phenotype of musculature.

- Choose an animal other than cattle that we have seen with extra-big muscles, such as sheep, dogs, pigs, or fish.
- Label the components of your model in the column on the left. Be sure to indicate cause-and-effect relationships.
- Show how these components influence the phenotype we see for both a typically muscled animal and a heavily muscled animal.
- You may choose to use words from the following list to make your ideas clear, but you may not need to use all of them: genotype, phenotype, sperm, egg, allele, protein, myostatin, receptor, gene, food, chromosomes, offspring.

How does an animal's genotype influence its phenotype?

Component	Animal other than cattle with typical musculature	Heavily muscled animal
sex cells from parents ↓		
Resulting phenotype we see		

GENETICS | 104

TEACHER RESOURCES

Assessment Opportunity

Building towards: 7.A Develop a model to show how genetic factors influence (cause) variation in a trait (effect) by controlling the production of specific proteins.

What to look for: See *Key for the "Revise Your Model" Assessment* for sample student responses and *Rubric for the "Revise Your Model" Assessment* for scoring guidance.

What to do: Have students use their *Gotta-Have-It Checklist* to be sure they are including all the components to explain how these individuals' genotypes influence their phenotypes. Circulate the room during the assessment and watch for students who are struggling. Make a plan for how you will support them in the next part of this lesson when they will use this model to predict the phenotype of a sibling, which is another opportunity to practice applying this model and deepen understanding of it. What you notice during the assessment can inform your creation of deliberate partnerships to support students who showed understanding of different areas of the model. You might also pull a small group of students to guide them through using the model again to predict the phenotype of a sibling.

6. Use our model to predict the phenotype of a sibling.

15 MIN

Materials: science notebook, classroom consensus model

Predict the phenotype of a sibling. Display **slide N**. Refer to the classroom consensus model as you give these directions. Say, *Let's give ourselves a little more practice with this model. Since we worked backwards from phenotype to genotype last time, let's start from the genotype this time and use that to predict the phenotype we expect to see. We can practice by predicting the phenotype of a sibling from the same parents we were just using in our model. By sibling, we mean an animal who had the same male and female parents. You'll work with a partner to predict what phenotype a sibling of these individuals will have. Use your notebook to record the model ideas that support your thinking.*

***Supporting Students in Engaging in Developing and Using Models**

At this point, students may object that the model can't predict that all siblings will have the same phenotype because they already know that siblings do not all look the same. Remind students that

Assign phenotypes to the class so that

- about one third of the partnerships are predicting the phenotype of a sibling of the individual with typical muscles,
- about one third of the partnerships are predicting the phenotype of a sibling of the individual with medium muscles, and
- the final third of the partnerships are predicting the phenotype of a sibling of the individual with extra-big muscles.

Give students 5-6 minutes to work with partners on this task.

Share phenotype predictions with a new partner. Display **slide O**. Remind students of the protocol for Stand Up, Hand Up, Pair Up (previously used in Lesson 1) and direct them to share their ideas for 2-3 minutes.

we're using this model, as we have developed it so far, to predict an outcome. When a model does not accurately predict what happens in a system, it is an indication that the model is incomplete or needs revision.

Additional Guidance

"Stand Up, Hand Up, Pair Up" is a sharing strategy and movement break that works like this: When you say "Go", students stand up with their hand up in the air (and notebook and pen in the other hand). They roam around the room to find another person whose hand is also up (the first person they make eye contact with) and go talk with that person. After they've shared their predictions, both students put their hand up again to go find new partners (someone else whose hand is also up again). Students continue mingling to find partners as they're ready (no set signal from the teacher to rotate).

Share sibling phenotype predictions as a class. Display **slide P**. Ask, *What did our model predict for the phenotype of a sibling of your individual?*

Sample student responses

- I was finding a sibling of the heavily muscled animal, and I predicted the sibling would also be heavily muscled.
- I predicted that the medium-muscled animal's sibling would also have medium muscles.
- According to our model, the animal with typical muscles will also have siblings with typical muscles.

Allow several students to respond and make a point of highlighting that students repeatedly predict that, according to their model, siblings will have the same phenotype.*

Additional Guidance

If students disagree and suggest that the sibling might have a different musculature because of heterozygous parents or for some other reason having to do with inheriting something different from parents, you can add that question to your DQB and/or the top of the classroom consensus model with a question mark as something to explore further. Lesson 8 will focus on exploring inheritance patterns from parents to offspring. At the end of today's class, you will gather ideas to explore further or predictions students have, and you can include these ideas on that list.

Problematize the results of using our model for this prediction. Use prompts such as the following to further discuss these predictions.

Suggested prompts	Sample student responses
I hear you saying that our model predicts that offspring from the same parents will have the same phenotype, right?	*That's what our model predicted, yes.*
So according to our model, siblings should look the same, be identical. Is that how it is in the world? Do siblings all look the same?	*No!* *Siblings do not all look the same.*
Can anyone give us an example?	*My brother has curly hair, but mine is straight.* *My dog had puppies, and some of them had different colors of fur.*

Additional Guidance

Students may also mention that offspring don't always look exactly like their parents, either. If they do, ask what we could do to investigate that. Students may suggest looking more closely at phenotypes of parents and offspring (and siblings), which they will do in Lesson 8. Students can keep their ideas or predictions in mind as we consider siblings for the remainder of this lesson.

Say, *Hmmm. Our model predicted that siblings would look the same, but in our experience that is not the case. Let's stick with cattle for now. I have some photos of siblings of a heavily muscled cow. What data could we gather from those?*

Sample student response

- We could see if the siblings of that heavily muscled cow are also all heavily muscled.

7. Analyze photos of cattle siblings.

10 MIN

Materials: science notebook

Analyze photos of siblings. Display **slide Q**. Say, *Here is a cow named Fiona, and below her are her siblings. Take a moment to individually and silently observe the phenotypes of these cattle.*

Ask, *What do you notice about Fiona and her siblings?*

Sample student responses

- Uncanny is heavily muscled.
- Grayboy and Lydia are medium muscled.
- Everly has typical muscles.
- They do not have all the same phenotype or musculature!
- The siblings look different in other ways, too!

***Supporting Students in Engaging in Asking Questions and Defining Problems**

If your students propose ideas for why the alleles could be different from parents to offspring, you might jot those ideas down to explore next time or phrase them as questions to add to the DQB.

Lead an Initial Ideas Discussion about different phenotypes in siblings. Display **slide R**. Say, *OK, we have evidence that not all cattle siblings have the same phenotype, even though that's what our model predicted. Let's gather some ideas about what could be going on.*

Key Ideas

Purpose of this discussion: To problematize the next lesson question. We want students to start wondering, If we have this model for how offspring get traits from their parents via these alleles, then why don't all the offspring of those same parents look the same?

Listen for ideas such as these:

- Siblings don't always look like each other, in our experience.
- Why don't siblings look the same if they are getting the same alleles? Are they getting the same alleles?
- Where do the alleles come from? The parents … and their parents … and their parents ….
- Are they eating something different or exercising in some way, even if that might make only a small effect?

Use prompts such as the following to guide the conversation.

Suggested prompts	Sample student responses
It seems like we might have encountered a problem with our model, so let's recap. According to our model, where do offspring get their genotype?	*from their parents* *from the alleles and chromosomes that the parents give to their offspring in the sperm and eggs*
Where do the parents get their alleles?	*from their parents*
And those parents, the grandparents ... where did they get their alleles?	*from their parents*
And their alleles came from … ?	*Their parents—it just keeps going back to the parents before them and before that.* *The alleles keep getting passed down from parents to offspring.*
Hmmmm. What are you wondering about that?	*How would there ever be different alleles?* *Why don't offspring always look the same as their parents if they're getting the same alleles?* *Could siblings be eating or exercising so differently that it has a noticeable effect?*
And what does our model predict that siblings from the same parents would look like?	*Our model says that the siblings would all look the same because they all get their parents' genetic information.*

Suggested prompts	Sample student responses
Is this true? Do siblings always look alike?	*No, they don't!*
What about in other animals? Do siblings of other animals—dogs, cats, guinea pigs, humans, and so forth—always look the same?	*No! One time our dog had puppies, and three of them were all brown and one of them had white spots.* *Sometimes? My cousins are twins, and I can't always tell them apart.* *Everyone says my sister and I look nothing alike. She looks like my grandma and I look like my dad.*
*So what's the problem with this model? (It may be helpful to refer to the schematic of our model on **slide S**.)*	*Our model predicts that all offspring from the same parents should look the same, but they don't in real life!*
What are we wondering?	*Why is that? What happens to make siblings look different from each other?* *Why don't offspring always look the same as their parents?* *How can the alleles be so different between parents and offspring that we see different phenotypes?*

Say, *Let's dig into these questions more next time.**

ADDITIONAL LESSON 7 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.W.8.2

Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

CCSS.ELA-LITERACY.W.8.2.D

Use precise language and domain-specific vocabulary to inform about or explain the topic.

If students choose to write an explanation when they revise their model, they will articulate the chain of cause-and-effect relationships involved in how genotype influences phenotype.

Whether students choose to draw a model or write an explanation, they must use specific science vocabulary and organize their ideas in sequence.

LESSON 8

Why don't offspring always look like their parents or their siblings?

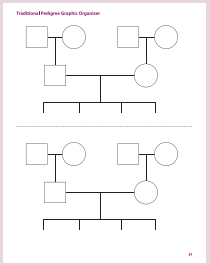
Previous Lesson

We updated our classroom consensus model and revised our initial models to include our recent findings about the roles of genes, alleles, and the myostatin protein in development of the typically, medium-, and heavily muscled phenotypes. Using our model, we predicted that a sibling's phenotype would be the same, but we saw examples of cattle siblings with different phenotypes, so we need to figure out more about that.

This Lesson

Investigation

2 DAYS



Students investigate several family trees that trace the inheritance of the myostatin gene and notice patterns in the proportion of offspring with different genotypes and patterns that are dependent on the genotypes of the parents. They connect these ideas to what they learned in Lesson 5 about how alleles are passed to offspring via sex cells and then can recombine in different ways in the offspring. This recombination explains why we don't look exactly like our parents or our siblings. Students use simple mathematical models to predict the probability that a known cross will result in a particular genotype. They consider the original source of the myostatin allele as a mutation.

Next Lesson

We will read about ways farmers breed animals for specific trait variations, and we will run a computer simulation to try our hand at selective breeding. We will figure out that by breeding animals with beneficial trait variations more often, we can increase the frequency they are seen in the population.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5

What Students Will Do

8.A Use mathematics and computational thinking to find patterns about genotypic and phenotypic outcomes resulting from crossing individuals with specific genotypes.

8.B Plan and carry out an investigation to collect data and uncover patterns that support the idea that chromosome pairs separate when sex cells form and then recombine at fertilization, so each parent contributes half of the genes acquired (at random) by the offspring.

What Students Will Figure Out

- Two homozygous parents produce offspring with the same genotype, but heterozygous parents result in offspring with a variety of genotypes.
- The proportion of offspring with different phenotypes can be predicted using a simple mathematical model when we know the genotypes of the parents.
- The likelihood of getting various genotypes for the myostatin protein is related to the phenomenon that parents' alleles separate into different sex cells and can recombine in different ways to produce the offspring's genotype.
- The patterns of separation of chromosomes into sex cells and the combination of chromosomes in fertilization allows us to develop a mathematical model to predict the probabilities of certain genotypes.
- A mutation is a structural change in the genetic information that can result in changes to proteins produced, which can affect the structures and functions of the organism, thereby changing its trait.

Lesson 8 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Observe family photos, consider the role of mutations in trait inheritance, and reflect on knowledge about genes to answer why family members don't look exactly alike if they share the same genetic information.	A-B	
2	8 min	**ORGANIZE NEW SIBLINGS INTO PEDIGREES** Organize individual cards to show relationships between individuals and to reconnect to what the symbols on the cards represent.	C-I	1 family set (10 individuals) of cards from *Siblings Cards* and *Protein and Chromosome Data Cards* (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)
3	3 min	**SIMPLIFY THE PHENOTYPE AND GENOTYPE TRACKER** Connect what we've learned so far to how it will be represented on the simplified pedigree representation and fill in the pedigree to show phenotypes of family members.	J-K	*Traditional Pedigree Graphic Organizer*, transparent tape, *Family Phenotype Graphic Organizer* from Lesson 5 (in notebooks), 1 family set (10 individuals) of cards from *Siblings Cards* and *Protein and Chromosome Data Cards*
4	7 min	**INVESTIGATE FAMILY GENOTYPES AND PHENOTYPES FOR MYOSTATIN** Transfer genotypes to a pedigree that already has phenotypes represented.	L-M	*Traditional Pedigree Graphic Organizer*, 1 family set (10 individuals) of cards from *Siblings Cards* and *Protein and Chromosome Data Cards*

Part	Duration	Summary	Slide	Materials
5	7 min	**BUILDING UNDERSTANDINGS DISCUSSION ABOUT THE PATTERNS IN PEDIGREES** Discuss ideas and patterns learned from organizing pedigree charts to connect to prior knowledge and to consider answers to our question about why offspring don't always look like their parents or siblings.	N-P	
6	10 min	**CALCULATE GENOTYPE PROPORTIONS FROM MORE PEDIGREES** Use data collected from pedigrees to calculate the proportion of offspring resulting from several different crosses. Pay close attention to crosses where offspring don't look like the parents.	Q-S	*Using Pedigrees to Make Predictions*
7	5 min	**DESCRIBE PATTERNS OF OFFSPRING** Consider the calculations students did and describe the patterns in proportions of musculature in offspring of different crosses.	T-U	*Using Pedigrees to Make Predictions*, *Family Phenotype Graphic Organizer* from Lesson 5 (in notebooks)
				End of day 1
8	5 min	**MAP ALLELES OF INDIVIDUALS BACK TO SEX CELLS RECEIVED FROM PARENTS** Discuss how, for a given trait, the sex cells of homozygous individuals all have the same allele, but the sex cells of a heterozygous individual split the different alleles 50/50.	V-Z	
9	10 min	**SIMULATE RANDOM EGG AND SPERM COMBINATIONS** Use a coin toss simulation and calculations of the proportion of offspring genotypes resulting from mating of individuals with certain genotypes to support the description of random allele combination during sexual reproduction.	AA	*Using Pedigrees to Make Predictions*, 2 poker chips per pair students—1 of each color, small pieces of masking tape, marker, chart paper or white board, markers
10	15 min	**BUILDING UNDERSTANDINGS DISCUSSION ABOUT HOW TO CALCULATE EXPECTED OUTCOMES** Motivate the need for a mathematical tool to help make these predictions. Develop two different ways to calculate probabilities of offspring genotypes.	AB-AS	*Student Support for Probability Work* (optional)
11	8 min	**PRACTICE MAKING PREDICTIONS USING PROBABILITY** Give students a choice to use a Punnett square or the probability calculations to find the expected outcomes of two practice crosses and complete an exit ticket.	AT-AU	half sheet of 8.5" x 11" paper, *Student Support for Probability Work* (optional)

Part	Duration	Summary	Slide	Materials
12	5 min	**WHERE DO THEY COME FROM?** Learn about the source of the extra-big-muscles allele and characterize mutations as the source of such alleles.	AV-AZ	classroom consensus model from Lesson 7
13	2 min	**NAVIGATION** Consider our questions for next time.	BA	

End of day 2

Lesson 8 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Traditional Pedigree Graphic Organizer* • transparent tape • *Family Phenotype Graphic Organizer* from Lesson 5 (in notebooks) • *Using Pedigrees to Make Predictions* • *Student Support for Probability Work* (optional) • half sheet of 8.5" x 11" paper	• 1 family set (10 individuals) of cards from *Siblings Cards* and *Protein and Chromosome Data Cards* • 2 poker chips per pair students—1 of each color • small pieces of masking tape • marker	• chart paper or white board • markers • classroom consensus model from Lesson 7

Materials preparation (20 minutes)

Online Resources

Have a half-sheet of copy paper ready to post the word "mutation" on the Word Wall. Do not post this word on the wall until after your class has developed a shared understanding of its meaning.

Gather the *Protein and Chromosome Data Cards* from Lesson 6 and organize them into sets by family—you should have 2 sets each of the 5 cattle families. (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)

Gather the *Siblings Cards* from your materials kit. If you do not have premade cards from the materials kit, prepare them as follows:

- Print 2 color copies on cardstock of *Siblings Cards* and cut the cards apart.
- Consider laminating these cards since you will reuse them for each class you teach and can keep them year to year.

Each group of students will need the 3 sibling cards from *Siblings Cards* to add to their family from *Protein and Chromosome Data Cards*, so you may choose to bunde the combined family cards (10 total cards per family/group) with rubber bands or binder clips so they're easier to distribute.

Plan to organize students into the same groups for this lesson as they were in for Lesson 5, working with the same cattle family(ies).

Prepare the following copies:

- Make copies of *Traditional Pedigree Graphic Organizer*, one per 2 students, and cut them in half.
- Make copies of *Using Pedigrees to Make Predictions*, one per student.
- *Student Support for Probability Work* is a print version of the steps used on **slides AC-AS**. It is available for reference in the *Student Edition*, or you may make color copies of the handout for any or all students as you think would be helpful.
- Prepare a half sheet of 8.5" x 11" paper for each student to use for their exit ticket.

Have transparent tape available for students to attach handouts to their science notebooks.

Have half-sheets of copy paper ready to add the word **mutation** to the Word Wall. Do not post this word on the wall until after your class has developed a shared understanding of its meaning.

Gather enough poker chips, checkers, or nickels and pennies (something that comes in two different colors and that can be flipped easily and land randomly on one side or the other) so that each group of 4 has two chips of each color (one chip for each student). Each group will also need masking tape and a marker to label both sides of the chips.

Create a table on chart paper, board space, or a digital document for students to record the results of their chip-flipping activity. See the example shown here.

Cross: EE x EE Breeding pair(s): _____

Phenotype of offspring	Genotype of offspring	Keep track of how many offspring by making hash marks or writing numbers for each family	Total number
Heavily muscled	EE		
Medium-muscled	Ee		
Typically muscled	ee		
		TOTAL of all offspring:	

B. Both parents were homozygous for the allele for myostatin that results in typical muscles:

Cross: ee x ee Breeding pair(s): _____

Phenotype of offspring	Genotype of offspring	Keep track of how many offspring by making hash marks or writing numbers for each family	Total number
Heavily muscled	EE		
Medium-muscled	Ee		
Typically muscled	ee		
		TOTAL of all offspring:	

Lesson 8 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students wonder how offspring can sometimes look different than their parents and siblings if they share the same genetic information. To investigate these questions they look for patterns in pedigrees of the families they worked with before with the addition of several siblings to compare.

Students reflect on what they learned in Lesson 7 about how making different forms of the myostatin protein results in different phenotypes with regard to musculature. Uncovering the patterns in the pedigrees reveals that each parent has two alleles for each gene, and by getting one of the alleles from each parent, an offspring may end up with a different combination of alleles than either parent or any sibling has. Finally, students streamline their original family phenotype organizers by consolidating the information using the conventional symbols used in pedigrees. They use these models to figure out how to predict the probability that a particular phenotype and/or genotype would result from a specific parental cross.

Alleles can show different degrees of dominance and recessiveness in relation to each other. We refer to this range as the *spectrum of dominance*. The alleles for some characters fall in the middle of the spectrum of dominance. In this case, the first-generation hybrids have a phenotype somewhere in between the phenotypes of the two parents. This phenomenon, called the *incomplete dominance* of either allele, is seen in the myostatin gene. The *Ee* cattle have a phenotype in between the *EE* and *ee* homozygous genotypes.

Note: While students may suggest using *M* and *m* to symbolize the myostatin alleles, we found that handwritten uppercase and lowercase Ms are often difficult to distinguish. Therefore, we use *E* and *e* (for "extra-big muscles") in these materials, but you and your students may choose symbols that make sense to you.

Students will wonder about where the alleles that the farmers are interested in propagating came from initially. A discussion about the source of alleles by mutation will conclude that mutations represent changes in the gene that are inherited as alleles and that gene mutations affect the proteins that are produced by the allele.

Where We Are NOT Going

Students will reflect on a simplified version of the mechanism of cell-protein interaction that will lead to an intermediate phenotype for heterozygous individuals, but they will not name the type of inheritance nor will they define the term *incomplete dominance*. So far, students have discovered that only one chromosome of an individual's pair of chromosomes ends up in each sex cell. In this lesson we will follow the fate of a single chromosome pair that contains the myostatin gene (chromosome 2). While the chromosomes in this activity have two other genes represented, we focus only on the recombination of the alleles at that single locus. Independent assortment will not be addressed since we will show only a single chromosome here and because crossing-over is introduced in the 9-12 grade band.

While we will discuss the idea of a change happening to the gene creating different instructions for a protein to be made, we are not going to discuss the specific types of mutations that happen with DNA, such as deletions, insertions, and substitutions. These details are beyond the scope of this unit and are not needed to understand the phenomena.

While we are using uppercase and lowercase letters to represent alleles in this lesson, these symbols are not being used to specifically represent dominant and recessive alleles, and we are not introducing those terms and ideas at this time. While simple dominant-recessive patterns do occasionally occur in nature, they are rare, and we want students to work with a more-complex inheritance pattern first so that their foundational understanding of genetics accounts for the complexity that typically occurs for most traits. Musculature is also greatly impacted by environmental factors, which students investigated at the beginning of the unit. Students will investigate a dominant-recessive pattern in Lesson 16, and you can refer to the guidance in that lesson to help guide you in deciding whether to use the terms *dominant* and *recessive* with your students. A simplified understanding of these concepts and patterns is not sufficient for students to comprehend real-world genetic complexity.

LEARNING PLAN FOR LESSON 8

1. Navigation

5 MIN

Materials: science notebook

Look back to what we wondered about last time. Display **slide A**. Say, *So in the last lesson we looked at some siblings from the same parents.*

Suggested prompts	Sample student responses
What did we notice about siblings that came from the same parents?	*We noticed that siblings don't always look like each other, and not only that, but they don't always look like their parents either.*
Was that surprising to you?	*When we think about ourselves, this makes sense. We don't look exactly like our biological parents or our biological siblings either.*
What were we wondering about at the end of last class?	*How come siblings don't look the same if they have the same genetic information as their parents?* *What happens that makes babies not always look like their parents?*

Show **slide B**. Say, *We have a lot of questions on our DQB about alleles and how they get passed on, and we also talked last class about how siblings don't always look the same as each other or as their parents. How might we investigate how siblings from the same family look different from one another?*

Refer to previous investigations to gather ideas. Say, *Take a minute to look back in your science notebook for some ideas about how we've investigated patterns in families. If you see something that might help us here, jot down your ideas. And then discuss your ideas with your partner after they have had some time to jot down ideas as well.* Point students to Lessons 5 and 6 to guide their search.

Bring the class back together for a brief discussion. Use the suggested prompts.

Suggested prompt	Sample student response
What have we done before that could again help us investigate family patterns in traits?	*We looked at family trees and family pedigrees.*

Suggested prompts	Sample student responses
What information did we use to create these pedigrees in Lessons 5 and 6?	*We had cards with pictures of different cattle that said who each individual was related to.* *We used pictures of proteins and chromosomes.* *(Accept all responses.)*
*How might we investigate how **siblings** from the same family look different from one another?*	*We didn't have any sibling data before. Maybe we need more information about cattle siblings?*

Summarize for the class. Say, *It sounds like we have a lot of information already, but we want to look at more siblings. I have some data and images from cattle siblings that might help us.*

Additional Guidance

The purpose of this navigation is to resurface the ideas we will be revisiting in depth during this lesson. There isn't a need to ensure that students remember all the details at each level of scale at this point. The discussion is only to serve as a reminder and draw attention to the physical structures that are important at each level so the ideas are within reach moving forward. If students don't make the connection at this point between inheritance of alleles and inheritance of traits, that is all right. They will make that connection in depth later in the lesson.

2. Organize new siblings into pedigrees.

8 MIN

Materials: 1 family set (10 individuals) of cards from *Siblings Cards* and *Protein and Chromosome Data Cards*

Organize family photos in small groups. Advance to **slide C**. Say, *OK, let's go back and collect some of that information and look for patterns that might shed light on some of this. We will study the same families we worked with in Lessons 5 and 6, but I've added some siblings to each of the families. Take a moment to organize the individuals in your pedigree to show their relationships like we did before and add the new siblings in the appropriate place based on their relationships.*

Have the students arrange themselves into their working groups from Lesson 5 and redistribute the combined sets of cards from cards from *Siblings Cards* and *Protein and Chromosome Data Cards* so each group is working with the same cattle family they had in Lesson 5. Give the groups a few minutes to organize their individuals into a pedigree.

Make connections between symbols and visible cell structures. Show **slide D**. Say, *Let's take a minute to get oriented again to what we are looking at. The information cards you have for each of your cattle have a lot of symbols and structures. Let's take a moment to remind ourselves what these symbols represent, so we can keep the actual structures in mind as we move through the rest of our investigation.**

*** Supporting Students in Developing and Using Scale, Proportion, and Quantity**
By looking at each successively smaller scale and explaining what we can and cannot detect with our eyes or with the aid of a microscope, we can highlight the need to use symbols to represent the structural differences between the chromosomes that are beyond what is observable with the level of technology a typical classroom has access to.

Suggested prompts	Sample student responses
If we zoom in to individual muscle cells and look at the nucleus, what are we looking at?	*If you zoom in you will see the chromosomes that the muscle cells have.*
*(Show **slide E**.) What do these two sets of colored symbols represent?*	*The two stacks of symbols represent one pair of chromosomes.*
*(Show **slide F**.) Right, we had this jumbled mess of chromosomes, and we saw that scientists organize them into a karyotype, which helps us better see patterns. Under a microscope, chromosomes look pretty similar because the molecules that are differently shaped in the different alleles are too small to see.*	*The symbols are showing that there are several genes on each chromosome. Each gene is represented by a different color of symbol.* *The symbols also show there are different alleles for the genes that are on each chromosome. The different alleles are represented by different shapes of the symbols.*
How did adding these symbols help us make sense of these data?	*Even though they look the same and have the same genes, they are not exactly the same because they might have different alleles.*
What does the different shape of the allele mean?	*Different alleles mean there is a small difference in the shape of the chromosome that causes a difference in the protein.*

Show **slide G** and comment on how the colors indicate where coordinating genes are located on the chromosomes, then advance to **slide H**. Remind students that the symbols represent alleles of these different genes.

Allow students to study the image for a moment, then advance to **slide I**. Say, *Let's do a self check. Without talking to anyone, think about the following question: Where did the chromosomes in this offspring's muscle cells originally come from?* Bring students back together as a class to discuss their ideas.

Suggested prompt	Sample student responses
OK, this has really helped me. We can see that individuals have pairs of these chromosomes. Where did these chromosomes originally come from?	*We saw in Lesson 5 the egg and sperm each have half the number of chromosomes as body cells have. So when the sperm fertilized the egg, they combined.* *Each pair of these chromosomes has one chromosome that came from the individual's female parent and one from the individual's male parent.*

Additional Guidance

We have not revisited the idea that there are half the number of chromosomes in eggs and sperm since Lesson 5. This is an important point we will be building on in this lesson, and there will be several opportunities to revisit this idea. If students struggle to recall this idea, pull up Lesson 5 slide T or have students return to the *Chromosomes in Sex Cells* diagram they annotated in Lesson 5 to see the patterns that led them to realize that the egg and sperm chromosomes combined to give an individual their chromosomes.

3. Simplify the phenotype and genotype tracker. 3 MIN

Materials: *Traditional Pedigree Graphic Organizer*, science notebook, transparent tape, *Family Phenotype Graphic Organizer* from Lesson 5 (in notebooks), 1 family set (10 individuals) of cards from *Siblings Cards* and *Protein and Chromosome Data Cards*

Reflect on what we figured out so far by looking at our pedigrees. Show **slide J**. Say, *So far we've looked at a lot of different pieces of information to help us make sense of how the phenotypes of our cattle are related to the phenotypes of their other family members and how all the cattles' phenotypes are related to their genotypes. But now we're really interested in tracking the alleles. So let's simplify so we can focus mostly on the alleles.*

Prepare science notebooks to record family information on a pedigree chart. Give all students a copy of one half of *Traditional Pedigree Graphic Organizer.* Ask them to open to the next available page in their science notebook. Have students attach the pedigree organizer to their notebook page. They should leave space at the bottom of the page for a key under the pedigree.

Say, *Add a title to your pedigree that indicates the trait we are following and the name of the family member used to identify your family. Study your new family member cards and determine how many circles and/or squares you need to add to the bottom row to represent all four siblings. You will need to draw in four shapes total: one for the original offspring you saw and three more for the new siblings.*

Create a pedigree showing each individual's phenotype for musculature. Display **slide K**. Ask students to examine their *Family Phenotype Graphic Organizer* from Lesson 5. Say, *We are simply recreating this portion of our tracker, right now but we are also adding the new siblings.* Give students time to independently add this information to their science notebooks.

Consider other information to add to the pedigree. Ask students to look at the cards in their family to examine the symbols that represent the different alleles on chromosome 2.

Suggested prompt	Sample student responses
How many chromosomes are represented by the symbols we are looking at?	*The symbols represent a pair of chromosomes.* *The two vertical stacks of symbols represent two different chromosomes.*

Suggested prompts	Sample student responses
Do we see genes on these chromosomes? *How many different genes do we see?*	*There are three different genes. The same three genes are on both chromosomes.*
How are the different genes represented?	*We can tell they are different genes because of their position on the chromosome, and we are showing them as different colors too.*
Is the idea of alleles represented here? *How many different alleles for each gene do we see?*	*Looking at a few different examples, it looks like there are two different alleles for each gene.*
How are the different alleles represented?	*We can tell there are different alleles for a gene because they are the same color but different shapes.*
What else do you notice about how the alleles are arranged?	*Not all cattle have two different alleles for a gene, sometimes they have the same allele for one gene and different alleles for other genes.*
Which of these colors represents the myostatin gene?	*the gene at the bottom of the stack* *the blue circles and stars*
What do the different allele symbols for myostatin represent?	*The symbols are different shapes because the alleles are different, and because they are different shapes they will make different proteins.* *The circle symbol allele is the one that is responsible for making the usual version of myostatin—the typical, full protein, and those individuals will have typical muscles.* *The star symbol allele has a mutation and changed shape, so the protein it is responsible for making is also a different shape and causes bigger muscles.*

4. Investigate family genotypes and phenotypes for myostatin.

7 MIN

Materials: science notebook, *Traditional Pedigree Graphic Organizer*, 1 family set (10 individuals) of cards from *Siblings Cards* and *Protein and Chromosome Data Cards*

Develop a simpler way to reference alleles in the genotype. Display **slide L**. Say, *While it is often helpful to have more information about the other genes on the chromosome we are looking at, it is also valuable to focus on only the gene we are interested in. By simplifying the model in this way we can look for patterns that are associated with this gene alone.* To further simplify our work with our model, we can use letters instead of drawing symbols to indicate the different alleles.*

*** Supporting Students in Developing and Using Systems and System Models**
We have developed a complex set of components to describe

This will make it a lot faster for us to record our genotypes because we will be recording quite a few of them. Let's plan to use a capital letter E *for extra-big muscles. Since the star symbol is associated with the allele for extra-big muscles, let's replace the star with an uppercase letter* E, *and the circle symbol for typical muscles will be replaced with a lowercase* e. *Add this information to your pedigree key.*

Additional Guidance

While we are using uppercase and lowercase letters to represent alleles here, the myostatin gene does not operate in a simple dominant or recessive pattern, so these letters do not represent dominant and recessive alleles, and we are not introducing those terms and ideas at this time.

If you have a student who has some background in genetics and mentions that these letters mean an allele is dominant or recessive, acknowledge that there are many different patterns for designating symbols (and what these symbols mean) for alleles. In this case our letters do not correspond to whether an allele is dominant or recessive; they only represent what version of the gene we have. Add that it is OK to designate any symbol you want, as long as you have a key to identify it properly. One example of an alternate lettering scheme might be something like this: *T* = typical-muscles allele and *t* = big-muscles allele.

what is happening when proteins are made, and now we admit we need to simplify the model to help us figure out what is happening at a different scale. Making this move visible helps students realize models have different utilities at different scales. We sometimes need to simplify a model to best highlight the part of the system we are studying.

Add genotype to the pedigree. Show **slide M**. Ask students to create a Notice and Wonder chart on the notebook page next to their pedigree. Say, *We're trying to figure out how alleles are getting passed from parents to offspring, so let's focus on the alleles. Go ahead and use the symbols in your family data set that show the myostatin genotype and record the genotypes in the appropriate places on the pedigree using the uppercase* E *and lowercase* e *system. When you've finished filling them all in, take a look to see if you notice any patterns between parents and offspring or if you have any questions about parents, offspring, and siblings. Record any patterns you see or questions you have in the Notice and Wonder chart.*



5. Building Understandings Discussion About the Patterns in Pedigrees

7 MIN

Materials: science notebook

Discuss patterns and how these connect to what we know and the questions we are trying to answer. Display **slide N** and say, *Turn to your elbow partner and take thirty seconds each to share one pattern or key idea you noticed and one question that came up for you while you were looking for patterns between parents and offspring.*

Move to **slide O** and ask students to share their ideas about the following questions that are displayed on the slide:

- What patterns did you notice between parents and offspring?
- What patterns did you notice between siblings?
- Have we answered our questions completely yet about why parents and offspring do not always look the same or why siblings do not always look the same?

*** Attending to Equity**
Supporting Emergent Multilingual Students: Moving from a concrete (images of chromosomes and shape symbols) to a more symbolic (uppercase and lowercase letters) description of genotype could be confusing for emerging multilingual students, especially if one of their languages does not use or distinguish between uppercase and lowercase letters. Some teachers may be

Suggested prompts	Sample student responses
Did you have any general noticings about phenotype that you may not have noticed earlier? How many of these individuals had really big muscles?	*Only some of the individuals had extra-big muscles. Not all offspring of individuals with extra-big muscles had extra-big muscles, but some did.* *If an offspring had extra-big muscles, though, it always had someone in the family, like a parent or grandparent, that also had extra-big muscles.*
What patterns did you see between parents and offspring?	*Two typically muscled parents always had all typically muscled offspring.* *Two extra-big-muscled parents had extra-big-muscled offspring.* *Extra-big and medium-muscled offspring always have at least one parent with bigger-than-typical muscles. In other words, two typically muscled parents never had an extra-big or medium-muscled offspring.*
What patterns did you see among offspring of certain pairs of parents?	*If the parents are the same as each other, the offspring are usually the same as each other.* *If there's a mixture of different phenotypes of the parents, the offspring seem to be more mixed up or have more different kinds.*

used to discussing genotypes by their letters, but choosing to say "homozygous" and "heterozygous" instead will give all students more practice with those scientific terms.

Key Ideas

Purpose of this discussion: To ensure that students have noted all the patterns of inheritance that they will use in the next activity to figure out how inheritance works

Listen for these critical ideas to surface in the discussion:

- If the parents are the same as each other, the offspring are usually the same as each other.
- If there's a mixture of different phenotypes of the parents, the offspring seem to be more mixed up or be of more different kinds.

The general patterns (that homozygous x homozygous crosses result in all one genotype and phenotype of offspring, while crosses involving a heterozygous parent or parents result in a distribution of different genotypes and phenotypes of offspring) are the critical ones for students to notice at this point.

Students may or may not call out any or all of the following:

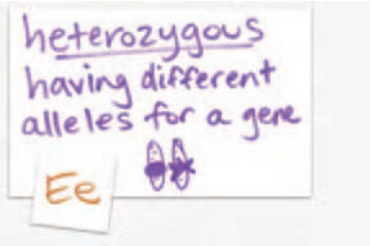
- Two typically muscled parents always had all typically muscled offspring.

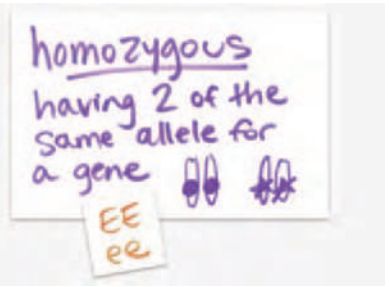
- Two extra-big-muscled parents had extra-big-muscled offspring.
- Big-muscled offspring (both extra-big and medium muscled) always have at least one parent with bigger-than-typical muscles.
- Wherever there's a medium-muscled parent, it's more complicated.

These patterns are the ones that students will use to discern that random assortment of sex cells from parents results in the genotype of offspring. However, if these patterns are not all named at this time, they will become more obvious during the next activity.

Remind students about the terms *homozygous* and *heterozygous*. Say, *Remember the terms "homozygous" and "heterozygous" that we added to our Word Wall in Lesson 7?* It's kind of cumbersome to say "big* E, *big* E*" or "big* E, *little* E*," and we're going to be talking about these genotypes even more often. Let's use the term "homozygous" for individuals that have two of the same allele for a gene, and let's use "heterozygous" for individuals that have two different alleles for a gene.*

Update the Word Wall cards for "homozygous" by adding "EE" and "ee" and "heterozygous" by adding "Ee" as shown here.





Note the relationship between genotype and phenotype with regard to the myostatin protein. Say, *There are two ways to be homozygous in this case, correct? When there are two of the alleles that make typical proteins or two alleles that make the partial proteins. And there's one way to be heterozygous: when there is one allele that makes the typical protein and one allele that makes the partial protein. So then both of the proteins are made in heterozygous cattle.*

Suggested prompts	Sample student responses
So if an individual is homozygous for the myostatin gene and inherits two alleles that make the typical version of myostatin, what we have used little e to represent, what will the phenotype of the individual be? Can someone walk us through how the gene contributes to the phenotype?	*The cow will have typical muscles.* *The typical myostatin will keep the muscle cells to the typical size and amount of muscles.*
Great, can someone walk through this process for an individual that is homozygous for the gene and inherits two alleles that make the partial version of myostatin—what we used big E to represent?	*If an individual has two alleles that make the partial myostatin, it will only be able to make that kind of myostatin protein, so it will have extra-big muscles.*
OK, so what if the individual is heterozygous and therefore has one of each allele?	*The individual would make both the typical and the partial form of myostatin. When they are both present, some of the cells get bigger and some stay typical sized, so those cattle have medium-sized muscles.*

Share whether we've answered our lesson questions. Display **slide P**. Say, *So what do you all think? Have we completely answered these questions? Do we now know why offspring don't always look like their parents? Do we know why they don't always look like their siblings?*

Suggested prompts	Sample student responses
So what have we figured out so far?	*We noticed that of course the genotypes match the phenotypes in our pedigrees.* *We've figured out that there seem to be some patterns between parents and offspring and among siblings of certain parents.*
What might help us figure out what's going on?	*We need to look at more families to see if the patterns are the same.* *We need to look at what happens in reproduction with eggs and sperm and chromosomes.*

6. Calculate genotype proportions from more pedigrees.

10 MIN

Materials: *Using Pedigrees to Make Predictions*

Offer students more data. Say, *I learned that people who raise cattle keep something called "herd books". Herd books keep track of pedigrees by showing what parents and offspring look like for a lot of different crosses in whole herds of cattle like the ones we are studying. Ranchers and breeders wanted to know if they could determine if certain individuals were more likely to have the heavily muscled offspring they wanted, which would be good for them if they could predict it. Let's look at some of these and see if we can find some clearer patterns.*

Introduce the skills necessary to complete the activity. Give all students a copy of *Using Pedigrees to Make Predictions* and show **slide Q**. Review the symbols on the slide. Then move to **slide R** and tell students they will work in their small groups to determine the number of times certain kinds of offspring result from certain kinds of parental crosses to see if it might help us figure out how to make a prediction.

Count the number and phenotypes of offspring from different crosses. Have students divide the work among their group members (there are 6 different types of crosses, lettered A through F) and count up the total number of offspring for each of the different types of parental crosses and count how many offspring have each of the three different types of musculature phenotypes.

Compare the numbers in different categories of phenotypes. Have some students share with the class the numbers they found for particular crosses. Be sure to ask them how many they saw of each phenotype and genotype out of the total number of offspring. Note that the total number of offspring isn't the same in each family and ask how we might compare across different categories of phenotypes. Say, *We keep having to say so many with a particular*

phenotype out of so many total offspring. Is there a single number we can use to describe these quantities so we can compare them more easily? If no one suggests using a proportion, ratio, or percentage, raise the possibility yourself. Say, *In order to determine if some of these breeding pairs result in more-muscled phenotypes, let's calculate the proportion or percent of offspring with certain traits.* Use the suggested prompts below to encourage students to explain these concepts to their classmates.

Suggested prompts	Sample student responses
Who can give me a quick explanation of how I could calculate this or what I mean by finding the proportion.	*Proportions are kind of like ratios.* *It's like what fraction of something we are looking at. It's like the percentage of the traits found.*
Right, so all those could be used to describe the proportion. If I wanted to know the proportion of students in the room that preferred writing in pen, how would I get that value?	*First, you would count how many students preferred pens. Then you would divide that number by the total number of students in the room.*
Great, so if I was interested in finding the proportion of offspring that were big E, big E that result when a heterozygous individual is crossed with an individual that is homozygous for big E, where would I start?	*I would count all the big E, big E offspring and divide them by the total number of offspring for that kind of cross.*

Calculate proportions from the crosses. Display **slide S**. Have students add a column labeled "Proportion" to the right of each table in *Using Pedigrees to Make Predictions* and fill in the proportion of each offspring phenotype as both a ratio (or fraction) and a percent value. Say, *OK, we're going to work as a group so we can get our calculations finished quickly. Divide the work among your group members and then share your calculations with one another. As you are sharing results, discuss whether you noticed any cases where offspring didn't look like their parents and if you have thought of any new questions.*



7. Describe patterns of offspring.

5 MIN

Materials: science notebook, *Using Pedigrees to Make Predictions*, *Family Phenotype Graphic Organizer* from Lesson 5 (in notebooks)

Describe the patterns using proportions found during the pedigree analysis. Show **slide T** to remind students what they should discuss when they finish sharing calculations. Have them review the calculations they did on *Using Pedigrees to Make Predictions* for all the different types of crosses. After they have had a few minutes to review, say, *So, what did your group figure out about the proportion of offspring that resulted from these different crosses?*

Suggested prompts	Sample student responses
Did you notice any patterns in the proportions?	*Yes. Some of them had 100% proportions, and others had different patterns.*
What were the patterns that you saw?	*When the cattle parents crossed had the same genotypes and were homozygous, 100% of the offspring were the exact same as the parents, like in EE crossed with EE and ee crossed with ee.* *If the parents were the same genotype but heterozygous, some of the offspring, half of so, looked like the parents, but a couple were randomly EE or ee and did not look like the parents.* *If you cross a homozygous individual with a heterozygous one, it seems like you got about half like one parent and about half like the other.*
Do these patterns match the ones we saw with our families?	*Yes. These are the same patterns, but they're a little easier to see with more data and more numbers.* *The proportions are a way of describing the patterns we already saw by using numbers.*
I heard you say that there were a few times that offspring showed up from a cross that didn't look like either parent, for example two heterozygous parents, as well as the homozygous big E crossed with homozygous little e. Does this help answer our questions about whether all offspring look like their parents?	*Yes, we definitely saw that some of the offspring did not have the same phenotype as the parents, and some didn't even get the big muscles that their parents had.*

Say, *OK great. I feel like this thinking is really helping us get farther. But we just said that sometimes offspring don't look like their parents. Like a cross between two heterozygous parents* (write "Ee x Ee" on the board) *can have a homozygous, extra-big-muscled* (write "EE" on the board) *offspring.*

Display **slide U**. Say, *Hmmm …. Is it possible that a parent could pass on different alleles to their individual offspring? Look back in your science notebook at your notes on the Family Phenotype Graphic Organizer from Lesson 5, and then share your answers to these questions with your elbow partner:*

- Where did these offspring get the *E* or *e* alleles?
- Is it possible that a parent could pass on different alleles to their individual offspring?
- How would that happen?

Assessment Opportunity

Building towards: 8.A.1 Use mathematics and computational thinking to find patterns about genotypic and phenotypic outcomes resulting from crossing individuals with specific genotypes.

What to look and listen for: When students are calculating on *Using Pedigrees to Make Predictions* proportions of genotypes that result from certain crosses and during the class discussion that follows—prior to displaying slide U—listen for students to identify specific groups with clear patterns of genotypes that they describe by comparing numbers. For instance, students might notice or say the following:

- When two homozygous parents with the same genotype were crossed, 100% of the offspring were the exact same genotype as the parents.
- If a homozygous individual is crossed with a heterozygous one, about half the offspring look like one parent and about half look like the other.

What to do: If students make only general statements (e.g., there is a pattern in all the crosses) or do not use quantities to compare the distribution of genotypes among the offspring, direct their attention to individual crosses in the class data and explicitly ask them to try to describe the pattern using numbers or proportions. You may ask them to represent the patterns graphically using a pie chart or other representation. Students should have a good intuitive sense of the size of fractions or percentages, and expressing these proportions in that way may help them visualize the patterns.

End of day 1

8. Map alleles of individuals back to sex cells received from parents.

5 MIN

Materials: None

Trace the alleles through the different levels of scale we have investigated. Have some students share their ideas from the previous class about how different alleles might get passed from parents to offspring. Then, as you move through the following slides, ask various students to explain what is illustrated on each of the slides and to describe how they think the allele is getting passed along at each step.

Show **slide V** to remind students about the number of chromosomes in body cells versus sex cells. The allele that gets passed on must be in one of the sex cells.

Then move to **slide W**, which zooms in to the cells all the way to the level of the chromosomes. Remind students that chromosomes are found in the nuclei of these cells, even though the nuclei are not specifically shown in these diagrams. This slide should remind students that chromosomes occur in pairs in body cells and only one of each pair is in the egg or sperm, which means that only one chromosome with the myostatin allele is in each sex cell and thus gets passed on.

When you move to **slide X**, the *E* and *e* symbols used for alleles should remind students that the alleles have a physical place at each of these levels (in the body cell, in the sex cell, on the chromosome). The allele that gets passed on is

in the position of the *E* or *e* symbol at each level. The symbols help us trace the process through different scales to allow us to make the connection that when we say "separating the alleles", it is the same as saying "separating the chromosomes".

Key Ideas

Purpose of this discussion: To help students link the ideas they have learned about what is going on with alleles in the egg and sperm and then in the offspring and to highlight the ideas that there is a probability tied to any given egg or sperm having a certain allele and that the probability is dependent on what alleles the parents had

Listen for these ideas:

- Alleles on chromosomes are passed from parents to offspring when the sperm and egg fuse during fertilization.
- Egg and sperm each have half the number of alleles as the body cells (or the offspring's body cells).
- The allele present in any given egg or sperm depends on what alleles the parent has for that gene.

Facilitate a brief discussion about what happens in fertilization. Use the suggested prompt.

Suggested prompt	Sample student response
In the example we're looking at, the male and female are both homozygous, so we know for sure that all the male's sperm have a big E allele and all the female's eggs have a little e allele. What does this allow us to know about all their potential offspring?	*If there are only sperm that have big E alleles and only eggs with little e alleles, all the offspring will be heterozygous.*

Display **slide Y**. Allow students to orient themselves to the symbols and images on the slide for a moment, then direct their attention to the alleles of the heterozygous female parent, the alleles in the two potential eggs, and the alleles of the potential offspring.

Suggested prompts	Sample student responses
But what if the female parent is heterozygous? It looks like half the eggs have one allele and half have the other allele.	*Yes. An egg could have either allele in it.*
When these parents mate, how is it decided which egg is the one that gets fertilized?	*It's probably just a random chance, whatever egg happens to be where the sperm is.* *It could be either egg that gets fertilized, just by chance. Either one is possible.*

Key Ideas

Purpose of this very brief discussion: To ensure that students identify that egg and sperm combinations are likely to happen randomly during fertilization

Listen for this idea:

- Which egg combines with which sperm is likely to be a random process.

The idea of randomness is critical to understanding the probabilities that determine the genotype (and therefore the phenotype) of offspring in any particular cross. While we have not confirmed the randomness of this process yet, raising the idea that which egg and which sperm combine in fertilization is likely to be random drives the activities and calculations that follow in the rest of the lesson.

Display **slide Z**. Say, *If the egg and sperm that combine just do that randomly, does that random combination explain all the different patterns in the proportions that we saw in all those pedigrees? Is there a way we could test that idea?*

Suggested prompts	Sample student responses
If we wanted to simulate how fertilization happens with eggs and sperm combining randomly, what could we do to make sure we were choosing randomly? Can we think of something people use when they have to randomly decide between two things?	*We could flip a coin!*
So if random combinations are actually what's happening and we use a random way to mimic egg and sperm combinations, would we expect to see the same proportions with coin tosses as we saw in our pedigrees? Would that help convince us that it's random?	*Yes, if it really just depends on a random combination of eggs and sperm, then we should see the same proportions in coin flips as we saw in the pedigrees.*
Great, so we can test a lot of different hypothetical breeding pairs to see if, when eggs and sperm combine randomly, we can replicate the same kind of data we analyzed from the herd books. If we wanted to see the most convincing data, how many "offspring" would we create, how many coin flips should we do?	*The more we make the better, but since we don't want to run out of time before class is over maybe we can each do ten flips and then share the data with the class.*

9. Simulate random egg and sperm combinations.

10 MIN

Materials: science notebook, *Using Pedigrees to Make Predictions*, 2 poker chips per pair students—1 of each color, small pieces of masking tape, marker, chart paper or white board, markers

Prepare to collect data from breeding pairs. Show **slide AA**. Ask students to turn to the next blank page in their science notebook to set up a place to collect data for this investigation.* They will record the alleles contributed by each parent as well as the genotype and phenotype for each flip. Ask students to pair up within their small group and give each pair of students 2 poker chips (one of each color—one will represent the sperm and the other will represent the egg).

Assign each pair of students one of the six different breeding pairs listed in tables A-F on *Using Pedigrees to Make Predictions*. Within their group of four, assign at least one pair to collect data from a cross with at least one heterozygous parent. Multiple pairs will be working on the same crosses. If a pair finishes quickly, have them work through another example that includes at least one parent that is heterozygous so they can add those data to the class tabulation. Overall, there should be more pairs of students working with various crosses involving heterozygous parents since those are the crosses that will result in the most meaningful patterns to compare.

Students in each pair will select which individual they want to be (the sperm producer or the egg producer) and write one allele on each side of their poker chip using tape and a marker. The pair of students will each flip their chip at the same time and write down the allele combination in their notebook.

While students are working on their investigation, post the table you made to record class data. See the example shown here. Remind students to be sure to record their data in the correct column for their breeding pair(s). Have students use hash marks for easy counting or record numbers they can add up once the whole class has contributed.



EE x EE	Offspring	Proportion	ee x ee	Offspring	Proportion	EE x ee	Offspring	Proportion
EE			EE			EE		
Ee			Ee			Ee		
ee			ee			ee		
Total			Total			Total		
EE x Ee	**Offspring**	**Proportion**	**ee x Ee**	**Offspring**	**Proportion**	**Ee x Ee**	**Offspring**	**Proportion**
EE			EE			EE		
Ee			Ee			Ee		
ee			ee			ee		
Total			Total			Total		

Calculate the proportions of each genotype for each cross based on the whole-class data.

*** Attending to Equity**

Universal Design for Learning

Crosses of two homozygous parents will be the quickest and easiest for students to conduct and record, and some students' sustained effort will be enhanced by engaging with a quicker and easier analysis. However, these homozygous crosses will not give students an opportunity to notice any proportions or think about probability patterns. Many students may realize quickly that crosses with two homozygous parents will always result in the same offspring genotype.

It is important to vary demands on students' skills to *optimize the challenge* for all students. Consider your students' skill level and processing and learning needs when assigning particular breeding pairs to groups. Regardless of student skill levels, have at least some pairs work with homozygous crosses so the data are available and the pattern of probabilities is obvious when the class data are tabulated.

Assessment Opportunity

Building towards: 8.B Plan and carry out an investigation to collect data and uncover patterns that support the idea that chromosome pairs separate when sex cells form and then recombine at fertilization, so each parent contributes half of the genes acquired (at random) by the offspring.

What to look and listen for: As students work on setting up the coin flips, their roles, and how to collect and record data, they should be clear that they are playing the role of biological parents and that the coin flips represent the random contribution of half the genes to an offspring. As they complete their investigation, they should be organizing their results in groups based on the genotypes of the parents that mated. They should be focused on looking for the patterns of genotype distribution they are generating with the simulation to see if the patterns are the same as what they found when they looked at the distribution of phenotypes that correspond to these genotypes in existing cattle families.

What to do: As students work, circulate among them and ask questions about why they're doing what they're doing and what the result of each coin flip means to elicit their understanding of the investigation setup. Refer them to their understanding of sex cells, chromosomes, alleles, and fertilization to help them identify this information. As they work in their groups to organize information, watch how they organize their results and assist them to focus on the results of different crosses separately. Give them positive verbal feedback pointing out where they are identifying a pattern in the offspring results and encourage them to think explicitly in terms of what patterns they can identify within and between the different crosses.

10. Building Understandings Discussion About How to Calculate Expected Outcomes

15 MIN

Materials: *Student Support for Probability Work* (optional)

Determine that there is a more-efficient way to make predictions about outcomes of breeding pairs. Display **slide AB**. Say, *OK, that was a lot of fun. Let's come back together and talk about what we found.*

Suggested prompts	Sample student responses
What were we simulating with the flipping of the poker chips?	*How the alleles just end up combining randomly in fertilization.* *the random combination of alleles*
OK, so you are saying each side of your poker chip was an allele. Where are the alleles found?	*The alleles are in eggs and sperm.*
Right, so what were we simulating? If we go back to the processes that happen, what is going on that would make these eggs and sperm combine in the first place?	*uhhhh, ummmm, well ...* *Mating and fertilization—we were simulating the sperm fertilizing the egg.*

*** Supporting Students in Engaging in Using Mathematics and Computational Thinking**
Draw attention to the fact that although Rodeo is *EE* and we know that all his sperm will have the *E* allele, for the purpose of this example and to understand how the calculations work at each step, it is easier to start here and keep them separate at first (we can use a shortcut later). Also, keep in mind that just because all the sperm have the same allele with regard to musculature, the sperm still carry one of two different chromosomes,

Suggested prompts	Sample student responses
OK, great! So let's look at our class data. Were the patterns of offspring we observed the same as for the pedigrees? Can we describe those patterns mathematically?	*Yeah, they were the same kinds of patterns, and the proportions were pretty close. But they weren't all exactly the same.*
Can you think of any reasons that your data might not match up?	*We had more offspring than we saw from our pedigree data, but we still don't have a lot of examples. It would probably look better if we did, like, 100 flips instead.*
That could be, but is that a very efficient way to answer these questions? Would farmers who were trying to figure out how often they'd get the kind of cattle they want from certain crosses do it this way, by flipping chips?	*No. That would be silly.* *We should be able to describe this mathematically.*
Is there a way we can use the probability of certain alleles being present in egg and sperm to figure out the probability that an offspring will have a certain genotype and phenotype?	*It seems like there should be.*
Have you ever used any tools in your math class, or anywhere else, to help make predictions about probabilities?	*We learned about probability. But it was kind of complicated, and I don't really remember much about it.* *Yes. We learned about probability. I can explain it!*

Key Ideas

Purpose of this discussion: Linking the physical entities of eggs and sperm that have certain alleles that will randomly combine and, depending on the alleles that the parents have, will then dictate the proportion of offspring with certain combinations.

Listen for these ideas:

- Flipping the chip shows that the allele that shows up is random—there is a 50/50 chance of getting either allele (if you have both types).
- The simulation had similar results in genotype distribution as we saw when we looked at the actual data collected from families where the parents had the same genotypes we simulated.

Use mathematical thinking to simplify predictions. Say, *OK, there are a few different ways we can address this problem by taking advantage of what we already know about what happens in these crosses. We're looking at trying to figure out what is the probability that certain offspring would occur when certain breeding pairs mate.*

so we are still looking at two different sperm with regard to the chromosomes (so this isn't just an extra step).

*** Supporting Students in Engaging in Using Mathematics and Computational Thinking**

Students have likely learned multiple algorithms for solving problems in math class, even in elementary school, but they may not have called them *algorithms*. If you'd like to explore the idea of algorithms a bit more with your students, you might ask them how they learned to divide multidigit numbers. Students might mention, for example, using repeated subtraction, the partial quotients method, the area method, and traditional long division (though there are more, and different students may call any of these examples by different names). Explain that these ways or methods are all algorithms—series of ordered steps used to solve problems.

*** Attending to Equity**

Universal Design for Learning

Providing students with another form of *representation* of these methods will give them an opportunity to reread and interact with the text and diagrams at their own pace, differently from when

Additional Guidance

Offer students the opportunity to explain to their classmates the concept of determining probabilities of random combinations. Many students may have a common experience or explanation from their math classes that will facilitate classmates' understanding and use of the probability algorithms. If no one is able (or eager) to explain, working through the next several steps will offer a semi-guided way of understanding how probabilities are calculated.

Show **slide AC**. Say, *OK, again, we're starting with what we already know about the chromosomes in eggs and sperm. We know there are two possible alleles in eggs and two possible alleles in sperm, so the probability that either will be involved in fertilization is 50%, or one half.**

Work through an example of the steps we could use to find the likelihood, or probability, of offspring. Say, *OK, how many different ways can these egg and sperm alleles possibly combine? Let's try to find out. Note that we know the probability of each egg allele or sperm allele happening—one half or 50%). We're trying to figure out how often those specific egg and sperm alleles would combine in fertilization.* Click through **slides AD**, **AE**, **AF**, and **AG** to show all the possible ways the egg and sperm alleles could combine. Ask students to explain using the following suggested prompts.

Suggested prompts	Sample student responses
So what is the likelihood of Sperm 1 combining with Egg 1?	*It will happen one out of four fertilizations, or one quarter or 25% of the time.*
So what is the likelihood of Sperm 1 combining with Egg 2? (Of Sperm 2 with Egg 1? Of Sperm 2 with Egg 2?)	*one quarter or 25%*
Can we use the probabilities of the egg and sperm combinations to predict the probability, the likelihood, of a particular offspring forming in fertilization?	*If you multiply one half by one half, you get one quarter, which is the probability of each fertilization happening.* *We can multiply the probability of each egg or sperm to get the probability of each fertilization.*

Use probability calculations to find the likelihood of offspring. Display **slide AH**. Say, *OK, we can calculate the probability of each way the sperm and egg can combine by multiplying the probability of each of the sex cells together. We can use that way of calculating with all our different crosses if we know the probability of having each type of egg or sperm allele in a particular parent. And we do know that because we know what alleles we have. This may be familiar to some of you from your math classes. When we want to know the probability of one thing and something else happening, we multiply those probability numbers together.*

the class was working through the slides orally.

In addition, students can consider the different ways of working out this problem and identify what type of *representation* works best for them. Offering, and honoring students' individual choices of, the multiple ways to solve for probability reinforces the actual meaning behind finding the probability of possible offspring genotypes (the separation of alleles when sperm and egg are formed and their combining randomly during fertilization).

*** Supporting Students in Engaging in Using Mathematics and Computational Thinking**

Giving students both ways to think about this problem, and in particular presenting the Punnett square option second, helps students make sense of how a Punnett square is just another way to represent the probability of seeing certain outcomes from a particular mating. When modeling this, be sure to always use vocabulary that connects the probability to the physical event that is happening. For example, say, "We can find the probability of this kind of sperm fertilizing this kind egg by …" instead of, "What is the probability of getting 'big E, big E'?"

Display **slide AI**. Note for students that there is an alternate way to calculate this a little more quickly and allow interested students to look over the alternate calculations.

Combine probabilities of offspring with the same genotype by adding them. Show **slide AJ** and invite students to notice that some of the offspring genotypes are the same. Use the suggested prompts.

Suggested prompts	Sample student responses
What proportion of the offspring will be big E homozygous?	*two out of four or one half or 50%*
What proportion of the offspring will be big E, little e?	*two out of four or one half or 50%*
Can we use the probabilities of offspring having specific genotypes to calculate the predicted proportions or probabilities of genotypes in those offspring?	*Yes. We can add the genotype probabilities to determine the probabilities of particular offspring with certain genotypes because one quarter plus one quarter equals one half.*

Display **slide AK** to confirm students' calculations. Summarize by saying, *OK, so we can calculate the predicted proportions—the probability—of offspring with a certain genotype by adding the probabilities of offspring with the same genotype. When we want to know the probability of one thing or another thing happening, we add those numbers together.*

Turn and talk about the steps we're using. Display **slide AL**. Say, *An algorithm is a series of ordered steps used to solve a problem.* What are the steps we can use each time we want to determine the probabilities of the possible genotypes of the offspring of two parents? Turn and talk with a neighbor to review the steps we just took.*



Take a moment to review the steps in this algorithm with the whole class. Flip back through the slides as needed to support pointing out what we did first, second, and third. Note that the steps are numbered and described explicitly in the upper left corner of the slides.

Assessment Opportunity

Building towards: 8.A.2 Use mathematics and computational thinking to find patterns about genotypic and phenotypic outcomes resulting from crossing individuals with specific genotypes.

What to look and listen for: This is an opportunity to assess students' ability to create, or at least identify, algorithms. Listen for students to call out the functions necessary for calculations as you work through the slides. As they turn and talk with a partner, or as you flip back through the slides to explicitly review the steps with them, listen for students to identify and sequence the precise steps in determining the probability of offspring genotypes. They should articulate steps similar to those described in the upper-left corner of the slides.

What to do: If students are struggling to identify the steps, flip back through slides AC-AS and have them describe what is being done on each slide. Note for them that this set of descriptions of what to do and in what order is the algorithm. Students may benefit from viewing and working with a copy of *Student Support for Probability Work*, on which they can follow the steps in order.

The information in these slides are also available in *Student Support for Probability Work*, which students can reference in the *Student Edition* or you can provide copies of for extra support.*

Predict, using a visual representation, the probability of these events occurring. Say, *While these probability problems are valuable to understand, especially if we are looking at more-complicated problems and attempting to keep track of several genes at once, there is another, supersimple way to set up and determine the likely proportion of offspring using a sort of table that you might like.*

Show **slide AM**. Say, *OK, we're going to use the same example we used for the first problem, and just like that problem we will start with what we already know. We know what kind of sperm cells and egg cells are possible, so we'll start with that. You can record the probability here like we did last time. It won't be a problem if you don't, but if you do choose to write it down, you will better see how these two methods are connected.**

Show **slide AN** and introduce the idea of using a grid to organize the ways our sperm and egg could potentially meet. Say, *This grid is called a Punnett square, and it helps us easily keep track of which egg is being fertilized by which sperm, and it gives us a place to draw the resulting offspring.* Show **slide AO**, **slide AP**, and **slide AQ** to demonstrate how to complete the grid.

Display **slide AR** and say, *To determine the probability of getting any of the genotypes, just count the number of that type you see and divide by the total number of offspring.* Advance to **slide AS** and explain that, just like with the previous example, there is a way to do a shortcut version that counts on understanding that homozygous individuals can make only one type of sex cell with respect to the alleles that are being considered.

11. Practice making predictions using probability.

8 MIN

Materials: science notebook, half sheet of 8.5" x 11" paper, *Student Support for Probability Work* (optional)

Practice predicting outcomes of crosses using students' preferred method. Display **slide AT** and ask students to turn to the next blank page in their science notebook. Let them know that the purpose of this practice is for them to self-assess and to identify any ideas they are still struggling with so they can ask questions or get help to understand. Remind students that the first step of recording the type of egg and sperm alleles that are possible is important, and they should not to skip that. Give students time to work independently on these in their notebook.*

Additional Guidance

The slides that step through the process of setting up the probability problems and the Punnett squares are available as an optional handout. If some students would benefit from the extra structure or feel like they would like to try more practice problems at home, this handout can be printed for students' use: *Student Support for Probability Work*.

Complete an exit ticket. Show **slide AU.** Distribute half sheets of paper and instruct students to complete the answer to the question shown on the slide: Describe the pattern of offspring using an algorithm: If a male is heterozygous for the myostatin gene (Ee) and a female is homozygous for the allele that leads to typical muscles (ee), what are the probabilities of each genotype their offspring might have? Collect these papers as a formative assessment.

*** Attending to Equity**
Universal Design for Learning

Students are likely to prefer one strategy to the other. Allowing them to choose to use one of multiple, different tools (probability calculations or Punnett squares) for constructing their answer honors multiple ways of *expression* that both get to the same end result.



Exit Ticket

If a male is heterozygous for the myostatin allele (Ee) and a female is homozygous for the allele that leads to typical muscles (ee), what are the probabilities of each genotype their offspring might have? You may choose to use either the probability calculations algorithm or a Punnett square to figure this out, but be sure to show all your work.



Assessment Opportunity

Building towards: 8.A.3 Use mathematics and computational thinking to find patterns about genotypic and phenotypic outcomes resulting from crossing individuals with specific genotypes.

What to look and listen for: At this point, students should be comfortable with the idea that the proportion of offspring with different genotypes, and hence phenotypes, can be predicted using a simple mathematical model when we know the genotypes of the parents. In their science notebook, students should have recorded their work using the probability calculations or the Punnett squares to determine the following:

- If one parent is *EE* and the other is *ee*, 100% of the offspring have medium muscles.
- If both parents are heterozygous, we see about 50% of the offspring with medium muscles and 25% of offspring with typical muscles. The other 25% have extra-big muscles.

In the work they show on the exit ticket, they should use either algorithm to determine the following:

- If one parent is *ee* and the other is *Ee*, 50% of offspring have typical muscles and the other half have medium muscles.

What to do: Provide feedback for students who have not come up with the predicted results by directing them on *Student Support for Probability Work* to the step, or steps, in their favored method (calculations or Punnett squares) that they may have missed or not done correctly. Encourage them to redo the problems, paying special attention to those steps. Some students may benefit from additional practice solving for probabilities in two-allele, single-gene crosses that you may provide for them.

12. Where do they come from?

5 MIN

Materials: classroom consensus model from Lesson 7

Wonder about the source of the heavily muscled cattle. Show **slide AV**. Say, *So we've figured out that farmers and ranchers can predict the genotypes and the phenotypes of the offspring of these heavily muscled cattle once they have heavily muscled cattle or medium-muscled cattle to breed.* Then use the prompts and follow-up questions below to motivate thinking about the source of the alleles themselves.

Suggested prompt	Sample student responses	Follow-up questions
What if a farmer wants to start breeding these cattle, and they don't have any heavily muscled or medium-muscled cattle to start with, how would they do that?	*They could get those cattle from another farmer.*	*Where would that farmer get their cattle from?*
	They could get the heavily muscled cattle from other heavily muscled cattle.	*Where did those heavily muscled cattle get their phenotype from?*
	Heavily muscled cattle inherit their phenotype from their parents by the parents passing on their alleles to their offspring.	*Where did the heavily muscled allele—the big E, big E allele—come from?*
	Maybe the farmers could mutate the cattle to make them have extra-big muscles.	*How would that happen?*

Discuss where the alleles came from. Refer to the classroom consensus model from Lesson 7 and point to the circle-symbol allele in the offspring genotype as shown in this photo. Ask students the following prompts:



Suggested prompts	Sample student responses
Where did this circle-symbol allele in the offspring come from?	*It came from the egg and sperm from the parents.*
Where did the parents get their circle-symbol allele?	*It came from their parents, or the grandparents of the offspring we are looking at.*
Where did the grandparents get their circle-symbol allele?	*They got it from their parents!*

Refer to the classroom consensus model and point to the star-symbol allele in the offspring genotype as shown in this image. Ask students the following prompts:



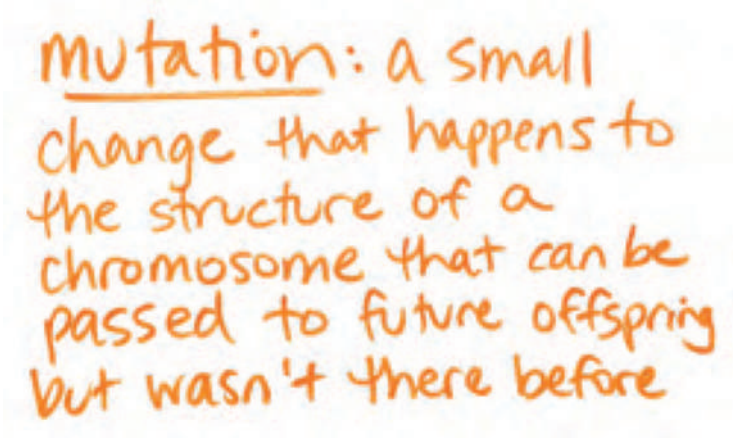
Suggested prompts	Sample student responses
Where did this star-symbol allele in the offspring come from?	*It came from the egg and sperm from the parents.*
Where did the parents get their star-symbol allele?	*It came from their parents, or the grandparents of the offspring we are looking at.*
Where did the grandparents get their star-symbol allele?	*They got it from their parents!*
Now zoom back to the great, great, great, great, great grandparents. Where did they get their star-symbol allele?	*still from their parents*

Discuss as a whole class the origin of these alleles. Say, *We know that these extra-big muscles in the offspring are caused by the presence of a specific allele, indicated by the star symbol or a big* E. *And we know that this star-symbol or big-*E *allele is something that was inherited from that individual's parents. So then it would seem reasonable to argue that any star-symbol or big-*E *allele that is inherited from a set of parents is also one that they inherited from their parents. In this line of reasoning, we should be able to find that any allele can be traced back in time across many generations. Do you think that in our case of typical and extra-big muscles that there were always these two kinds of alleles?* Allow a moment to respond.

Say, *It is interesting that we actually know this part of the story.* Display **slide AW**. *The historical records indicate that in the 1800s in a small town in Italy called Guarene d'Alba a mutation for heavy musculture appeared in a cow that wasn't in the local population of cattle before that point. Once this mutation occurred, that individual was able to pass it on to its offspring and thus to all its descendants.*

Use the model to trace the historical story of mutations. Point out that all cattle used to have two copies of just the circle-symbol or little *e* allele, but when this mutation occurred, it was the first time any cattle had the big *E* allele. That individual continued to pass that big *E* allele on to its offspring.

Say, *By the start of the 1900s, there were already 680,000 of its descendants with the big* E *allele living in Italy alone. Each of them had inherited the allele, which had originally appeared as a single mutation in that one ancestor many generations earlier. When an event occurs in which an allele appears in a genotype of an offspring that wasn't there in the parents' genotypes, it is referred to as a* ***mutation.*** *A mutation is a small change that happens to the structure of a chromosome that can be passed on to future offspring, but it wasn't there before. These small structural changes can sometimes happen randomly when sex cells are being produced. And each mutation can result in there being a new allele of a gene.*



Add "mutation" to our Word Wall and discuss its implications. Take a moment and have students help add "mutation" to the Word Wall.

Display **slide AX** and ask the following prompts:

Suggested prompts	Sample student responses
If a mutation changes a gene, what do you think it does to the protein that gene makes?	*It probably changes the protein so it's different, like the two different myostatin proteins.*
Do you think mutations are common or rare? Why?	*They are probably common because there are so many variations out there!* *They are probably rare because I don't think new things come up that frequently.*

Display **slide AY**. Say, *Scientists have tried to determine how common mutations are. In the many different types of organisms they have examined, they have found that mutations are generally quite rare. In mammals, for example, mutations of the alleles for a single gene tend to occur less frequently than one out of 10,000 genes. At this rate, this means that for any given gene, 9,999 out of 10,000 individuals that are born can expect that the alleles in their cells will be ones that their parents also had.*

Revisit our DQB briefly. Display **slide AZ**. Say, *We had some questions about mutations on our DQB. Since we now know that when mutations happen, a new allele can be created, can we rephrase any of these as questions about alleles?* Read a couple of questions from the DQB that students had regarding mutations, or mutated traits, and challenge students to rephrase them using the language of genes and alleles.

13. Navigation

2 MIN

Materials: None

Connect to how we could use the information we figured out. Show **slide BA**. Say, *So this is cool, we know where the two different alleles came from, and we can predict the patterns of muscularity in cattle now that we know how this inheritance pattern works. I bet ranchers are all over this information to make sure they have the most muscular cattle.*

Suggested prompts	Sample student responses
What genotype cattle do you think the farmers are mating together to get the phenotype they want?	*We think they mate homozygous big E with homozygous big E cattle, because then you get the most muscles guaranteed every time.*
So if that's true, how do they do that? How do they make sure they make the right bulls with the right cows?	*Not totally sure . . .* *Ummmmmm . . .*

Reassure students that we will investigate this in our next lesson.

ADDITIONAL LESSON 8 TEACHER GUIDANCE

Supporting Students in Making Connections in Math

CCSS.MATH.CONTENT.7.SP.C.5 Understand that the probability of a chance event is a number between 0 and 1 that expresses the likelihood of the event occurring. Larger numbers indicate greater likelihood. A probability near 0 indicates an unlikely event, a probability around 1/2 indicates an event that is neither unlikely nor likely, and a probability near 1 indicates a likely event.

CCSS.MATH.CONTENT.7.SP.C.7 Develop a probability model and use it to find probabilities of events. Compare probabilities from a model to observed frequencies; if the agreement is not good, explain possible sources of the discrepancy.

CCSS.MATH.CONTENT.7.SP.C.7.B Develop a probability model (which may not be uniform) by observing frequencies in data generated from a chance process.

CCSS.MATH.CONTENT.7.SP.C.8 Find probabilities of compound events using organized lists, tables, tree diagrams, and simulation.

CCSS.MATH.CONTENT.7.SP.C.8.A Understand that, just as with simple events, the probability of a compound event is the fraction of outcomes in the sample space for which the compound event occurs.

CCSS.MATH.CONTENT.7.SP.C.8.B Represent sample spaces for compound events using methods such as organized lists, tables and tree diagrams. For an event described in everyday language (e.g., "rolling double sixes"), identify the outcomes in the sample space which compose the event.

CCSS.MATH.CONTENT.7.SP.C.8.C Design and use a simulation to generate frequencies for compound events.

Students investigate chance processes and develop, use, and evaluate probability models in this lesson. Specifically, they develop a probability model and use it to find probabilities of events. They generate data from a coin-toss simulation. Then students compare the probabilities from this model to observed frequencies they calculate from records of this trait in existing cattle families.

Students find probabilities of compound events using pedigrees, organized lists, and Punnett squares to demonstrate that, just as with simple events, the probability of a compound event is the fraction of outcomes in the sample space for which the compound event occurs. They represent sample spaces for compound events using organized lists, tables, and tree diagrams. They identify outcomes for an event described in everyday language (e.g., "when a sperm fertilizes an egg"). Finally, students co-design and use a coin-toss simulation to generate frequencies for compound events.

LESSON 9

How do farmers control the variation in their animals?

Previous Lesson

Students investigated the inheritance patterns of the myostatin gene using pedigrees and noticed interesting patterns in the proportion of offspring with different genotypes. They connected these patterns to how alleles are transferred and recombined during fertilization. They used mathematical models to help predict the outcome of known genetic crosses and considered mutations as sources of alleles.

This Lesson

Investigation

2 DAYS





We read about ways farmers breed animals for specific trait variations, and we run a computer simulation to try our hand at selective breeding. We figure out that by breeding animals with selected-for variations more often, we can increase the frequency of seeing those variations in the population.

Next Lesson

After a brief navigation conversation, students will work independently to demonstrate their understanding on a midpoint assessment—a transfer task involving goldfish breeding.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5



What Students Will Do

9.A Obtain, evaluate, and communicate information regarding the effect of selective breeding in one type of sexually reproducing organism.

9.B Use mathematics and computational thinking to determine the beneficial and harmful effects of selective breeding in sexually reproducing organisms by examining the frequency of certain trait variations and combinations in a population over time.

What Students Will Figure Out

- Farmers can use selective breeding to change the frequency of specific trait variations over time in a population of sexually reproducing organisms.
- Mutations can have beneficial or harmful effects on an organism.
- In selective breeding, people choose which individuals with selected trait variations are bred more often together than individuals without those selected trait variations.

Lesson 9 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Discuss how farmers can make sure they get offspring from two specific parents.	A	
2	25 min	**READ ABOUT SELECTIVE BREEDING IN CATTLE** Use a checklist to evaluate three readings about selective breeding in cattle.	B-C	*Interview with Penny, Cattle Farmer*, *Raising Heavily Muscled Cattle to Reduce Environmental Impacts of Cattle*, *Interview with Wilbur, Cattle Breeder*
3	10 min	**BUILDING UNDERSTANDINGS DISCUSSION ABOUT SELECTIVE BREEDING IN CATTLE** Discuss similarities and differences from three readings. Reflect on the sources of information to check for reliability and bias.	D	
4	5 min	**INVESTIGATE SELECTIVE BREEDING IN OTHER ORGANISMS** Brainstorm examples of selective breeding in other organisms and what requirements are needed in order for selective breeding to occur.	E-F	chart paper, marker
				End of day 1
5	25 min	**USE SELECTIVE BREEDING SIMULATION** Use an online simulation to selectively breed virtual birds.	G-I	computer with internet access, *Instructions for Bird Breeder Simulation*, Bird Breeder simulation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), *Bird Breeder Simulation Results*, calculator
6	10 min	**BUILDING UNDERSTANDINGS DISCUSSION ABOUT SELECTIVE BREEDING** Discuss what students have figured out through data from the simulation on how farmers can selectively breed organisms.	J	
7	5 min	**UPDATE PROGRESS TRACKERS** Update students' Progress Trackers to reflect their new understanding.	K	
8	5 min	**NAVIGATION** Share Progress Tracker updates with a partner.		
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 9, students are ready to read Student Reader Collection 3 and then respond to the writing exercise.		Student Reader Collection 3: *Picking Parents*

Lesson 9 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Interview with Penny, Cattle Farmer* • *Raising Heavily Muscled Cattle to Reduce Environmental Impacts of Cattle* • *Interview with Wilbur, Cattle Breeder* • computer with internet access • *Instructions for Bird Breeder Simulation* • Bird Breeder simulation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • *Bird Breeder Simulation Results* • calculator		• chart paper • marker

Materials preparation (20 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare the handouts. Make 1 copy each of *Bird Breeder Simulation Results* for each student. Each student will also need to access the following readings, either in their *Student Edition*, or as copies you prepare:

- *Interview with Penny, Cattle Farmer*
- *Raising Heavily Muscled Cattle to Reduce Environmental Impacts of Cattle*
- *Interview with Wilbur, Cattle Breeder*

Have computers with internet connection available for each student for day 2.

Make sure you can open the Bird Breeder simulation and test it yourself before introducing it to students. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Be prepared to share the Bird Breeder simulation link with students so that they will be able to run it on their own computers.

Lesson 9 • Where We Are Going and NOT Going

Where We Are Going

In order for students to understand that selective breeding results in a change in the distribution or frequency of selected-for trait variations in a population over time, students use mathematics and computational thinking to analyze data produced from a computer simulation.

The key ideas that students will gain from the simulation is to notice exactly what variation we are getting. How is it that offspring can look so different from parents? How are humans manipulating combinations and predicting? We can choose specific organisms to mate in order to get the combination of trait variations we're looking for. Because recombination happens with every single chromosome, we can see how you do get very different offspring. The simulation is also useful to highlight the idea that choosing parents will not guarantee the offspring will have the trait variation you want. There is still a degree of randomness and probability we learned about last lesson.

Please note that we intentionally choose to say "selected for" instead of "desirable" when describing the trait variations that breeders select for. While consumers, farmers, and others may desire certain trait variations, the development team did not want to promote thinking about desirable or undesirable trait variations that could carry over into thinking about humans.

Where We Are NOT Going

While artificial insemination, AI, is mentioned in this lesson's readings, we are not discussing the process at length. The important take-away students should have regarding AI is that humans are able to control exactly which organisms are reproducing by controlling which individual's sperm will be used to fertilize an egg from a specific individual. Discussion of the genetics of the heavily muscled cattle is not required understanding to determine the effects of selective breeding. Students can see a symbolic representation of different alleles in the computer simulation to get a better understanding of the genetics behind selective breeding and artificial selection, at least for breeding for certain combinations of variations in single-gene trait variations.

LEARNING PLAN FOR LESSON 9

1. Navigation

5 MIN

Materials: science notebook

Lead an Initial Ideas Discussion about heavily muscled cattle. Display **slide A** and say, *In the last class, we discussed the idea that farmers and cattle breeders are taking advantage of being able to predict the outcomes of crosses between certain cattle in order to control the offspring they get in their herds. But how do they actually do that?* Ask students to turn and talk with a partner to discuss the question, "What are the farmers doing to make sure certain parents get crossed?" Give students a few minutes to discuss with a partner and record their ideas in their science notebook before sharing with the whole class.

Suggested prompt	Sample student responses
What are the farmers doing to make sure certain parents get crossed?	*Maybe they keep certain cows and bulls together in a room for a while.* *Maybe they have methods like people use at fertility clinics.*

2. Read about selective breeding in cattle.

25 MIN

Materials: science notebook, *Interview with Penny, Cattle Farmer*, *Raising Heavily Muscled Cattle to Reduce Environmental Impacts of Cattle*, *Interview with Wilbur, Cattle Breeder*

Identify goals for reading about selective breeding in cattle. Show **Slide B**. Say, *I have three readings about selective breeding in cattle. One is from the interview with our farmer from earlier lessons, another is an interview with another farmer that raises heavily muscled cattle, and the final reading is from another source that discusses some of the larger implications of breeding these cattle. Before we dive in, let's think about what our goals are as readers, how we can compare the three readings, and how we can identify and evaluate the claims made by each reading.*

Suggested prompts	Sample student responses
What type of information are we hoping to figure out from these three readings? *OK, so we know what type of information we are looking for in the readings. How can we keep track of that information while we are reading?*	*We want to figure out how farmers breed cattle for the heavily muscled trait variation.* *I like to use a highlighter or underline the key ideas when I'm reading.* *I put question marks next to parts that I don't understand and need to come back to later.* *I try to make sure that I can explain what I've read to someone else.*

***Attending to Equity**

Universal Design for Learning: Struggling readers may have more success *engaging* with the readings by implementing strategies such as these: reading with a partner, reading aloud, chunking the text, highlighting unknown words, or looking for key ideas.

***Supporting Students in Engaging in Obtaining, Evaluating, and Communicating Information**

You may choose to allow students to do a quick online search of the resources the *Raising*

Suggested prompt	Sample student responses
How can we determine if the readings are reliable?	*Make sure authors use evidence to support what they're saying.* *They might cite other sources where they got their information.* *They might say things like, "in my experience," or have firsthand knowledge.*

Say, *Those ideas sound great. While you read, mark up the text to track your thinking. And when we're finished, we'll discuss how the readings compare, so be ready to tell others what you learned from each of the readings.*

Use our checklist to obtain and evaluate information from the readings. Ask students to set up their notebook as seen on the slide to give them a space to organize the information they read about. Hand out *Interview with Penny, Cattle Farmer*, *Raising Heavily Muscled Cattle to Reduce Environmental Impacts of Cattle*, and *Interview with Wilbur, Cattle Breeder* or direct students to find these readings in their *Student Edition*.

Display **slide C**. Remind students of the checklist they used in Lessons 3 and 6 to evaluate three texts. Give students 15 minutes to read and take notes on the three readings. Leave slide C displayed so students may consult the checklist as they are reading.**

A sample table with possible student responses based on these new readings is provided below.

	Interview with Penny, Cattle Farmer	Raising Heavily Muscled Cattle to Reduce Environmental Impacts of Cattle	Interview with Wilbur, Cattle Farmer
What is the goal(s) of the text?	*The text explains how farmers select for trait variations and use artificial insemination to control which animals are mating.*	*The text explains why farmers might want to choose to raise heavily muscled cattle over non-heavily muscled cattle.*	*The text explains the benefits and drawbacks of raising heavily muscled cattle and which characteristics help cattle have good longevity.*
What claims is the reading making?	*The article claims that the farmers can change the occurrence of trait variations in their herd through selective breeding.*	*Artificial insemination and selective breeding have reduced some of the problems associated with heavily muscled cattle.* *Raising heavily muscled cattle is better for the environment.*	*The meat from these cattle is better for you from a health standpoint, and it also tastes good, and each animal provides more meat than a typically muscled animal. To feed a growing population it is important to find a healthy and sustainable way to do this.*

Heavily Muscled Cattle to Reduce Environmental Impacts of Cattle article cites. This gives them a chance to see the information from multiple sources and develop the practice of doing this as a step to assess the credibility of the sources from which they get information.

***Supporting Students in Engagingin Obtaining, Evaluating, and Communicating Information**

Students should use the checklist the class developed in Lesson 3 and used in Lesson 6 to determine the claims and conclusions of each of the readings. In this lesson, the readings are in agreement around the main claims they are making: that farmers are able to change the frequency of trait variations in their herd through selective breeding. The readings differ in the types of data used to support the claims and in some of the techniques used to achieve the selected-for results. If students struggle, remind them to think about what information we decided as a class to look for as we read.

What evidence is given to support the claims?	*The farmer gives examples of how they were able to select for a trait (pelvic readings, in this case) so that their heavily muscled cattle didn't need to have a C-section in order to give birth.*	*The author provides data to support the claim.*	*The farmer says the animals provide 20% more meat. He also says the meat is "lean" with less cholesterol and calories.*
Where does the evidence come from? Are there sources that are cited?	*The evidence was from their firsthand experience.*	*Articles written by scientists that studied the breed and people that have raised the breed. The reading has sources listed.**	*The evidence was from their firsthand experience.*
Does the reading provide a way for us to review the actual data its claims were based on for ourselves if we were interested?	*We would have to reach out to the farmer, so yes, we could review the evidence provided by the farmer.*	*We can search and find the articles the author cites.*	*We would have to reach out to the farmer, so yes, we could review the evidence provided by the farmer.*
Does the reading make sense or fit with what we already know?	*The article fits with the idea that while heavily muscled cattle can be a beneficial trait, there are some problems associated with it, like having to have C-sections.*	*The article does fit with the idea that heavily muscled cattle have some problems associated with being heavily muscled, but it is also a good trait we want.*	*The article expands on the idea that heavily muscled cattle can have good longevity as long as other trait variations like their legs and hoofs can support them.*

3. Building Understandings Discussion About Selective Breeding in Cattle

10 MIN

Materials: science notebook

Lead a Building Understandings Discussion about selective breeding. Lead students in a discussion about what they figured out from the three readings. Display **slide D**.



Suggested prompt	Sample student responses
What was similar among the three articles?	*All three say that specific traits are selectively bred to decrease problems these cattle could have. Two said that AI was used to breed the heavily muscled cattle so that they didn't need C-sections which is one of the drawbacks of breeding these animals.* *They both said you get a higher yield of meat from the heavily muscled cattle.*

Suggested prompts	Sample student responses
What was different among the three articles?	*They had different views on what beneficial trait variations in the heavily muscled cattle they were breeding for.* *Penny described looking for good hooves and legs because the cattle need to be able to walk around a lot on the farm. She also said they looked for a wide pelvis so that birth was easier and didn't require a C-section.* *They used different techniques. Sometimes they just let the cattle mate in the pens and other times they used artificial insemination. The other article said that they also controlled what the mother ate while she was pregnant.* *The article about environmental impacts focused on why the heavily muscled cattle are a good breed to have because they need less food to grow as big, and the meat is healthier for people due to the lower fat content.* *Wilbur focused on the idea that meat from heavily muscled cattle is healthier, and tastier, similar to what the article about environmental impacts said, but Wilbur also talked about how we can get more meat per animal so they could allow more people to have protein in their diet.* *Wilbur also talked about the longevity of each animal—the idea that if the animal has the right kind of feet and structure, it will live longer.*
The articles mentioned words like "drawbacks" and "beneficial"? Do you think what is beneficial for the farmer or breeder is always also beneficial for the animal? Who else might have a stake in deciding what is beneficial or harmful?	*It might not be a beneficial trait for an animal to have really big muscles if it makes them hard to be born, or hard for their legs to hold them up to walk around, even if the farmer sees it as beneficial.* *The farmers or breeders don't really want animals with problems either though, so they try to breed cattle to have trait variations that go better together.* *Other people on Earth can also have an opinion on what is beneficial or harmful with regard to the environmental impact.*
These readings overall seem pretty positive—do you think any of these sources may be biased?	*Since the farmers breed these heavily-muscled cattle, they are probably biased in favor of those cattle.* *The article about the environmental impact was not by farmers, so that probably wasn't biased in the same way.*
What kinds of organizations or sources might be places where you would find a different bias?	*We could interview farmers that have chosen not to breed heavily-muscled cattle to see what they have to say.*

Suggested prompts	Sample student responses
Do the conclusions in the articles make sense based on the information we already know?	*All of the articles support the idea that while the heavily-muscled trait is useful or helpful, there are some drawbacks of breeding the heavily-muscled cattle. If the babies are too big to be born, the cow has to have a C-section. Or sometimes the animals could be too heavy for their legs and feet to hold them up.* *All of the articles explained there are ways to reduce these drawbacks by selective breeding.*
Are these articles valid just because they already confirm what we have figured out? What else can we use to help determine the validity of the three articles?	*The articles used evidence (personal experience and cited sources) to support their claims. That also helps us determine validity.* *We are able to determine if the articles have accurate information because we could contact the people who were interviewed, and we could also look up the references used.*
What questions do you have?	*How was the farmer able to breed the cattle over the course of 25 years so that they went from always having to have C-sections to not having to have C-sections? How were they able to do that so fast? How can farmers change trait variations over time in their own cattle?*

Key Ideas

Purpose of this discussion: Synthesize the main ideas based on the evidence we have read in the articles about how farmers select for trait variations when breeding cattle.

Listen for these ideas:

- Many different trait variations are taken into consideration when breeding cattle.
- Different farmers look for different trait variations depending on what the cattle requirements are.
- While there are benefits to having heavily muscled cattle, like increased yield of meat, there are some harmful effects too, like complicated births and mobility issues.
- Farmers can use techniques like selective breeding to help reduce negative effects of the trait.

Assessment Opportunity

Building towards: 9.A Obtain, evaluate, and communicate information regarding the effect of selective breeding in one type of sexually reproducing organism.

What to look and listen for: Listen for students to identify that conclusions in all the sources are valid because of their use of data and firsthand knowledge. Listen for students to identify that selective breeding causes changes over time in the frequency of selected-for trait variations in a population of organisms. Students should also discuss the idea that while the mutation for the heavily muscled cattle had some benefits, there were also some harmful effects.

They should identify that farmers think about many different trait variations while breeding cattle and use different methods for breeding based on what the goal for their herd is.

What to do: Scaffold the activity using a checklist to evaluate the credibility of and determine the claims made by each article. If students need support, chunk the articles and encourage students to identify key pieces of information. If students struggle, ask probing questions and refer them to the checklist to refine their thinking.

4. Investigate selective breeding in other organisms.

5 MIN

Materials: science notebook, chart paper, marker

Motivate considering other organisms. Display **slide E**. Say, *OK, so we've read about how this approach of selective breeding can be used to affect the trait variations in a cattle population. But what these breeders are describing they do through selective breeding isn't limited to working on just cattle. There are other kinds of organisms that people have selectively bred over time. Let's take a moment to brainstorm some of the other types of organisms that you think people may have selectively bred.*

Investigate selective breeding in other organisms. Give students 2 minutes to turn and talk with a partner to brainstorm examples and then have them share these with the whole class. Record their answers on a piece of chart paper.

Suggested prompts	Sample student responses
What are other types of animals you think people may have tried to selectively breed besides cows?	*dogs, cats, pigs, birds, rabbits*
Besides animals, what are some other types of organisms that you think people may have tried to selectively breed? Draw on your experiences from the grocery store for some possibilities.	*apples, grapes, lettuce, tomatoes, potatoes, carrots*

Transition to the next investigation. Say, *In many cases, breeding organisms also takes a lot of time. For example, the time it takes to produce a single generation of apples and seeds from a flowering tree is not just an entire season, there is also the time it takes for those seeds to grow into trees before they can produce their flowers. Or in the case of cattle, it takes nine months from conception to birth and still another fifteen months on average before they mature enough to have babies of their own. We don't have that sort of time available in class to test out our ideas of what it takes to selectively breed for specific trait variations with real organisms. But I do have a computer simulation that we can use to investigate what it might take to breed virtual organisms to see what kind of variation we see in offspring based on trait variations of the parents. In the case of the particular simulation we will use next time, you will have an opportunity to selectively breed virtual birds. This is indeed a type of sexually reproducing animal that people have bred in real life.*

Show **slide F**. Have students turn and talk about the following prompt: If we are breeding birds to see if we can get specific traits, what kinds of things would we want to keep track of in our simulation as we do the breeding?

End of day 1

5. Use selective breeding simulations.

25 MIN

Materials: computer with internet access, science notebook, *Instructions for Bird Breeder Simulation*, Bird Breeder simulation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), *Bird Breeder Simulation Results*, calculator

Connect to the ideas we started generating last time. Display **slide G**. Remind students that we are going to try selective breeding of a type of virtual organism ourselves today using a computer simulation. Ask students to recall what type of virtual organism we were anticipating to work with. Students should say birds. Ask students to share their ideas of some of the kinds of things we would want to keep track of in our simulation as we do this breeding. Accept all answers.

Introduce the breeding simulation. Say, *This simulation will let us breed birds for anywhere from two to four specific traits, depending on the difficulty level we choose to set the simulation to. At first you will spend five minutes just reading through the directions and doing some initial explorations of it.*

Hand out the *Instructions for Bird Breeder Simulation* reference or have students find it in their Student Procedure Guid, and have students launch the simulation. Instruct them to follow the directions on the handout to explore the simulation for 5 minutes before we regroup to do more-focused investigation.

After 5 minutes have all students pause the simulation (and close their computers or turn off the monitors for now).

Distribute the *Bird Breeder Simulation Results* handout and show **slide H**. Use this slide to introduce students to the types of data they will collect after they set the difficulty level they want to try and press "setup" again. Show an example of this using the screenshot on **slide I**.

This is what the example data will look like for the bird population shown on the slide:

*** Supporting Students in Engaging in Using Mathematics and Computational Thinking**

If students struggle to use mathematical and computational thinking to analyze their data, support them by helping them visualize the data numerically. Have students use various groupings, like different-colored highlighters, to identify individuals with the same genotypes. Once students have grouped individuals by genotypes, they can then count them and determine the percentage of each in the population.

		Before selective breeding		After selective breeding	
		% of birds	# of birds	# of birds	% of birds
For all difficulty levels	with no selected for trait variations	6	75%		
	with one selected for trait variation	2	25%		
	with two selected for trait variations				
For difficulty level 2 or 3 only	with three selected for trait variations				
For difficulty level 3 only	with four selected for trait variations				
	Total birds	8	100%		100%

Then tell students that they will need to tally up these values at the start and at the end of their selective breeding and use a calculator to determine the percentages for each category, which should add up to 100% for that column. Point out that there is an additional data table on the handout where they will record number of matings, number of offspring, and number removed at the end of their selective breeding investigation, as well as Making Sense questions to respond to. Tell students that they will have 10 minutes to conduct their simulation, at which time you will give a signal to record the results for the current simulation and answer the questions on their handout in the last 5 minutes.*

6. Building Understandings Discussion About Selective Breeding

10 MIN

Materials: None

Lead a Building Understandings Discussion about selective breeding. Display **slide J**. Say, *So we've figured out a lot of information from our readings and the simulation about how people use selective breeding in different organisms.*

Key Ideas

Purpose of this discussion: Summarize take-aways from the selective breeding simulation.

Listen for these ideas:

- People can control trait variations in organisms by choosing to mate individuals with the trait or traits they are selecting for.
- The parents pass their alleles to their offspring, which sometimes leads to the selected-for phenotype and sometimes not, based on the inheritance pattern.

Suggested prompts	Sample student responses
By the end of the selective breeding simulation, you were able to increase the percentage of birds with beneficial trait variations. What sort of strategies did you use to do this?	*I turned on the "see-alleles?" box, which made it easier to choose specific birds.* *I stored extra birds in the breeding sites to keep them for possible future use when I ran out of space in my cages.* *I picked birds that had at least one allele for each trait that I was trying to get in my birds.*
What process did you use to get the trait variations you were looking for?	*I didn't have any birds to start with that had all the trait variations I was trying to achieve. This meant I needed to ask for birds from other breeders that had the trait variations I was looking for.*
How could people use these same strategies to change the characteristics over time of any sexually reproducing organism?	*I think this is what they did in the readings. Like, they chose cattle that had the trait variations they wanted and bred them together.* *I think we do this when we breed dogs too! My family likes to watch dog show competitions on TV, and they are looking for specific trait variations in each type of dog.* *I wonder if they did this with plants too. Maybe farmers are choosing to pollinate watermelon plants that don't have a lot of seeds, so that's how we got seedless watermelons?*
In the simulation and readings, there were trait variations that we selected for and those we didn't want to select for. What are some variations of traits you think breeders try to avoid in our pets?	*Shedding! I know there are some dogs that shed a lot, so maybe they bred dogs that don't shed a lot.* *What about allergies? Like, I've seen hairless cats. Maybe people that are allergic to cats but like them could get a hairless cat?* *My friend has a pug, and they have a lot of breathing problems. Maybe breeders try to breed pugs together that don't have a lot of breathing issues.*

7. Update Progress Trackers.

5 MIN

Materials: science notebook

Update Progress Trackers in science notebooks. Display **slide K** and direct students to add to their Progress Tracker in their science notebook. Explain that we need to record our new understandings on how people can use selective breeding to change trait variations in organisms.*



Assessment Opportunity

Building towards: 9.B Use mathematics and computational thinking to determine the beneficial and harmful effects of selective breeding in sexually reproducing organisms by examining the frequency of certain trait variations and combinations in a population over time.

What to look and listen for: Look for students to identify that because of selective breeding of organisms with beneficial trait variations, the frequency of individuals with those trait variations increases in the population over time as evidenced by information found in *Interview with Penny, Cattle Farmer, Raising Heavily Muscled Cattle to Reduce Environmental Impacts of Cattle*, and *Interview with Wilbur, Cattle Breeder* and in data from the computer simulation. Look for students to cite specific data from either the readings or the computer simulation to support their understanding.

What to do: If students are struggling, ask probing questions and refer them to the data they recorded and analyzed in the computer simulation or information from the readings.

Since this chart is a loose structure, students can take up a lot of space or a little space for each entry in their Progress Tracker. When students complete their thinking for today, they can draw a line after their work to indicate the space for the next Progress Tracker entry.*

In the example two-column Progress Tracker row for this lesson, each column has been completed with *possible* student ideas.

*** Supporting Students in Developing and Using Cause and Effect**

Students should identify that selective breeding is a way that farmers can control trait variations in their livestock, or system. The act of selective breeding leads to different effects in the population, such as having more individuals with selected-for trait variations. If students struggle to identify the cause-and-effect relationship, ask probing questions about how specific actions by farmers caused different effects in the offspring that were produced.

*** Attending to Equity**

This Progress Tracker serves as teacher guidance for what students might say at various points throughout the unit. However, some students may say more and others may say less. It is important that what the students write in the Progress Tracker reflects their own thinking at that particular moment in time.

The Progress Tracker can be a valuable tool for formative assessment, giving you a clear picture of students' thinking and allowing you to direct your instruction accordingly. However, avoid scoring Progress Tracker

Question	What I figured out in words and/or pictures
How do farmers influence the trait variations of their animals?	• People breed for beneficial trait variations using selective breeding. • Animals with selected-for trait variations are bred more often than animals without those trait variations. • The heavily muscled allele has some benefits, but it also can lead to some harmful effects. People can use selective breeding to reduce the harmful effects that are associated with certain trait variations. • By controlling what organisms are bred with other organisms, people can change trait variations over time so that the selected-for trait becomes more common in the population. Farmers in Denmark were able to go from over 50% C-sections to less than 10% C-sections over time.

entries for a grade—provide feedback only. Scoring for a grade would invalidate their purpose, which is to be a safe space for students to process and record their thoughts honestly and without worry about evaluation.

8. Navigation

5 MIN

Materials: science notebook

Navigate to our next steps. Ask students to compare and share Progress Tracker notes. Have them look for similarities and differences and give them a chance to add any good ideas to their own trackers that they see on their partner's tracker.

Then say, *We've learned so much! Let's pop out and revisit our original questions and see how much progress we've made.*

Direct students to the DQB. Ask them to jot down any questions they would like to discuss. These may be questions they feel like they completely answered, partially answered, or have not answered yet. Let them know we will discuss these in an upcoming class.

ADDITIONAL LESSON 9 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.RST.6-8.8 Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

CCSS.ELA-LITERACY.RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

Students work with SEP8 in order to evaluate the conclusions of three articles to determine the validity of the claims made in each. If students need additional guidance, refer them to the checklist the class developed to identify the claims and evidence used to back up those claims.

Supporting Students in Making Connections in Math

CCSS.MATH.CONTENT.7.RP.A.3 Use proportional relationships to solve multistep ratio and percent problems. Examples: simple interest, tax, markups and markdowns, gratuities and commissions, fees, percent increase and decrease, percent error.

Students use SEP5 to make sense of experimental data from a simulation. If students need additional guidance making sense of the experimental data, encourage them to identify and count the number of individuals with each genotype as a result of a mating. Once students have determined the number of each genotype, they can determine the percentage of the selected-for genotype in the population over time.

Picking Parents

1 The Hazard of Royal Bloodlines
2 Inheritance Misconceptions
3 Finding Mates
4 History of Selective Breeding

Literacy Objectives

- ✓ Summarize key points related to inheritance, wildlife mating, and selective breeding.
- ✓ Distinguish cause(s) and effect(s) related to inheritance, wildlife mating, and selective breeding.
- ✓ Translate text to visual/graphic representation of ideas.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 7–9.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a science cartoon in response to the reading.

Instructional Resources

Student Reader



Collection 3

Science Literacy Student Reader, Collection 3
"Picking Parents"

Exercise Page



EP 3

Science Literacy Exercise Page
EP 3

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 7: How does an animal get extra-big muscles?
- Lesson 8: Why don't offspring always look like their parents or their siblings?
- Lesson 9: How do farmers control the variation in their animals?

Standards and Dimensions

NGSS

Disciplinary Core Ideas:
LS1.B: Growth and Development of Organisms Animals engage in characteristic behaviors that increase the odds of reproduction. (MS-LS1-4)

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-LS3-2)

LS4.B: Natural Selection In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring. (MS-LS4-5)

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concept: Cause and Effect

CCSS

English Language Arts

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.

RST.6-8.5: Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6- 8 text complexity band independently and proficiently.

WHST.6-8.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

selective breeding

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

gene pool
genetically modified crop
heterozygous
homozygous
inbreeding
pheromone
recessive allele/gene

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

Exercise Page



EP 3

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Genetics unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
  - *First, you will read an article about patterns of inheritance that emerged in a royal family from Europe.*
  - *Next, you'll learn the real science behind some common misconceptions people hold about genes and inheritance.*
  - *Cartoons and comics aren't just about superheroes. You'll read two science cartoons that communicate serious science in an enjoyable way.*
  - *Finally, you'll interpret a timeline showing that humans have practiced and improved selective breeding of plants and animals for thousands of years.*
- Distribute Exercise Page 3. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to generate a science cartoon in response to something you learned by reading Collection 3.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*

- *Revisit the reading selections to complete the writing exercise.*
- *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What facial trait was common among members of the royal Habsburg family?	*a protruding lower jaw*
What types of alleles does someone who has blue eyes have to inherit?	*They have to inherit two recessive alleles for blue eyes.*
What is one way animals use pheromones?	*to attract mates*
When humans first selectively bred wheat and corn, what traits were they selecting for?	*They were selecting for the size of the seeds/grains. They wanted larger seeds.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
Would all the siblings of Charles V have had the same unusual trait?	*no, not necessarily*
In the "Inheritance Misconceptions" article, are Nadia's alleles for eye color heterozygous or homozygous?	*homozygous*
What beneficial traits were Chinese farmers selecting for when they first bred wild peaches?	*larger sizes, sweeter fruit, wax-free skin, and smaller pits*

- Refer students to the Exercise Page 3. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to draw a cartoon in which characters inspired by one or more readings in this collection talk about inheritance of traits, wild animal mating, or selective breeding.*
- *Have the characters talk to one another about points from the reading that you found interesting.*
- *Because it's a cartoon, it's okay if nonhuman animals talk!*
  - *Decide what drawing materials you want to use and if you want to work in black and white or use color.*

Exercise Page



EP 3

- *Don't worry about your drawing skills, you will not be evaluated on how accurately you draw. Stick figures are fine. If you are not sure the reader of your cartoon will recognize what organism you have drawn, use text to identify it.*
- *The important criteria for your work are that the cartoon shows your understanding of the topics discussed in the readings and that it is creative.*

- Explain that thinking about cause-and-effect relationships should help students organize their ideas.
- Answer any questions students may have relative to the reading content or the exercise expectations.

4. Facilitate discussion.

(FRIDAY)

Facilitate class discussion about the reading collection and writing exercise. The collection begins with an article about how inbreeding has affected one royal family. Students should note that the third selection can be used as inspiration for the writing exercise to produce a cartoon.

Pages 24–33 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "The Hazard of Royal Bloodlines"?	*It explains how an unusual trait of members of a royal family becomes commonplace in their family.*
How was the deformed jaw a health problem for the people who inherited this trait?	*It made it difficult for the person to chew their food, because their upper and lower teeth did not line up properly.* *Because they had trouble chewing their food, they could choke.*
The author uses the term gene pool. *What do you think it means, and how could you confirm it?*	*I think it means all the genes available in a population. I could look it up in an online dictionary or encyclopedia.*
What is the general purpose of the second selection, "Inheritance Misconceptions"?	*It explains that some ideas people hold about inheritance are incorrect and why.*
Summarize why Nadia will have blue-eyed children if their father is also blue-eyed.	*A blue-eyed person has two alleles for blue eyes, so any combination of four blue-eyed alleles will produce offspring with blue eyes.*

Student Reader



Collection 3

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Online Resources



CHALLENGE—Have interested students do research to learn about the effects of inbreeding on dogs. Students should begin by asking questions such as "How were dog breeds developed?" or "Why do certain dog breeds have specific health problems?" Guide students to use reliable sources of information, such as interviewing

Pages 24–33 Suggested prompts	Sample student responses
From whom does a grandson directly receive genes for male pattern baldness?	*from his mother*
Think back to the preface to this unit when Isaiah said, "Technically, I jump higher than you right now, and that's because I inherited my mom's legs." Which misconception(s) from this reading relates to what Isaiah said?	*the misconception that blue-eyed children must have a blue-eyed parent (The traits of parents do not always appear as traits of their offspring.)* *Also, Isaiah may think there is one gene for good jumper's legs, and that is not always true.*
What is the general purpose of the third article, "Finding Mates"?	*It compares and contrasts mating behavior of water wildlife with land wildlife.*
There are many interesting facts in this selection. What questions do you have about them that can be answered with research?	*Where do shark embryos develop?* *Do most species of bony fish fertilize eggs outside the female's body? Doesn't that mean most of the eggs will get eaten by predators?* *Do male fish change into female fish because there are too many male fish in the population?* *How is molting related to reproduction in crabs?* *Do both male and female insects release pheromones?* *Aren't humans another type of mammal that fight over females?* *What is it about porcupine pheromones that make them "work"?* *If all the male club-winged manakins make the sound, how does the female decide which one will be her mate?*
Take a look at the Connection box. What similarities do you notice in the ways land and water animals mate?	*It looks like the males usually approach the females, rather than the other way around.*
How did the presentation of this selection help you in creating your written response?	*It showed me that science cartoons can have accurate science but still show some humor.*

a veterinarian or reading online reports about recent scientific research. Encourage students to share their findings with the class.

Pages 24–33 Suggested prompts	Sample student responses
What is the general purpose of the fourth article, "History of Selective Breeding"?	*It describes some highlights in the history of domestication and selective breeding of animals and plants in a visual way.*
What traits might hunter-gatherer humans select for when breeding wolves?	*the ability to run down game but not eat it until the hunter gets there* *the ability to warn sleeping humans when dangerous animals approach* *size and strength to pull sleds* *friendliness to human children*
Genetically modified crops are produced using genetic engineering techniques that alter, remove, or add genes inside living cells to affect the traits of the plants. How is this similar to and different from selective breeding?	*It's similar in that the goal is to produce offspring with desired traits.* *It's different in how it's done. Selective breeding just brings sperm and egg cells together from males and females that have the desired traits.*
Use the terms genotype *and* phenotype *to summarize this selection.*	*For thousands of years, humans have used selective breeding to change the genotypes and thus the resulting phenotypes of organisms to make them more useful.*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 3, students should create a cartoon, using from one to four panels, that responds to their reading of Collection 3. Look for two characters who talk about a pattern of inheritance, respond to a misconception about inheritance, comment on how wild animals mate, or comment on how humans selectively breed plants and animals. This is an open-ended task that allows students to go in many directions.

Consider hanging the cartoons on a wall and conducting a gallery walk so that the class can share and comment on their work displayed.

Use the rubric provided on the Exercise Page to supply feedback to each student.

Online Resources



EXTEND—Some students may prefer to use an app or online tool to draw their cartoons. Point them to online resources that are suitable for middle school students, offer curriculum support, and conform to your school's Internet-use policy.

LESSON 10

How can we use our model to explain a different trait variation?

Previous Lesson

We read about ways farmers breed animals for specific trait variations, and we ran a computer simulation to try our hand at selective breeding. We figured out that by breeding animals with beneficial trait variations more often, we could increase the frequency they are seen in the population.

This Lesson

Putting Pieces Together

1 DAY



Goldfish by Shisan C. Chen, cropped from original image

After a brief navigation conversation, students work independently to demonstrate their understanding on a midpoint assessment—a transfer task involving goldfish breeding.

Next Lesson

We will check in on our DQB to acknowledge what we've figured out so far and take note of where we still have questions: about organisms other than cattle and traits other than muscles. We will sort images of other organisms and discover that their variations encompass a continuous range rather than a few distinct phenotypes. Based on our model, we will record new questions to drive further investigation.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5

What Students Will Do

10.A Critically read scientific texts and construct an explanation using models and math to describe how sexual reproduction results in offspring with genetic variation in the context of goldfish coloration.

What Students Will Figure Out

- Our model to explain trait variations from the parents' genotypes to the offspring's phenotype can be used to explain a phenomenon other than cattle musculature.

Lesson 10 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Reflect on what we've figured out to navigate into the work of this lesson.	A	
2	40 min	**DEMONSTRATE UNDERSTANDING ON AN ASSESSMENT TASK** Demonstrate individual understanding on an assessment about breeding goldfish.	B-C	*Goldfish Assessment*, *Checklist for Obtaining and Evaluating Information from Scientific Text*

End of day 1

Lesson 10 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**  	• *Goldfish Assessment* • *Checklist for Obtaining and Evaluating Information from Scientific Text*		

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make 1 copy each of *Goldfish Assessment* and *Checklist for Obtaining and Evaluating Information from Scientific Text* for each student.

Online Resources



Lesson 10 • Where We Are Going and NOT Going

Where We Are Going

This lesson ends our first lesson set, and students complete a midpoint assessment on *Goldfish Assessment* using the following DCI elements in the context of goldfish breeding:

- LS3.A: 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 affect the traits of the individual. (Mutations are not specifically addressed in this assessment.)

- LS3.A: Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited.
- LS3.B: 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.
- LS4.B: In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.

Since we are at a natural "taking stock" moment in the storyline, the class will revisit the Driving Question Board at the beginning of Lesson 11 in order to celebrate what they've figured out so far and determine where to go next based on the questions they still have.

Where We Are NOT Going

Note that the *Goldfish Assessment* involves a trait which has an incomplete dominance inheritance pattern like myostatin does. However, we do not ask that students name this inheritance pattern as "incomplete dominance" because we have not studied dominant or recessive inheritance patterns in this unit. See the Unit Overview for more information.

Goldfish Assessment focuses on how genetic factors influence the phenotypes we see. However, on the final, unscored item, students propose examples of local conditions that could be affecting goldfish size. Students will continue to explore in the second lesson set how local conditions affect the growth of plants and animals.

At this point in the unit, students have investigated only how sexual reproduction leads to variety in inherited traits. Students will go on to contrast sexual and asexual reproduction in the second lesson set.

LEARNING PLAN FOR LESSON 10

1. Navigation

5 MIN

Materials: None

Reflect on what we figured out last time. Display **slide A.** Give students a minute or so to turn and talk with a neighbor and recall what we figured out in our last class. Then, ask a few students to share.

Sample student responses:

- We figured out how farmers can use selective breeding to get more offspring with trait variations they want.
- We used a simulation to see how we could use selective breeding to change the variations in a group of birds.
- We checked in on the DQB and we have ideas about lots of the questions there—answers, partial answers, and things we're still wondering about.

Navigate to today's assessment. Say, *So we've figured out how a farmer could have a whole herd of heavily muscled cattle, and we got a chance to try selective breeding ourselves with birds. I think we're ready to use our model for predicting how genotype influences phenotype to explain another trait variation example. Now you'll get an opportunity to demonstrate everything you've figured out so far.*

2. Demonstrate understanding on an assessment task.

40 MIN

Materials: *Goldfish Assessment*, *Checklist for Obtaining and Evaluating Information from Scientific Text*



Administer the *Goldfish Assessment* to students. Display **slide B**. Explain that you have an example of trait variation in goldfish for students to work with today. Distribute the *Goldfish Assessment* and the *Checklist for Obtaining and Evaluating Information from Scientific Text* to each student. This assessment will take students most of the class period to complete.

Students will obtain and evaluate the information from the text in the assessment. *Checklist for Obtaining and Evaluating Information from Scientific Text* is provided to support students' work in this practice and give you insight into their development of this practice.

Assessment Opportunity

Building towards: 10.A Critically read scientific texts and construct an explanation using models and math to describe how sexual reproduction results in offspring with genetic variation in the context of goldfish coloration.

What to look for: See *Key for Goldfish Assessment* and *Key for Checklist for Obtaining and Evaluating Information from Scientific Text* for expected student responses and *Rubric for Goldfish Assessment* for scoring guidance.

What to do: If students need extra support you can choose to allow them to use their science notebook or classroom consensus models to help them with this transfer task. You may also choose to help students extract information from the text in the assessment so they can then apply that information to explain and model the new phenomenon, bearing in mind that students will have future opportunities to demonstrate their use of these practices.

Look forward to next time's work before students leave the classroom. Show **slide C**. Say, *We have figured out so much from our investigations. Next time, we will go back to our Driving Question Board to see what questions we can now answer and what we still need to figure out.*

ADDITIONAL LESSON 10 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.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*.

Students need to interpret the results for Dr. Chen's research study conducted in 1928. They need to understand this information in order to explain on the *Goldfish Assessment* how the trait of coloration in goldfish is inherited.

LESSON 11

How can we answer the rest of our questions?

Previous Lesson

After a brief navigation conversation, students worked independently to demonstrate their understanding on a midpoint assessment—a transfer task involving goldfish breeding.

This Lesson

Problematizing

1 DAY



We check in on our Driving Question Board to acknowledge what we've figured out so far and take note of where we still have questions. We have questions on our DQB about organisms other than cattle and traits other than muscles, so our teacher suggests exploring some other organisms that might help us answer those questions. We sort images of these organisms and discover that their variations encompass a continuous range rather than a few distinct phenotypes. We consider whether our model can explain these variations and record several new questions to drive further investigation. We decide to start our investigations with the organism that we think is most different from cattle.

Next Lesson

We will plan an investigation to break open plant cells from strawberries and test if plants also have genetic material. Then we will carry out our investigations and discuss the results as a class.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5

What Students Will Do

11.A Ask questions to refine our model explaining the causes of trait variations we see in other organisms.

What Students Will Figure Out

- Variations can be a continuous range, not always distinct types or categories.
- We have a lot of questions about other organisms and the variations we see in their traits.

Lesson 11 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	15 min	**REVISIT OUR DRIVING QUESTION BOARD** Review our DQB questions to take stock of what we've figured out and highlight what we are still wondering about.	A-D	*Questions from Our DQB*, transparent tape, chart paper, markers, 3" x 3" sticky notes, Related Phenomena list
2	8 min	**INTRODUCE NEW ORGANISMS TO EXPLORE** View images of organisms other than cattle and consider what variations they have.	E-K	chart paper, markers
3	10 min	**SORT TRAIT IMAGES AND SHARE HOW WE SORTED THEM** Work together in small groups to sort images of example organisms into categories of variations, then observe one another's results in a gallery walk.	K-U	1 set of photo cards per group (see Materials Preparation section)
4	10 min	**INITIAL IDEAS DISCUSSION TO GATHER QUESTIONS** Share ideas from the sorting task and ask questions about how our model might or might not work to explain the variations we saw in these organisms.	V-W	1 set of photo cards per group (see Materials Preparation section), 3" x 3" sticky notes, markers, classroom consensus model
5	7 min	**PLAN WHAT TO INVESTIGATE NEXT** Construct a chart to compare the organisms we explored today with cattle. Consider which organism(s) is most different from cattle so we can start investigating there.	X-Y	chart paper, markers

End of day 1

Lesson 11 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Questions from Our DQB* • transparent tape	• 1 set of photo cards per group (see Materials Preparation section)	• chart paper • markers • 3" x 3" sticky notes • Related Phenomena list • classroom consensus model

Materials preparation (30 minutes)

Online Resources



Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Create the handout *Questions from Our DQB* for your class:

- Use a digital copy of *Questions from Our DQB* as a template. List on the handout all the questions students developed on the Driving Question Board.
- For ease of reference you can number each question on the DQB and make sure the handout has the corresponding number next to that question.
- Then, print one copy for each student.
- Note: You will create an updated copy of this list in Lesson 17 for *Questions and Answers from Our DQB*.

Gather the pre-cut *Planaria Photos*, *Arms Photos*, *Strawberry Photos*, *Apple Photos*, *Wheat Kernel Photos*, and *Flamingo Photos* cards from your materials kit for the variation sorting activity. Set aside 4 sets of *Wheat Kernel Photos* to use in Lesson 16. If you do not have pre-cut cards, see the **Online Resources Guide** for links to these items (**www.coreknowledge.org/cksci-online-resources**), and prepare them as follows:

- Print 2 color copies on cardstock of each of these sets: *Planaria Photos*, *Arms Photos*, *Strawberry Photos*, *Apple Photos*, and *Flamingo Photos*.
- Print 6 sets of *Wheat Kernel Photos*. You will use 2 sets in this lesson and all 6 sets in Lesson 16.
- Consider laminating these cards since you will reuse them for each class you teach and can keep them year to year.
- Cut the photos into sets of 10-16 individual images per organism. The images are numbered in each set so you can be sure each set includes its cards 1-10, 1-12, or 1-16 depending on the organism.
- You will have 12 sets of images total (duplicate sets for each of the 6 organisms) so that you can divide your class into 12 partnerships or trios for this activity.
- Consider bundling each set of cards with rubber bands or binder clips so they're easier to distribute.

If possible, prepare space to display one set of each of the card sorts students use in this lesson (ideally posted in the way they arranged it) for future reference throughout this second lesson set of the unit. Depending on how many classes you have, you might wait to have the last class of the day post their organized cards, or you could take photos of how groups organized their cards and print them to display.

Consider preplanning for this lesson the partnerships or trios of students who will investigate each organism. **Slide S** includes blank space for you to list names of students in each group to facilitate quick identification of group mates and which organism they will work with.

Lesson 11 • Where We Are Going and NOT Going

Where We Are Going

This lesson is the beginning of the second lesson set and functions to re-anchor us in the DQB questions we haven't yet answered and prompts new questions that will help us refine our model and deepen our science ideas.

The organisms students explore in this lesson were intentionally chosen to motivate investigations around plant reproductive structures, asexual reproduction, environmental factors that influence trait variation to different degrees, and influences of multiple genes on a trait. While these choices align with DCI content in the unit, the variety presented here should provide connections with many other organisms that students have mentioned on the DQB and Related Phenomena list.

Where We Are NOT Going

Students do consider whether the organisms they're exploring in this lesson are bred by humans, and the second lesson set does offer a few opportunities to investigate organisms that have not had such a heavy human influence on them as cattle. However, this unit does not address natural selection. If your students have questions about natural selection, encourage them to add them to the DQB and then keep those questions available for the next unit, *OpenSciEd Unit 8.6: How could things living today be connected to the things that lived long ago? (Penguins Unit)*.

LEARNING PLAN FOR LESSON 11

1. Revisit our Driving Question Board. 15 MIN

Materials: science notebook, *Questions from Our DQB*, transparent tape, chart paper, markers, 3" x 3" sticky notes, Related Phenomena list

Navigate into today's work. Display **slide A**. Say, *Last time we were together, you were able to use what we've figured out about cattle muscles to explain how genetic factors influence the colors of goldfish. Let's start today by looking over our DQB questions to see which of them we can now answer and which ones we still need to figure out.*

Have students work individually to evaluate what questions the class has answered from the DQB. Display **slide B**. Provide students with *Questions from Our DQB*, which you created to contain all the student questions from the DQB, and have students tape it into their science notebook.

Direct students to work individually for about 3 minutes to mark questions they think the class has answered using this key:

- We did not answer this question or any parts of it yet: **O**
- Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
- Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓+

Remind students that if new questions come up while they're working, they can jot them in their notebook and we'll use them in a moment.

Share answers with a partner. Display **slide C**. Pair students up with a partner and have them spend about 3 minutes taking turns sharing answers to the questions they think we can answer now, using evidence from their work in the unit so far. Again, if new questions arise, students can record them in their notebook for now, and we will use them soon.

Identify questions we have answered. Display **slide D**. Invite students to share questions they think the class has answered, along with a brief explanation. If the class agrees that the question was fully answered, move that sticky note to a new poster near the DQB titled "Questions We Have Answered." If the question was partially answered, put a check mark on the question to keep track of questions we are making progress toward, but leave it on the DQB.

If students had noted new questions during the independent or partner work time, have them write them in marker on individual 3" x 3" sticky notes and post them on the DQB as well.

Students will realize that we have answered a lot of questions about cattle and muscles specifically and many of our questions about genetic material. However, we still have questions about organisms other than cattle and trait variations other than musculature.

2. Introduce new organisms to explore.

8 MIN

Materials: chart paper, markers

Introduce other organisms and variations to explore. Display **slide E**. Say, *I have some other example organisms for us to consider. They're not exactly the same as what we have listed on our DQB and Related Phenomena list, but let's spend some time today exploring their variations to see if we think parts of our model could explain them too.*

Display **slide F**. Say, *The organism pictured here is a type of flatworm called a planarian—the plural "planaria" is on the slide since there are two of them. What trait seems to be showing variation in these images of the planaria?*

Sample student response: color

Present **slides G-K**, each time naming the organism pictured and deciding on the trait that's showing variation, as listed here:

- strawberries (size)
- wheat kernels (color)
- flamingos (color)
- humans (arm span length)
- apples (color)

Determine possible categories of these variations. Present **slide L**. Say, *When we explained our cattle muscles, we had three phenotypes: typical, medium, and heavily muscled. The goldfish you read about last time had brown, transparent, or speckled scales. What categories of variations, or what phenotypes, would you expect to see for the traits in each of these new organisms?*

As you show **slides L-Q** and invite students to share how they would categorize examples of each organism by the variations displayed in the slide photos—What groups would we have? List ideas on a chart for reference.

Possible variation categories or phenotypes are shown in this example table:

Organism	Trait	Variation categories and phenotypes
apples	color	red, green, striped
planaria	color	brown, white
strawberries	size	small, medium, large
wheat kernels	color	brown, yellow
flamingos	color	light pink, dark pink
humans	arm span length	long, medium, short

3. Sort trait images and share how we sorted them.

10 MIN

Materials: 1 set of photo cards per group (see Materials Preparation section)

Prepare to sort organisms by phenotype. Display **slide R**. Say, *Let's continue to explore these variations by looking closer at more examples. I have cards with more photos of these organisms. You will take a few minutes with your group to observe the photos and sort or organize them into the variation categories we were just describing.*

Divide the class into 12 groups. Display **slide S**, which lists group numbers and organisms and includes spaces for you to list group members' names. Direct students to gather with their group mates.

Distribute photo sets and direct groups to sort them. Display **slide T**. Give each group a set of photos of the organism they're focused on. Direct them to sort or organize these cards into categories or groups by phenotype.

Allow groups 3-4 minutes to sort their photos.

You can expect some struggle with this task as students realize that distinct categories are difficult to form with these variations. If students express concern about trying to decide which examples go into which category, allow them to form additional groups or rearrange their organization in another way. Some groups may want to make a line of photos showing a spectrum—that's fine! You can also ask specific students or groups to be ready to share about their struggles when the class meets together again for discussion.

Take a gallery walk to see how others sorted their photos. Display **slide U**. Direct students to leave their cards as they are arranged on their desks or tables. Invite students to stick with their partner(s) and circulate the room to see how other groups arranged their trait variations. Have them look to notice any similarities or differences in how the phenotypes are organized or arranged.

After a 2-3 minutes of gallery walking, bring the class together for a discussion.

4. Initial Ideas Discussion to Gather Questions

10 MIN

Materials: 1 set of photo cards per group (see Materials Preparation section), 3" x 3" sticky notes, markers, classroom consensus model

Gather the class in a Scientists Circle for an Initial Ideas Discussion. Display **slide V**. Direct students to sit with their group mates in the circle and bring along their photo sets for reference during the discussion.

Key Ideas

Purpose of this discussion: Elicit sharing about the sorting task and questions about how our model might or might not work to explain the variations we saw in these organisms.

Listen for these ideas about sorting:

- It was hard!
- We couldn't decide what fit in which category. What's the dividing line between big, medium, and small?
- There weren't just two or three types—it was more like 5 or 6 or 10 types.

Listen for these questions:

- Do these organisms have genetic material?
- Do they have sperm and eggs?
- Do they have parents? (What do the parents look like?)
- Is this range of variations caused by something different happening with the chromosomes and alleles?
- Is there a protein involved? What's its function?
- What environmental factors might be influencing this trait?

You might also hear predictions about possible causes for these variations. If so, go ahead and capture those ideas as questions, also.

Use prompts such as the following to invite students to share about the sorting task.

Suggested prompts	Sample student responses	Follow-up questions
What did you notice about sorting your organisms into categories?	*It was hard!* *We couldn't decide what fit in which category.* *Even with the measurements on the arm spans, it was hard to say what would count as "long" or "short" or "medium."*	*What makes you say that?* *Tell us more.*
Did two or three categories or types make sense for these trait variations?	*No! We had a lot that were hard to tell how to sort them.* *We made five groups for ours.* *We think each one of ours needs its own group or type. There wasn't a good way to decide how to categorize them.*	*How did that help you sort them?* *What did you notice about how other groups sorted theirs?*
How could you better organize your photos in a way that makes more sense?	*Make them into more than three groups.* *Just put them all in a line from smallest to biggest.*	*Can you show us with your set of photos?*
How many variations could our model that we developed for cattle muscles explain?	*We were focused on three phenotypes with the cattle muscles.*	*How many variations for the goldfish?*

Summarize for the class. Say something like, *I hear you saying that these trait variations did not have three distinct categories or phenotypes like we had with our cattle musculature. Instead, these were more like ranges, continuous from one end of a line to another, or each individual needed its own group.*

Refer to our classroom consensus model to generate questions. Display **slide W**. Say something like, *We are trying to figure out answers to these DQB questions that we still have. Let's think through what we would need to know about these organisms and these traits to see if our model works to explain them. While we talk, let's record questions on sticky notes right on our model to show where our areas of uncertainty are. What would we have to know in order to decide if our model could explain these other variations? Turn and talk with your partner(s) before we share as a class.*



After about a minute of partner talk, ask students to share their questions with the class: *What are we wondering about these organisms and traits?*

Sample student responses

- Do these organisms have genetic material?
- Do they have sperm and eggs?

- Do they have parents? (What do the parents look like?)
- Is a range of variations caused by something different happening with the chromosomes and alleles?
- Is there a protein involved? What's its function?
- What environmental factors might be influencing this trait? (Strawberries can't exercise!)
- Is this variation caused by … something they eat? How much sun they get? What fertilizer the farmer uses?
- How do plants reproduce?
- Where do planaria live?

As students share their questions, have them write them with marker on 3" x 3" sticky notes. If they are questions specific to our model, post them directly onto the classroom consensus model. Questions can be added to the DQB, as well.

Assessment Opportunity

Building towards: 11.A Ask questions to refine our model explaining the causes of trait variations we see in other organisms.

What to listen for: Students should raise questions that connect components or interactions in our model to the causes of ranges of trait variations in these other organisms. Examples are listed in the Key Ideas box above.

What to do: If it's helpful, point to each component or interaction on the classroom consensus model and ask, *What do you wonder about this part of our model? What additional data or investigations would help you figure out if this part of the model explains the variation you saw in your organism's trait?*

5. Plan what to investigate next.

7 MIN

Materials: chart paper, markers

Propose a method to help us decide where to go next. Display **slide X**. While the class is still gathered in the Scientists Circle, say, *We have a lot of great questions here to figure out. In order to see if we can explain variations in other organisms we're curious about, we need to think about what assumptions our model makes about these organisms. Let's think about these assumptions with cattle since that's how we made this model in the first place.*

On a blank piece of chart paper, set up a quick table like the one shown here:

Model assumes ...	Cattle						

Have students talk through the classroom consensus model and describe what cattle have that makes this model work for them: What is the model assuming about an organism? About the trait variation it's explaining? Add "these criteria" to the left-column heading. Fill in the left column of the table with the criteria for this model as students name them. A sample is shown here.

Model assumes … these criteria	Cattle						
An animal	✔						
Reproduces with sperm and egg (sexual reproduction)	✔						
Has genetic material	✔						
People breed them	✔						
Variation in muscles	✔						

Use this chart to compare example organisms. Say, *Let's use this chart to help us compare these organisms, and that might help us decide where we have the most uncertainty and want to investigate first.*

Add column headings in the chart for the organisms students explored today. Discuss each as you work together to mark whether they do (✔) or do not (X) fit these criteria or whether we're unsure (?). If questions arise during this conversation that have not already been recorded on the classroom consensus model or DQB, have students add them now.

See the sample chart here.

Model assumes… these criteria	Cattle	Planaria	Strawberries	Wheat kernels	Flamingos	Humans	Apples
An animal	✔	?	X	X	✔	✔	X
Reproduces with sperm and egg (sexual reproduction)	✔	?	?	?	✔	✔	?
Has genetic material	✔	?	?	?	✔	✔	?
People breed them	✔	?	✔	✔	?	X	✔
Variation in muscles	✔	X	X	X	X	?	X

Navigate into next time's work. Display **slide Y**. Refer to the chart you just created to support a decision about what organism to investigate first in order to expand our model. Say, *If we start with investigating an organism that is the most different from cattle or the most confusing to explain, then maybe explaining other organisms and variations we're curious about will be easier from there. Which of these organisms do you think is most different from cattle? Which would be the best choice to really push on our model and help us expand it? Why?*

Sample student responses

- The plants are the most different.
- We should investigate strawberry size or wheat kernels or apple colors first.
- We're not sure if plants even have genetic material like we saw in animals.
- Some of those plants could grow wild and wouldn't be so influenced by humans.
- Plants don't even have muscles! They're way different!

Say something like, *It sounds like we need to investigate a plant next. Before we can dive into a specific one, it seems like we should figure out if they even have genetic material to be influencing the trait variations we see. That can be our work for next time!*

Additional Guidance

If possible, plan to display one set of each of the card sorts students use in today's lesson (ideally, posted in the way they arranged it) for future reference throughout this second lesson set of the unit. Depending on how many classes you have, you might wait to have the last class of the day post their organized cards, or you could take photos of how groups organized their cards and print them to display.

LESSON 12

Do plants have genetic material?

Previous Lesson

We checked in on our DQB to acknowledge what we've figured out so far and noted where we still have questions: about organisms other than cattle and traits other than muscles. We sorted images of other organisms and discovered that their variations encompass a continuous range rather than a few distinct phenotypes. Based on our model, we recorded new questions to drive further investigation. We decided to start our investigations with the organism that we think is most different from cattle.

This Lesson

Investigation

1 DAY



We question whether plants also have genetic material and wonder if there is an investigation that would allow us to see that material. We watch a video of someone isolating genetic material from animal cells, and then we plan an investigation to break open plant cells and see if we can isolate the same material from our plant cells (strawberries). We carry out our investigations and discuss the results as a class.

Next Lesson

We will investigate flower structures and their equivalence with human reproductive structures. Video observations will prompt us to share ideas about how the structures of flowers interact with pollinators. We will learn about how farmers breed and propagate tulips with a lot of trait variations, and we will discover that some plants can reproduce both sexually and asexually.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5

What Students Will Do

12.A Plan and carry out an investigation to produce data to serve as the basis for evidence that plants have genetic material inside their cells that can be visualized (scale).

WHAT STUDENTS WILL FIGURE OUT

- Genetic material is so small we can't see it when it is from a single cell (and we normally can't see single cells without a microscope).
- There is a lot of genetic material in each cell because there are thousands of genes in each cell.
- There are many cells in a small sample of muscle or plant tissue, so we are able to get enough genetic material out of the cells to see it.

Lesson 12 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	2 min	**NAVIGATION** Recall what we figured out from the prior lesson and navigate to today's work.	A	
2	5 min	**BRAINSTORM IDEAS FOR HOW TO GET AT THE GENETIC MATERIAL** Work with a partner to come up with initial ideas for how to get chromosomes out of the nuclei of cells.	B-C	
3	10 min	**EXAMINE PROTOCOL TO EXTRACT CHROMOSOMES** Watch a video of a scientist extracting genetic material from animal tissue. Discuss how students will use that protocol to extract genetic material from plant cells.	D-G	1 computer connected to a projector and speakers to play video, 8.5 Lesson 12 Extracting Genetic Material (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
4	5 min	**OBSERVE THE RESULTS OF USING THE GENETIC MATERIAL EXTRACTION PROTOCOL ON THINGS WE KNOW DO NOT HAVE GENETIC MATERIAL** Watch the teacher demonstrate the protocol on plain water and on a solution of water and protein powder.	H-J	Negative Control Demonstration (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
5	18 min	**CARRY OUT EXPERIMENT TO EXTRACT GENETIC MATERIAL FROM PLANTS** Prepare for and carry out the Extracting Genetic Material Lab in small groups.	K-I	Extracting Genetic Material Lab
6	8 min	**CLASS DISCUSSION AND PROGRESS TRACKER UPDATE** Record what students figured out from the lab investigation.	Q	
7	2 min	**DISCUSS NEXT STEPS** Discuss as a class next steps that the whole group should take.	S	

End of day 1

Lesson 12 • Materials List

	per student	per group	per class
Negative Control Demonstration materials			• *Negative Control Demonstration* • 20 mL of plain tap water • 1 serving protein powder mixed with water per the product instructions • 2 1-qt. heavy-duty ziplock bags • 2 pieces of 4″ x 4″ cheesecloth • 40 mL of ice-cold 91-100% isopropyl alcohol or 95% ethanol • 2 100-mL beakers • 2 wooden skewers • 2 cups each with 20 mL of warm water • 2 Tbsp. salt • 2 Tbsp. (30 mL) dish soap • 1 pinch of meat tenderizer • 2 rubber bands • 1 spoon
Extracting Genetic Material Lab materials	• indirectly vented chemical-splash goggles • 1 nonlatex apron • vinyl or nitrile gloves gloves • science notebook • *Lab v1: Extracting Genetic Material* or *Lab v2: Extracting Genetic Material*	• 1 1-qt. heavy-duty ziplock bag • 1-2 pieces of 4″ x 4″ cheesecloth • 20 mL of ice-cold 91-100% isopropyl alcohol or 95% ethanol • 1 100-mL beaker (or similar container) • 1 wooden skewer • 20 mL of warm salt water in a Styrofoam cup (or similar container) • 1 Tbsp. (15 mL) dish soap • 1 pinch meat tenderizer • 1 rubber band • 1 plastic spoon • 1 thawed frozen strawberry	

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook		• 1 computer connected to a projector and speakers to play video • 8.5 Lesson 12 Extracting Genetic Material (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Materials preparation (40 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare the handouts:

- Print one copy for each student (decide ahead of time how many of each version you will need for each class): *Lab v1: Extracting Genetic Material* or *Lab v2: Extracting Genetic Material* (The latter version includes more scaffolding to support students as they respond to prompts that ask them to use cause-and-effect statements in their responses.)

Set aside some space on your board to make a class data table.

Test the video:

- 8.5 Lesson 12 Extracting Genetic Material (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Negative Control Demonstration

- **Setup**
  - Watch the teacher preparation video 8.5 Lesson 12 Using DNA extraction protocol on water and protein mixture. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
  - Make warm salt water solution
    - Heat up 1 L water.
    - Add 60 g (¼ cup) of salt.
    - Stir until it is dissolved. (This will be enough for the demonstration and the student investigations.)
  - Gather and prepare the demonstration materials:
    - 30 mL of plain tap water
    - 1 serving protein powder mixed with water per the product instructions
    - 2 1-qt. heavy-duty ziplock bags

- 2 Styrofoam cups each with 20 mL of warm salt water (from the 1 L prepared earlier)
- plastic spoon
- 2 Tbsp. (30 mL) colorless dish soap
- 2 pieces of 4" x 4" cheesecloth
- 2 100-mL beakers or similar containers (note that glass will be easier for students to see through for the demonstration)
- 2 rubber bands
- 1 pinch of meat tenderizer
- 40 mL of 91-100% isopropyl alcohol (or 95% ethanol) kept cold using an ice bath
- 2 wooden skewers

Extracting Genetic Material Lab

- **Group size:** about 3 students per group; 10 groups per class
- **Setup**
  - Watch the teacher preparation video 8.5 Lesson 12 Strawberry DNA extraction procedure. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
  - Thaw frozen strawberries, enough for 1 whole strawberry per group. Place the bag(s) of frozen strawberries in the refrigerator 24 hours in advance of the lab or leave them out at room temperature a few hours in advance to thaw.
  - Make a warm salt water solution (you can skip this step if you have leftover warm water from the teacher demonstration).
    - Heat up 1 L water.
    - Add 60 g (¼ cup) of salt.
    - Stir until it is dissolved. (This will be enough for the demonstration and the student investigations.)
  - 200 mL of 91-100% isopropyl alcohol (or 95% ethanol) kept cold using an ice bath
  - 20 pieces of 4" x 4" cheesecloth (this is enough for all groups to have 2, in case they request an extra)
- **Prepare the following materials for each student group:**
  - 1 1-qt. heavy-duty ziplock bags
  - 1 thawed frozen strawberry
  - 1 Styrofoam cup with 20 mL of warm salt water (from the 1 L prepared earlier)
  - 1 Tbsp. (15 mL) colorless dish soap
  - 1 plastic spoon
  - 1 plastic 100-mL beaker (or similar container)
  - 1 rubber band
  - 2 pieces of 4" x 4" cheesecloth

- 1 pinch of meat tenderizer
- 20 mL of 91-100% isopropyl alcohol (or 95% ethanol) kept cold using an ice bath
- 1 wooden skewer

- **Notes for during the lab**
  - Make sure students do not agitate the bags too much after adding the soap. Too many bubbles will make straining the liquid difficult and could lower DNA yield.
  - Keep the isopropyl alcohol or ethanol on ice. Ice-cold alcohol gives a much higher yield of DNA.
  - Fresh strawberries will work; however, the freezing process breaks the cell walls and makes it much easier for students to get the strawberry mash needed for the investigation.



Safety

- Ensure that the lab has engineering controls (eyewash station and shower) available.
- Wear indirectly vented chemical-splash goggles, a nonlatex apron, and vinyl or nitrile gloves during the setup, hands-on, and cleanup segments of the lab.
- Immediately wipe up any spilled water on the floor—this is a slip and fall hazard.
- Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
- Wash your hands with soap and water immediately after completing this activity.
- Never eat any food items used in a lab activity.
- Never taste any substance or chemical in the lab.
- Use caution when working with heated liquids—this can burn skin!
- Make sure there is appropriate ventilation to remove alcohol vapors, which are flammable. Otherwise, this activity should be done under a fume hood.
- To prevent a fire hazard, make sure there are no active flames when using alcohol in this activity.
- Direct students to follow your specific instructions for disposing of waste materials.

- **Disposal:** Check your local policy about proper disposal of ethanol and isopropyl alcohol. All other materials can be disposed of in regular trash receptacles.
- **Storage:** All materials except ice can be stored at room temperature.

Lesson 12 • Where We Are Going and NOT Going

Where We Are Going

In this lesson we discuss extracting "genetic material" from inside of cells because the term "genetic material" is used in the middle school grade band according to *A Framework for K-12 Science Education*. If your students have previously been exposed to the term "DNA" you can help make this connection for your students based on their previous background knowledge.

This lesson helps build on these DCI pieces from *A Framework for K-12 Science Education*: "All cells contain genetic information" (p. 145) and "Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring" (p.146). In order to understand that plants also pass their genetic information to their offspring, students first need to be convinced that they have it in the first place.

This is important to help navigate to the next lesson because in Lesson 5 our framing for what is passed down from parents to offspring is through the sperm and egg, and inside those are mostly genetic material. So students may reason that plants also have genetic material, and maybe they also have sperm and egg to pass that information from parent to offspring.

In later lessons those ideas will be extended to organisms that are not using sex cells to reproduce. Students will be able to look back and reason that since there is genetic material in all types of cells, that information can also be passed on to the offspring without using egg and sperm to do so.

Where We Are NOT Going

In this lesson we are not figuring out whether plants have sperm and egg or the specifics of the type of reproduction the plant is using.

Students may bring up that strawberries can send runners to start new plants. We will be addressing that in a future lesson, so if students have questions about that now, ask them to write their questions on sticky notes and add them to the Driving Question Board.

While we are making the connection that the genetic material is a physical substance, we are not getting into exactly what this substance is made up of (nucleotides and so forth) because that is above grade band. We can, however, refer back to what we already know about genetic material—that genes are found on chromosomes, (in egg and sperm cells as well as other cells of the body, like muscle cells (Lesson 5 slide H).

LEARNING PLAN FOR LESSON 12

1. Navigation

2 MIN

Materials: None

Turn and talk to recall the conversation about whether we thought plants have genetic material from last class. Display **slide A**. Say, *At the end of last class we were thinking about whether we thought plants had genetic material like we saw in animals. Turn and talk with a partner about what we decided we should investigate and why.*

After students turn and talk, have partners share ideas with the whole class.

Suggested prompts	Sample student responses
What were we interested in investigating next?	*We wanted to be able to explain the variation we saw in other living things we were interested in.*
Did we have a plan for how we might investigate the other examples?	*We thought we should use our model to test the examples that were the most different from the cattle to see if our model could still work to explain variation.*
What organisms did you decide were the most different?	*We decided that plants would be good to look at, but we weren't even sure if plants have genetic material or chromosomes.*
OK, so we're not really sure if plants have genetic material. If we did want to look for it, where would we even look?	*We would look inside cells.*

2. Brainstorm ideas for how to get at the genetic material.

5 MIN

Materials: None

Brainstorm ideas in an Initial Ideas Discussion for how to get at genetic material. Display **slide B**.



Key Ideas

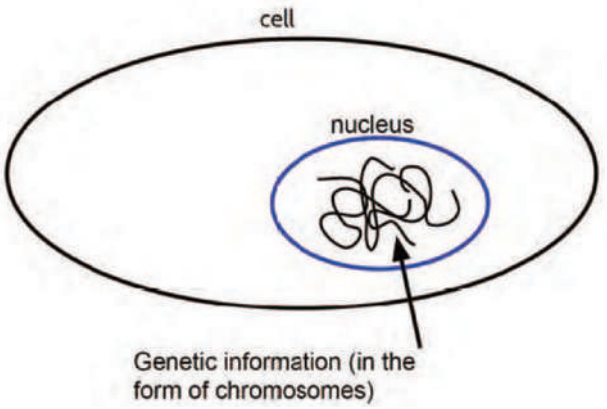
Purpose of this discussion: Students need an opportunity to think through the steps one might take to find out whether genetic material is inside a living thing and to see it. This is important so that students can make meaning from and connections to the steps in the extraction protocol that they will use to see if genetic material is inside plant cells too.

Listen for these ideas:

- We would need to break open or get inside cells.
- We would need to break open or get inside the nucleus.
- We would need a way to make the genetic material visible to our eyes because it's really small.

Suggested prompts	Sample student responses
Where in the cell do we find the genetic material?	*in the nucleus of the cells*
What would we need to do in order to get the genetic material out of the cell?	*There is a cell membrane around the cell, so we would have to break that apart to get into the cell.* *And we'll have to break into the nucleus to get the genetic material out.*
Is there anything else we need to consider?	

Draw on the board where chromosomes are found inside cells based on what students shared. Have students use the visual you put on the board and turn and talk with a partner about how to get at chromosomes inside of cells. Display **slide C**.



Suggested prompts	Sample student responses
If we break open only a single cell, would we be able to see the genetic material?	*Probably not, you can't even really see most cells without a microscope.*
In order to see genetic material from a single cell we would need a microscope that magnifies about a thousand times the actual size. We don't have those, so what are some ways we could make the genetic material more visible?	*If you could break open a lot of cells so the chromosomes could get out of the nucleus you might be able to see the chromosomes, if there was enough.*

Summarize and transition to the next activity. Say, *So if we wanted to see firsthand evidence of these pieces of genetic material, we would need a way to somehow get inside the cell and break open the nucleus, and we would need to do this to many cells in order to collect enough material to be able to visualize the chromosomes because they are so small.*

Assessment Opportunity

Building towards: 12.A.1 Plan and carry out an investigation to produce data to serve as the basis for evidence that plants have genetic material inside their cells that can be visualized (scale).

What to listen for: Students should be linking back to ideas they learned about where the genetic material is located in the cell, and then they should use that information to think about how to get the chromosomes out of the nucleus. Students should also surface the idea that cells are small (microscopic), and so the genetic material would also be microscopic. Listen for students bringing up ideas about needing to get genetic material from a lot of cells because if there are many cells, there should also be a lot of genetic material. If there is a lot of a substance, even though individually it would be too small to see, you could see a bunch of it all together.

What to do: Students may struggle to get to the idea that they may be able to visualize something really small by having a lot of it. If they are having a hard time coming to the idea that we could see the genetic material if we were able to get it out of a lot of cells, cue students to think of ways this idea of scale presents itself in their lives. For example, ask them if they can see a single water molecule and then encourage them to think about what makes it so they can see the water in their drinking glass. You can replay the cell size and scale simulation from Lesson 5 to remind students of the scale of genetic material. An alternative, very similar scale simulation is also available. (See the **Online Resources Guide** for a link to these items. **www.coreknowledge.org/cksci-online-resources**)

3. Examine protocol to extract chromosomes. 10 MIN

Materials: 1 computer connected to a projector and speakers to play video, 8.5 Lesson 12 Extracting Genetic Material (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Watch a video of how scientists extract genetic material from animals. Say, *Scientists have figured out a way to get at chromosomes using some of the ideas you described. I have a video for us to look at where a scientist is showing us how they extract genetic material from different animal tissues.* Show **slide D** and ask students to create a data table in their science notebook to record the observations about the different animal tissues. Once students are ready, play 8.5 Lesson 12 Extracting Genetic Material (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**); it is also linked on the slide. Invite students to share with the class the observations they recorded in their table.

Show **slide E** and ask students to turn and talk about the questions on the slide. Then have students share their thoughts with the whole group.

Suggested prompts	Sample student responses
Does this investigation do the things we thought needed to be done to pull out or extract the genetic material from cells?	*Yes, there is a way to break open the cells and the nucleus.* *There is also a way to get all the genetic material separated from the rest of the cell so we can see a lot of it from all the cells all together.*
Do you think we might be able to use this same procedure for our investigation of plant cells?	*Maybe we could use their procedure to see if genetic material could be inside plants.*
What would we change to test the question we are interested in?	*Instead of different kinds of animal tissue, we would test plant tissue.*

Analyze the substances to extract genetic material from cells. Display **slide F**. Say, *I recorded some information about the materials the scientist used to extract the genetic material from the animal cells. Let's take a look. With a partner, read about the substances we need to use and talk about the following questions:*

- *Could we use these same substances in our class?*
- *What questions do you have about these substances?*

Surface the idea of needing a control for experimentation. Show **slide G** and give students a moment to discuss how we can be sure the material that we isolate is actually genetic material and not just a reaction among the soap, salt, and alcohol.

Suggested prompts	Sample student responses
Who can remind us, what question are we trying to investigate?	*We're trying to figure out if plant cells have genetic material in them like animal cells do.*
So if we try to pull out genetic material from a plant using the solutions we just looked at—like salt, soap, and alcohol— how will we know that the solutions worked? How will we know we actually got genetic material from the plant cells?	*We need to compare it to something we know has genetic material, like the animal cells.*
Great, so you're saying if we end up with a substance that looks like what we saw on the video we know it is the genetic material?	*Yes.*
But how do we know we aren't seeing some result of just mixing these ingredients together or if we are seeing some other substance that all living things have in common, like protein? What could we do to make sure that isn't the case?	*Maybe we need to test something that we know does not have genetic material.* *We could just test water since we know there should not be genetic material in water.* *We could test protein that isn't in a living thing too, like the kind people use to make shakes. There should be protein, but it wouldn't have genetic material.*

Summarize the discussion for the class. Say, *So we need to compare the material we get from our plants to material that we saw the scientist get from the animal cells that we know have genetic material. But you're saying we also need to see if we get a similar substance when we test things we know don't have genetic material, or even things that might give a positive test for a substance we aren't measuring for.*

4. Observe the results of using the genetic material extraction protocol on things we know do not have genetic material.

5 MIN

Materials: Negative Control Demonstration, science notebook

Observe the result of the protocol on water and a protein solution. Say, *It makes sense to first be sure we aren't just seeing some other substance when we mix all these things together, so let's test these items we know should not contain genetic material. Let's take a minute to set up a way to record our observations so they can be compared easily.* Show **slide H** and give students time to add columns to the data table for water and protein drink.

Then show **slide I** and give students a moment to discuss with a partner the following question:

- If this protocol is truly isolating genetic material and isn't just creating a reaction that results in a similar substance forming at the end of the protocol, what do you expect to see when we use this protocol on the sample of water or protein drink?

Then bring the class back together to share ideas.

Suggested prompts	Sample student responses
What do you expect to see when we use this protocol on water and the protein drink?	*We should not get the gooey, white stuff we saw when the scientist extracted genetic material from the animal cells.*
If we do see the same material at the end of the protocol when we apply it to water, what would that mean?	*It means the substance is just something that happens when you mix up all those ingredients. It's not really extracting the genetic material.*
What would it mean if you didn't see the material for water but you did see the material when we applied the protocol to the protein drink?	*It would mean that maybe we are isolating protein and not genetic material.*

Demonstrate the protocol applied to water and the protein drink. Say, *Great, water and protein drinks are really easy to get, and I have some right here.* Remind students to record their observations in the table they made. Once students are ready, demonstrate the protocol on a sample of water and on a sample of protein drink following the instructions in the *Negative Control Demonstration* teacher reference.

Alternate Activity

If you have time in your classroom you may choose to have students do this negative control portion of the investigation instead of performing it at a demonstration. As an extension for high-interest students they may work to develop their own protocol for this investigation based on the description in the video they just watched (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Additionally, students know about carbs, fats, and proteins being major molecules in our foods that our bodies use (from *Inside Our Bodies Unit* and *Maple Syrup Unit*). The demo is currently set to only show the results of the protocol with a negative control, and protein sample. If students bring up the idea that these other molecules should also be tested, ask students to suggest some substances they would test for carbs and fats (e.g. sugar water, cooking oil) and add these to your demonstration.

Discuss the results of this control test with the class. Facilitate a discussion to discuss the students' observations and what they mean.

Suggested prompts	Sample student responses
What did we observe when we applied the protocol to the sample of plain water?	*We didn't see any white, gooey substance form like with the animal cells.*
What does this tell us?	*Water doesn't have genetic material.* *The white substance isn't a result of just mixing the soap, salt, and water together.*
What did we observe when we applied the protocol to the protein drink?	*It was the same as the sample of water—we didn't have any white, gooey substance form.*
What does this tell us?	*The protein drink did not have genetic material.* *The protocol isn't isolating protein.*

5. Carry out experiment to extract genetic material from plants.

18 MIN

Materials: Extracting Genetic Material Lab

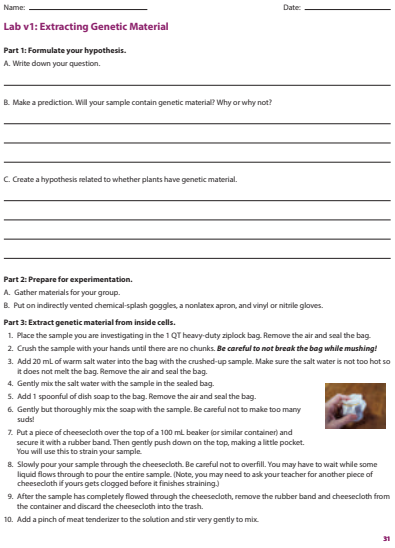
Prepare students for the lab experiment. Form groups of about 3 students. Project **slide J** and ask students to update their table to include a column to record their observations for plant tissue. Hand out one copy of *Lab v1: Extracting Genetic Material* or *Lab v2: Extracting Genetic Material* to each student.

Make a prediction. Show **slide K** and ask students to write on *Lab v1: Extracting Genetic Material* their predictions to the questions, "Will your sample contain genetic material? Why or why not?"

Show **slide L** and ask students to use the cause-and-effect framework to create their hypothesis and then also record that on *Lab v1: Extracting Genetic Material*.

Project **slide M**. Have students create a table in their science notebook to have a place to record their observations and what the results mean.

Show **slide N** and review the safety guidelines with students, then direct them to gather the materials and carry out the protocol.



Name: _____ Date: _____

Lab v1: Extracting Genetic Material

Part 1: Formulate your hypothesis.

A. Write down your question.

_____

B. Make a prediction. Will your sample contain genetic material? Why or why not?

_____

_____

_____

C. Create a hypothesis related to whether plants have genetic material.

_____

_____

_____

_____

Part 2: Prepare for experimentation.

A. Gather materials for your group.

B. Put on indirectly vented chemical-splash goggles, a nonlatex apron, and vinyl or nitrile gloves.

Part 3: Extract genetic material from inside cells.

1. Place the sample you are investigating in the 1 QT heavy-duty ziplock bag. Remove the air and seal the bag.
2. Crush the sample with your hands until there are no chunks. ***Be careful to not break the bag while mushing!***
3. Add 20 mL of warm salt water into the bag with the crushed-up sample. Make sure the salt water is not too hot so it does not melt the bag. Remove the air and seal the bag.
4. Gently mix the salt water with the sample in the sealed bag.
5. Add 1 spoonful of dish soap to the bag. Remove the air and seal the bag.
6. Gently but thoroughly mix the soap with the sample. Be careful not to make too many suds!
7. Put a piece of cheesecloth over the top of a 100 mL beaker (or similar container) and secure it with a rubber band. Then gently push down on the top, making a little pocket. You will use this to strain your sample.
8. Slowly pour your sample through the cheesecloth. Be careful not to overfill. You may have to wait while some liquid flows through to pour the entire sample. (Note, you may need to ask your teacher for another piece of cheesecloth if yours gets clogged before it finishes straining.)
9. After the sample has completely flowed through the cheesecloth, remove the rubber band and cheesecloth from the container and discard the cheesecloth into the trash.
10. Add a pinch of meat tenderizer to the solution and stir very gently to mix.

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While students are carrying out the investigation, create a large class data table on the board for students to record their group's data.

Group	Data: Observations about our sample	Results: Was genetic material found in our sample?

Safety Precautions

Have students wear indirectly vented chemical-splash goggles, a nonlatex apron, and nitrile gloves to protect clothing and skin and to avoid splashing soap or isopropyl alcohol or ethanol in their eyes during the setup, investigation, and cleanup of this activity. Make sure there is appropriate ventilation to remove alcohol vapors, which are flammable. Otherwise, this activity should be done under a fume hood. To prevent a fire hazard, make sure there are no active flames when using alcohol in this activity.

Alternate Activity

Students may question whether different plants, or even different parts of plants, also have genetic material. As an extension you may choose to allow students to use this protocol to test other fruits, seeds, leaves, stems, or roots. Keep

* Attending to Equity

Universal Design for Learning: Students have been using sentence starters to help them *express* their ability to use cause and effect to explain how data they collect serve as evidence to support a claim. There are two versions of this handout. If there are students with diverse levels of development with regard to using cause and effect, you may choose to give some students *Lab v1: Extracting Genetic Material* and others *Lab v2: Extracting Genetic Material* (which includes more scaffolding). In this case, you may choose to not show slide P to give students who are using version A a chance to *express* their ability to use cause and effect without the extra scaffolds.

in mind that different plant cells may have tougher cell walls, and a key factor in the success of these investigations is breaking those cell walls and membranes. Other fruits such as bananas are still easy to mash, but if students are interested in testing leaves, seeds, flowers, or stems (such as cabbage, peas, broccoli, or celery) they may need a blender, food processor, or mortar and pestle to successfully break through the cell walls.

Discuss the results of the investigation. After all groups' results have been recorded on the class data table, bring everyone together for a whole-class discussion. Show **slide O** and discuss the prompts on the slide.

- What patterns do we see in our data?
- What have we figured out about the question we had for this lesson?
- Do the data we collected serve as evidence to support your hypothesis?

Respond to the prompts on *Lab v1: Extracting Genetic Material*. Ask students to consider their group's results as well as patterns in the data the class posted to respond to the prompts in part 4 of *Lab v1: Extracting Genetic Material*. Show **slide P** to provide support to students as they formulate their responses.*

Assessment Opportunity

Building towards: 12.A.2 Plan and carry out an investigation to produce data to serve as the basis for evidence that plants have genetic material inside their cells that can be visualized (scale).

What to look for: Look for students' answers to list evidence that the genetic material was isolated from all types of cells (egg cells, muscle cells, and plant cells), but not from any nonliving things (water or protein drink) and that the material in all samples had similar properties. Students should also reason that they know most of what makes up eggs is genetic material (from Lesson 5), so if the substance isolated from all the other samples looks the same it must also be genetic material, further supported by the fact that we did not get this material when we used the protocol on the protein drink. Students' answers should also demonstrate that they must break open and collect genetic material from many cells in order to visualize it because the genetic material from only one cell would be much too small to see.

What to do: As students are working on their responses to part 4 of *Lab v1: Extracting Genetic Material*, circulate to look for students making a claim and connecting evidence they collected from today's investigation. If students are having trouble listing evidence, ask them to think about what data they collected today and what pieces of that data would serve as evidence to support their ideas. There are two versions of this handout. If there are students with diverse levels of development with regard to using cause and effect you may choose to give some students *Lab v1: Extracting Genetic Material* and others *Lab v2: Extracting Genetic Material* which includes more scaffolding. In this case, you may choose to not show slide P to give students using version A a chance to demonstrate the ability to use cause and effect without the extra scaffolds.

6. Class Discussion and Progress Tracker Update

8 MIN

Materials: science notebook

Discuss the results of the experiment as a class. Refer to the class data table. Strawberries, like the egg cells and muscle cells, have genetic material inside. Students may have noticed other surprising things when conducting

the experiment, such as that genetic material is really long and there might seem like a lot of it inside an organism. Encourage students to think about what this might mean in terms of how many genes living things have inside of them.

Suggested prompts	Sample student responses
Looking at our compiled data table, what patterns do we see in our data?	*Strawberries have genetic material inside!* *The genetic material from strawberries looks the same as the material from egg cells and muscle cells.*
So what have we figured out about the question we had for this lesson?	*Plants do have genetic material in their cells, just like animals do.*
Think about the genetic material you pulled out. Did anything surprise you about the scale of the genetic material you extracted?	*It was surprisingly long for such a little fruit.* *There seemed to be quite a lot of it!*
(Hold up a group's genetic material spooled around the woodenskewer.)	*It's a physical thing! Like we can really see it now with our eyes.*
We read that the alcohol was supposed to help the genetic material clump together to make it visible. So if it was clumped up when we pulled it out, how long do you think it would be not clumped together?	*I don't know!* *Maybe one foot?*

Project **slide Q**. Share the information on the slide with students, then ask the question on the slide.

Suggested prompt	Sample student responses	Follow-up question
Why do you think our genetic material is so long?	*I don't really know.* *Maybe we need a lot of genes?* *Do all genes make proteins like myostatin?*	*Humans have 20,000 to 25,000 genes!* *

Update the Progress Tracker individually. Project **slide R**. Have students individually record in a two-column Progress Tracker what they figured out. A sample of what students might say is shown here.



*** Supporting Students in Developing and Using Scale, Proportion, and Quantity**

Students are using the CCC of scale, proportion, and quantity to think about how genetic material is both very small yet also very long! The facts given to the students about the human genome to support thinking about how much genetic material there is are not central to understanding the DCIs. However, this may help prepare students to generalize about the amount of genetic material in future lessons. If students have a concept of just how much genetic material is in humans, they might start wondering how many genes there are, and how those genes within any organism work. Do all of the genes work like the gene for myostatin? What are all those genes doing?

Question	What I figured out in words and/or pictures
Do plant cells have genetic material like animal cells do?	• We can isolate genetic material from cells using a procedure that breaks cell membranes. • Genetic material is so small we can't see it from only a single cell. • Since there are so many cells in a small sample of muscle tissue and each cell has a lot of genetic material, enough genetic material can be extracted out of the cells of the sample to see it. • We can follow the same procedure to get the same material out of plant cells, which means plant cells must also have genetic material.

Assessment Opportunity

Building towards: 12.A.3 Plan and carry out an investigation to produce data to serve as the basis for evidence that plants have genetic material inside their cells that can be visualized (scale).

What to look for: Students should populate their Progress Tracker with ideas that demonstrate that evidence collected during the investigation supports the claim that genetic material is also found in plant cells. While every cell has genetic material, cells are very small, so to visualize the genetic material we need to extract it from many cells and separate the genetic material from the other cell parts.

What to do: Hold up the genetic material that a group collected to help students connect that this stuff we pulled out is a physical, 3-D structure that we can see without a microscope. One feature about its structure is that it's really long! So when it clumps together we can see it with our eyes. You can pull up **slide F** to remind students of the function of the alcohol in the protocol with regard to the clumping.

7. Discuss next steps.

2 MIN

Materials: None

Navigate to the next lesson. Project **slide S**. Summarize what the class figured out today, then ask the question on the slide. Say, *We just figured out plants have genetic material in their cells just like animals do. Do you think they also pass on the genetic material to their offspring the same way that animals do? What could we do to find out?*

Turn and talk to a partner about plant reproduction. Give students a minute to talk with a partner about the slide questions. If there is time, you can have a few students share their responses with the class. Otherwise, tell students you can pick up here next time to further explore how plants reproduce.

LESSON 13

How do plants reproduce?

Previous Lesson

We planned an investigation to break open plant cells from strawberries to see if we could isolate genetic material. Then we carried out our investigations and discussed the results as a class.

This Lesson

Investigation

2 DAYS





We identify flowers as being involved in reproduction in plants. We then investigate the structures of flowers and determine that their functions are similar to reproductive structures in humans. We obtain information from observing video footage of flowers and pollinators, prompting us to share ideas about how the structures of flowers can interact specifically with different pollinators. Revisiting the trait variations in tulips that we saw in Lesson 1, we read text and watch videos to learn about how farmers breed and propagate tulips. We realize that tulips and other plants can reproduce both sexually and asexually and wonder whether other organisms can reproduce asexually.

Next Lesson

We will do research about an organism that uses asexual reproduction and will share what we learn. We will discuss how the genetic information of offspring from asexual reproduction compares to that of the parent. Then, we will observe a video of planarian regeneration and discover that the resulting planaria don't look identical. We will wonder what could cause these planaria to look different.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5



What Students Will Do

13.A Construct an explanation, using a representation of plant reproductive parts, for how these specialized structures support sexual and asexual reproduction in plants (function).

What Students Will Figure Out

- Flowers have structures that support plants reproducing sexually, including structures equivalent to sperm and egg cells.
- Some structures of the flowers (and/or seeds) increase the chances of the plant's reproduction by attracting and using animals.
- Sexual reproduction in plants results in genetic variation that people can take advantage of to selectively breed for desirable trait variations.
- Some plants can also reproduce asexually (on their own or with human assistance), resulting in offspring with the identical phenotype as their parents.

Lesson 13 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	8 min	**NAVIGATION** Activate student prior knowledge about how seeds are involved in plant reproduction.	A-D	Navigation with Lima Beans
2	5 min	**INVESTIGATE HOW SEEDS ARE MADE** Observe fruits and videos of fruit formation to connect that seeds are produced in fruits that seem to be produced near or by flowers.	E-F	2 bell peppers, 2 apples, several pea pods, several strawberries, 8.5 Lesson 13 Bell Pepper timelapse (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), projector and speakers for playing video
3	22 min	**DISSECT A FLOWER** Identify flower structures and their functions, making comparisons with what students know about structures and functions involved in human or cattle reproduction.	G-K	*Flower Diagram*, Flower Dissection
4	10 min	**LEAD A BUILDING UNDERSTANDINGS DISCUSSION ABOUT REPRODUCTION IN FLOWERS** Facilitate a Building Understandings Discussion to summarize key ideas about the flower structures plants use to reproduce.	L-M	8.5 Lesson 13 Bell Pepper timelapse (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
				End of day 1
5	8 min	**INVESTIGATE PLANT STRUCTURES THAT INTERACT WITH ANIMALS** Watch a video showing multiple flower types with different kinds of pollinators and describe how the plants and animals interact to promote plant reproduction.	N-O	projector and speakers for playing video, 8.5 Lesson 13 Bee on Sunflower video, 8.5 Lesson 13 Pollinators video, This Bee Gets Punched by Flowers For Your Ice Cream | Deep Look video (optional), This Vibrating Bumblebee Unlocks a Flower's Hidden Treasure | Deep Look video (optional) (See the **Online Resources Guide** for a link to these items. **www.coreknowledge.org/cksci-online-resources**)

Part	Duration	Summary	Slide	Materials
6	25 min	**INVESTIGATE ARTIFICIAL SELECTION IN PLANTS** Hear from farmers who breed plants for selected-for trait variations and then reproduce the plants by asexual means.	P-S	*Reading: How do we get new tulip variations?*, *Breeding Tulips*, 8.5 Lesson 13 Hand Pollination of Strawberries video, 8.5 Lesson 13 Interview with Strawberry Farmer video (See the **Online Resources Guide** for a link to these items. **www.coreknowledge.org/cksci-online-resources**), 1 half-sheet of copy paper for the Word Wall, projector and speakers for playing video
7	10 min	**EXPLAIN HOW PLANTS REPRODUCE** Share understandings about the ways plants reproduce and give and receive feedback on that explanation. Complete an exit ticket explaining their understanding of plant reproduction.	T-V	*Flower Diagram*, *Exit Ticket*, *Peer Feedback Guidelines* (optional)
8	2 min	**NAVIGATION** Ask questions about other organisms and how they reproduce.	W	sticky notes
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 13, students are ready to read Student Reader Collection 4 and then respond to the writing exercise.		Student Reader Collection 4: *Plants and Variation*

Lesson 13 • Materials List

	per student	per group	per class
Navigation with Lima Beans materials	• 1 lima bean • 1 paper towel • safety glasses with side shields or safety goggles • vinyl or nitrile gloves • nonlatex apron		
Flower Dissection materials	• safety glasses with side shields or safety goggles • vinyl or nitrile gloves • nonlatex apron	• 1 paper towel • 1 flower bloom • tweezers • scissors • 8.5″ x 11″ paper • transparent tape or glue stick • ink pen or fine tip marker	• *Guidance for Flower Dissection*
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Flower Diagram* • *Reading: How do we get new tulip variations?* • *Breeding Tulips* • *Exit Ticket* • *Peer Feedback Guidelines* (optional)		• 2 bell peppers • 2 apples • several pea pods • several strawberries • projector and speakers for playing videos • 8.5 Lesson 13 Bell Pepper timelapse video • 8.5 Lesson 13 Bee on Sunflower video • 8.5 Lesson 13 Pollinators video • This Bee Gets Punched by Flowers For Your Ice Cream | Deep Look video (optional) • This Vibrating Bumblebee Unlocks a Flower's Hidden Treasure | Deep Look video (optional) • 8.5 Lesson 13 Hand Pollination of Strawberries video • 8.5 Lesson 13 Interview with Strawberry Farmer video (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**) • 1 half-sheet of copy paper for the Word Wall • sticky notes

Materials preparation (25 minutes)

Online Resources



Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Materials to print:

- *Flower Diagram*, 1 copy per student
- *Reading: How do we get new tulip variations?*, 1 copy per student
- *Breeding Tulips*, 1 copy per student
- *Exit Ticket*, 1 copy per student

Test the projection of all videos. (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**):

- bell pepper time lapse video
- hand pollination of strawberries video
- interview with a strawberry farmer video

Test and decide if your students will watch the provided pollination videos (very brief bee on sunflower) and (variety of pollinators) or one or both of the recommended alternate pollination videos (alfalfa bees) and (vibrating bumblebee).

Have 1 half-sheet of copy paper ready to add "asexual reproduction" to the Word Wall. Do not post this word on the wall until after your class has developed a shared understanding of its meaning, which you will further develop in Lesson 14.

For day 1: Get 2 red or green bell peppers, 2 apples, several fresh pea pods, and several fresh strawberries from a grocery store or other source. Cut in half one of the peppers and one of the apples to show the seeds. Open one or two of the pea pods to show the seeds. Be prepared to show these to students.

Day 1: Navigation with Lima Beans

- **Group size:** 1
- **Setup:** Soak lima beans in tap water in the light for 24 hours before class. A sunny windowsill will work during the day. A desk lamp or grow light should be provided for the nighttime hours.
- **Notes for during the lab:** Pass out a paper towel to each student for easy clean up. This is a very brief encounter with a lima bean seed so that students can visualize the plant embryo inside the seed.
- **Safety:** Use safety glasses with side shields or safety goggles, vinyl or nitrile gloves, and a nonlatex apron during the setup, investigation, and cleanup of the activity. Never eat or taste any food items used in the lab. Wash your hands with soap and water immediately after completing the activity.
- **Disposal:** Soaked lima beans and dissected lima beans can be disposed of safely in the regular trash.
- **Storage:** Unsoaked lima beans can be stored dry for extended periods of time, but they should be disposed of after use or after soaking if they are not used.

Day 1: Flower Dissection

- **Group size:** 2
- **Setup:** Obtain alstroemeria, lilies, tulips, or similar flowers with open blooms. Be sure to have an inch or two of stem attached to the bottom of each flower.
  - Prepare these materials per group: 1 flower bloom, 8.5" x 11" paper (cardstock is preferable if it is available), glue stick or transparent tape, scissors, tweezers, 1 paper towel, ink pen or fine tip marker
- **Notes for during the lab:** See *Guidance for Flower Dissection*.
- **Safety:** Check for student allergies to flowers. Allergies that are not severe can usually be mitigated with face masks and gloves. Scissors and tweezers can be sharp and should be handled carefully. Use safety glasses with side shields or safety goggles, vinyl or nitrile gloves, and a nonlatex apron during the setup, investigation, and cleanup of this activity. Never eat or taste any flowers used in the lab. Wash your hands with soap and water immediately after completing the activity.
- **Disposal:** Flowers and flower dissections attached to paper can be safely disposed of in the regular trash after the end of the lesson as students may want to refer to them at the end of day 2.
- **Storage:** Flowers can be maintained with their stems in water for several days before use.

Lesson 13 • Where We Are Going and NOT Going

Where We Are Going

In previous lessons, students figured out how chromosomes in egg and sperm combine to provide the genotype of offspring in cattle and how the proportions of offspring with certain genotypes can be predicted if the genotypes of the parents are known. As we began to investigate the reproduction of organisms very different from cattle, we figured out that plant cells have the same kind of genetic material as animals do and wondered whether plants could reproduce using egg and sperm. An investigation of the structures of flowers and a comparison of the functions of these structures with the function of reproductive structures in humans (and cattle) leads us to conclude that plants can reproduce sexually in a very similar process to what happens in animals.

When identifying plant structures, students may recall the functions of leaves from *Unit 7.4: Where does food come from, and where does it go next? (Maple Syrup Unit)*. If they have not already experienced this unit, students will still be able to make sense of the flower structures used in reproduction.

Students should know from second grade that there are some differences in plants in that they often need the assistance of animal pollinators to be able to reproduce. In this lesson we explore the ways that some of their reproductive structures (especially flower petals) have characteristics that specifically support that important plant-animal interaction. In addition, plants differ from most animals in that many are able to reproduce without the combination of male and female sex cells using an asexual reproduction process.

The variations that students work with on the *Breeding Tulips* handout represent a pattern of genes and alleles that was invented to serve as an opportunity to apply the same strategies they developed to explain probabilities in cattle inheritance patterns (probability calculations or Punnett squares). This exercise will allow students to see the potential complexity of inheritance patterns with a multiple-allele gene.

Where We Are NOT Going

In this lesson, students will be looking for egg and sperm equivalents in the structures that exist in flowers. Students will identify pollen as equivalent to sperm and ovules as equivalent to eggs. In reality, pollen is a more-complex structure which includes male sex cells, and an ovule is a cellular structure that is less complex than a mammalian egg. However, we want students to be investigating the functional equivalencies, not the specific structural equivalencies between flowers and mammals, so we will not learn about the specifics of the structures of pollen and ovules, nor how those compare specifically with sperm and egg.

We will not be memorizing the names of the structures or parts of plants or flowers. They will be referred to by name only when students have access to a labeled diagram showing what they are and what their function is.

In this lesson, we do not take the time to explore the specifics or consequences of self-fertilization in plants, which is a form of sexual reproduction, nor do we distinguish it from cross-fertilization. We will, however, identify that plants can reproduce in some ways that do not involve the combination of male and female sex cells, such as by forming bulb offshoots (tulips) or runners (strawberries). This can be noted and labeled as "asexual reproduction" in this lesson, but any details about the concept of asexual reproduction, or how to define it specifically, will not be investigated until Lesson 14.

LEARNING PLAN FOR LESSON 13

1. Navigation

8 MIN

Materials: Navigation with Lima Beans, science notebook

Review our questions from the last lesson. Display **slide A**. Briefly review what we figured out in our last lesson. Ask, *What were we left wondering about?* Listen for student responses:

- We wondered whether plants have eggs and sperm like animals do.
- We wondered how plants reproduce.

Record the lesson question. Display **slide B**. Have students start a page in their science notebook with the date and the lesson number and record a lesson question in their own words that is similar to "How do plants reproduce?" or "Do plants have eggs and sperm?" This is the question we will figure out the answer to in this lesson.

Surface prior knowledge about plant offspring.* Display **slide C**. Say, *If we want to understand how plants reproduce, let's start at the beginning. How do plants reproduce? What is a plant's offspring?* Have students turn and talk with a partner to share what they know, then share with the class.

Suggested prompt	Sample student responses
What is a plant's offspring?	*New baby plants that grow!* *Their offspring are sprouts or seedlings.* *Plant offspring are seeds.* *I don't know.*

Observe a plant baby inside a seed. Display **slide D**. Pass out to each student one of the lima bean seeds that you have soaked for 24 hours in the light (along with a paper towel for easy cleanup).

Ask them to take off the outer covering, or seed coat, of the seed, then try to gently separate the two halves of the seed half and look at what is between the halves. Many, though likely not all the seeds, will show what looks like a tiny plant with leaf-like parts and stem or root-like parts.

Ask students whether they are convinced by this observation that the seed is where the baby plant comes from. On the basis of their prior knowledge and/or their observations of the seeds, they should say yes.

*** Attending to Equity**

Students may come to the classroom with a wide variety of familiarity with plant life cycles and growth or reproduction. These differences may arise due to differences in the way plant life cycles were (or were not) taught in grades 2-5 or differences in experience with plants outside the classroom.

Depending on the background knowledge of your students, you may be able to move quickly through this section of the lesson. However, it is important that every student has access to the same set of phenomena to reference in the classroom so that every student can participate in figuring out and meaning making. For that reason, even if most of your students are familiar with much of the material in this and the following two activities, take the time to show them the physical demonstrations of the seeds, embryos, fruits, vegetables, and flowers, as well as the video. This will provide a set of references that are common to every student in the classroom as you move through the rest of the lesson.

2. Investigate how seeds are made.

5 MIN

Materials: 2 bell peppers, 2 apples, several pea pods, several strawberries, 8.5 Lesson 13 Bell Pepper timelapse (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), projector and speakers for playing video

Reason using what we already know about plant reproduction. Display **slide E**. Say, *We're trying to figure out how plants reproduce. And, if we know the seed is where the plant offspring comes from, how does the plant produce the seeds?* Again, depending on how much prior knowledge your students have they may know that seeds are produced near or by the flowers after flowers are pollinated, or they may only know that seeds come from plants.

To orient them to where the seeds are found on some plants, allow students to walk past or pass around the bell peppers, apples, pea pods, and strawberries that you have prepared and point out where the seeds are located. You may want to tell them that scientists call all these seed-bearing structures "fruits" even though we usually think of some of them as vegetables. Ask if anyone has seen any of these structures on plants. Suggest that there are a lot of videos about how these structures are produced on plants and show the timelapse of a bell pepper growing at 8.5 Lesson 13 Bell Pepper timelapse (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Additional Guidance

This video (3 minutes long) shows a pepper plant growing from seed through flowering and fruit production. If your students are familiar with how plants grow in general, you may want to skip some of the earlier parts of the video, especially those that don't show flowers giving rise to fruiting bodies. At a minimum, show the last section (from about 1:30) to give all students access to the idea that the structures that contain seeds arise nearby or from flowers.

Have students identify how the plant produces seeds. Display **slide F**. Have students turn and talk with an elbow partner to share their observations about how plants make seeds. Then engage them with the prompt below.

Suggested prompt	Sample student responses
How do plants make seeds?	*It has something to do with fruits because the fruits have the seeds inside.* *The peppers look like they grow out of the flowers after the flowers die.* *The flowers seem to be involved somehow in the seeds being produced.*

Identify what part of the plant to investigate to find out about reproduction. Ask, *If we're trying to figure out how plant reproduction works or whether plants have sperm and eggs, what part of the plant should we investigate more closely?*

Students should recognize that we need to understand more about what goes on with flowers.

3. Dissect a flower.

22 MIN

Materials: Flower Dissection, science notebook, *Flower Diagram*

Examine the structures of a flower. Display **slide G**. Assign students to pairs and distribute lab materials to each pair. Distribute one alstroemeria (or other) flower blossom to each pair of students. Be sure there is a couple of inches of stem attached to the bottom of each flower.

Have pairs look carefully at the structures of their flower without taking anything apart yet and consider the questions on the slide (also listed below). Students should come up with some ideas or questions about what the reproductive function of the different structures might be. They can record their initial observations and their questions in their science notebook.

- How would you describe the structures you see?
- What do you think is the function of those structures?
- Which of the structures do you think have to do with reproduction?
- What questions do you have?

Examine a diagram of flower structures. Display **slide H**. Distribute a *Flower Diagram* to each student. Have students examine the structures that are labeled on the flower diagram and ask them if they think these structures might have something to do with reproduction. Students should note that "reproductive cells" are called out in the labeling of the diagram.

Alternate Activity

If time is short, the primary goals of this activity can be achieved without doing the flower dissection: skip the "Dissect a flower" step that follows and have each student examine and annotate the *Flower Diagram* as described in the "Label the flower structures with human equivalents" step in this activity.

That said, students' understanding of the structure-function relationship of flower parts with the process of sexual reproduction will be significantly enhanced if they observe the characteristics of the three-dimensional structures of the flower themselves in the dissection. The stickiness of the stigma, the color of the pollen, the odor of the petals, the juxtaposition of the style and the stamens, and the similarity of the appearance of the inside of the ovary with the inside of a fruit are observable only in the dissection. The dissection is also an opportunity for students with greater facility with manual tasks to demonstrate those skills.

Remind students about prior knowledge regarding sexual reproduction. Display **slide I**. Remind students that they probably know a great deal about sexual reproduction because of what they've learned in health class or sexual education classes in school.

This can be a sensitive topic to discuss. As we consider whether plants reproduce sexually, use the material on the slide to remind students that we are investigating a biological process as scientists, and they should use scientific vocabulary and information appropriate to discussing that scientific process.

*** Supporting Students in Developing and Using Structure and Function**

Whether students did the dissection or not, probe their thinking about the human equivalents of the structures they are labeling. The similarities in functions of flower parts listed on the *Flower Diagram* and the functions of human (or cattle) parts that they are familiar with should serve as the link between the structures. Have them articulate what the equivalent functions would be. Ask them to consider what process they think would be necessary to happen in a flower in order for the flower to reproduce and form seeds.

Ask students to share with the class how we have described the process of reproduction that we've been studying in cattle. Be sure to surface the idea that sperm and egg combine and the combined cell becomes the baby, and the idea that the question we are investigating is whether plants undergo a similar process.

Key Ideas

Previously in Lesson 5 and Lesson 8, students have referred to the basic process of sexual reproduction in cattle as a sperm and egg combining to form a single cell that then grows and splits to make all the cells in the baby calf. This idea is critical to the activity that follows.

They may have additional information about gonads, gametes, or other sexual organs and structures. They may also be familiar with other academic information from science or health classes about the process of human sexual reproduction. Their knowledge about these details of structure and function in humans or animals will add depth to their understanding of plant sexual reproduction, but it is not necessary for students to complete the activity that follows. Any referencing of nonacademic information about human sexual reproduction should be avoided.

Additional Guidance

Having students discuss and reference their knowledge of sexual reproduction in humans as part of a scientific investigation can be challenging. Refer students to the term "sexual reproduction" on the Word Wall. Keep the focus of any discussion on using what we know from our academic learning to move our science thinking forward. We will be using information we know about sexual reproductive structures and their functions in humans specifically as a way to help us understand what is happening with flower structures. Insisting that students stick to scientific terms for structures and their functions as they talk with you and with their partners will help keep their attention on the process they are trying to understand in plants.

Dissect a flower. Display **slide J**. See the teacher reference *Guidance for Flower Dissection* for helpful information about the dissection and labeling.

Have students work in their pairs to locate on their flower each of the labeled structures from the *Flower Diagram*. They will need to slowly separate, or dissect, the various structures from each other in order to locate all of them. Students may want to use scissors to cut the ovary tissue apart to observe the ovules.

When they have found all the structures that are labeled in the diagram, have them arrange the structures on their 8.5" x 11" sheet of paper and attach them with tape or glue, similar to what is shown in *Guidance for Flower Dissection*.

Label the flower structures with their human equivalents.* Students should then label the arranged flower structures on their paper by referring to the names of the structures shown on *Flower Diagram*.

Display **slide K**. For each labeled flower structure on the paper (or for each labeled structure on their copy of *Flower Diagram* if they did not do the dissection), students should then also add labels of the names of what they think are the most equivalent parts in humans (or cattle). See *Guidance for Flower Dissection* for examples of potential student labels and bear in mind that it is most important for students to equate the functions of

- pollen with sperm and
- ovules with eggs.

Once they have finished labeling, ask students to think carefully about how fertilization could actually, physically take place in flowers.

As they work, circulate among them to help with identifications in the dissection and probe their thinking about the reproductive process in plants.

Remind students to put their names on their dissection paper. Gently stack them and keep them in the classroom for day 2, when students may want to refer to them again.

4. Lead a Building Understandings Discussion about reproduction in flowers. 10 MIN

Materials: science notebook, 8.5 Lesson 13 Bell Pepper timelapse (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Summarize the process of reproduction in flowers. Display **slide L**. Facilitate a Building Understandings Discussion to confirm details of the process of reproduction in flowers.

Key Ideas

Purpose of this discussion: Discuss flower structures and their functions, and identify plant reproduction that uses flowers as sexual reproduction.

Listen for these ideas:

- Pollen (sperm equivalent) needs to get to the ovules (egg equivalent) in order for them to combine.
- This process in flowers is sexual reproduction.
- Depending on the details of their knowledge about human (and/or cattle) reproduction, students may be able to add details regarding other functional equivalencies in the process such as how the pollen gets to the ovule (through the vagina and fallopian tubes in cattle; through the style in flowers).

Use the prompts below to help students articulate the steps in the process of reproduction in a flower.

Suggested prompts	Sample student responses
How do you think the pollen could get to the ovules?	*The pollen has to travel from the anther over to the female part of the flower (the pistil) to get to the ovules.*
What could move the pollen from the anther to the stigma?	*Maybe the filament bends over to the stigma and leaves pollen there. Or maybe something else moves it from the anther to the stigma.* *In second grade we learned that insects pollinate flowers.* *Also, I know pollen blows around in the summer and makes me allergic, so maybe the wind could move it.*

Suggested prompts	Sample student responses
How would it get down to where the ovules are? How would the pollen get from the stigma to the ovules?	*It would have to somehow move down through the style to get to the ovule in the ovary.*
Is that similar to anything that happens in cattle or human reproduction?	*Yes, sperm moves through the vagina into the uterus to get to the egg.*
What do you think happens once the pollen reaches the ovule?	*They probably combine similarly to what happens with sperm and egg, and they make a baby plant, which is a seed.*
We saw seeds inside peppers and apples and pea pods. What part of the flower do you think those are?	*Maybe the bottom part of the flower where the ovules are gets bigger and turns into the pepper or the apple, like when a female's uterus grows to hold the growing baby inside.*
This is very similar to what happens with cattle or humans. Would it be accurate to say that plants undergo sexual reproduction, too?	*Yes. It's basically the same thing.*

Additional Guidance

You may want to update your Word Wall definition of *sexual reproduction* to add "pollen" as a sperm equivalent and "ovules" as an egg equivalent in plants.

Additional Guidance

You may want to replay the video 8.5 Lesson 13 Bell Pepper timelapse to help students visualize what happens as these structures form. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) These fruiting bodies (the peppers, apples, pea pods, and strawberries, as well as other fruits on other plants) are actually the developed (matured) ovaries of the flowers that contain the fertilized ovules which become seeds.

Update Progress Trackers. Display **slide M**. Have students turn to the Progress Tracker section in their science notebook. Remind them we've figured out a lot about how plants reproduce and how similar it is to how humans and animals reproduce. Have them record their thinking in a Progress Tracker entry.

Home Learning Opportunity

If there is not sufficient time to complete the Progress Tracker during class, students can fill in their Progress Tracker as home learning.



End of day 1

5. Investigate plant structures that interact with animals.

8 MIN

Materials: projector and speakers for playing video, 8.5 Lesson 13 Bee on Sunflower video, 8.5 Lesson 13 Pollinators video, This Bee Gets Punched by Flowers For Your Ice Cream | Deep Look video, This Vibrating Bumblebee Unlocks a Flower's Hidden Treasure | Deep Look video (optional) (See the **Online Resources Guide** for a link to these items. **www.coreknowledge.org/cksci-online-resources**)

Facilitate a discussion about the plant structures not directly involved in reproduction. Display **slide N**. Use the prompts below.

Suggested prompts	Sample student responses
Who can remind us of the process of sexual reproduction in plants that we described last time?	*The pollen which is like the sperm travels from the anthers on the stamen to the stigma on the pistil and travels down the style to the ovaries where it fertilizes the ovules, and they go on to develop into seeds. The ovary grows into a big fruit containing the seeds.*
Which of the plant structures are not directly involved in that reproductive process?	*the sepals and petals* *The stem and leaves of plants are not directly involved in reproduction either.*
Did anyone have ideas about the functions of those structures?	*The sepals (and stem) could support the flower, keep it upright, kind of like a human's body.* *I know from the Maple Syrup Unit that leaves take in energy from light for photosynthesis. The leaves have chloroplasts to do photosynthesis, and they have little holes to let oxygen in and carbon dioxide out.* *The petals … they're bright and colorful. They might help the flower attract pollinators to move the pollen.*
What could the structure of the petals have to do with attracting pollinators?	*Maybe pollinators like the colors or the smell of the petals.* *Maybe the shape somehow fits the pollinators or helps them get into the flower to get the pollen?*

*** Supporting Students in Developing and Using Structure and Function**

By articulating ways that flower shapes and colors might affect interactions with pollinators, students are in fact describing how the functioning of the complex biological system of pollination relies on an interaction of flower structures with animal structures and behaviors. As they share their ideas, emphasize comments that include explicit structure-function interaction, such as the shape of the flower or the insect (or both together) resulting in pollinators getting pollen on their bodies or the size or shape of the flower allowing access to certain types of pollinators.

Additional Guidance

If students struggle to identify pollinators as being necessary for plant reproduction, refer them to experiences with plants from earlier grades. The identification of animals as pollinators and seed dispersers is a second grade standard. What we are adding here is the middle school DCI element that some of the ways plants reproduce depend on animal behavior and specialized features.

Watch a video showing a bee covered with pollen. Continue to display **slide N**. Have students create a Notice and Wonder chart in their science notebook. Ask them to watch for how different pollinators interact with flowers as you show a couple of videos.

Play the short video *Bee on Sunflower* (See the **Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) and ask students to describe how they think what they're seeing may be involved in plant reproduction. They should notice that the bee is covered in pollen and would carry that pollen to the next flower or that the pollen will get moved to the female parts of the flower by the bee.

Watch a video showing different petal types and different pollinators. Remind students to watch for how different pollinators interact with the flowers and continue to add to the Notice and Wonder chart in their notebook. Play the pollinators video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) through once and allow students to record their noticings and wonderings.

Have students share a few of the things they noticed or wondered about.* Then play the pollinators video through a second time with the sound turned off. As the video plays, talk over the pictures to point out the structures that they've identified, especially the anthers and pollen and the stigma where it is visible. You may want to pause the video to allow students to identify the male and female parts of the flowers.

Also, draw students' attention to what there might be about the shape or the color of the flower petals that could attract the pollinators to the flowers or that could help the pollinators move the pollen from one flower to another. You might also tell students that, while we didn't see this with our flowers, many flowers have a sweet nectar inside that is food for some pollinators.

Some examples of things students might notice

- The flowers have a lot of different colors and shapes; maybe some insects prefer particular colors or shapes. It seems like certain flowers have only the same kinds of insects on them.
- That tiny, bee-like insect is on those tiny, blue flowers, while the bigger butterfly is on bigger flowers.
- The hummingbird has a long beak, and the flowers are long and thin, too. And the bird moves from flower to flower quickly.
- The bees have to stick their heads way inside those cup-shaped flowers, so they'll get pollen all over them and they can carry it to the next flower.
- Moving the pollen to the stigma of the same or different flowers will allow the plants to reproduce, which they couldn't do if the pollen didn't get to the stigma.

It is important that students make a connection between the structure of specific petals, or of the rest of the flower, and the process of reproduction by pollination. If they are not making these connections, ask them to focus on how the petals or flower and the pollinator interact and probe with additional questions.

Additional Guidance

You might also remind students that they have learned how animals help plants disperse their seeds. Draw their attention to the pepper, apple, pea pod, and strawberry that they looked at earlier. These are all different fruiting bodies of plants. The apple and strawberry are juicy and sweet, which makes them delicious for animals to eat. The protective seed coat on the outside of the seeds allows them to pass through the digestive tract of many animals and get eliminated (pooped) out of their bodies at a distance from the parent plant, which enhances their ability to survive and grow. A quick internet search of "how animals disperse seeds" will pull up a number of interesting videos, if you and your students would like to see specific examples.

Alternate Activity

The provided pollination videos (very brief bee on sunflower) and (variety of pollinators) show a few examples of the interactions between pollinators and flowers. We recommend showing one or both of the videos linked below instead of or in addition to the videos included above to give your students specific examples of very specialized bee-flower structure interactions.

- This Bee Gets Punched by Flowers For Your Ice Cream | Deep Look (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
- This Vibrating Bumblebee Unlocks a Flower's Hidden Treasure | Deep Look (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Revisit the tulip varieties we saw in the anchor lesson. Display **slide O**. Remind students about the varieties of tulip petals they saw in the anchor lesson. Have students turn and talk for a minute about how we could have gotten all these tulip variations, then share some of their ideas with the class. Use the prompts below.

Suggested prompts	Sample student responses
Since we know that plants use flowers to reproduce in a way that is very similar to the way cattle reproduce, how do you think we got all these different kinds of petals on the tulips people can buy?	*The different variations in the traits were inherited from their parents.* *The combination of the parents' genotypes resulted in the offsprings' phenotypes for petals.*
What are you wondering about those tulip varieties then?	*Did this happen in nature, or did farmers breed these flowers with certain trait variations so they could sell them?* *We know farmers breed cattle. Do they breed plants, too?* *Do they breed tulips? How would they do that?*

Emphasize these questions to motivate the next activity.

6. Investigate article selection in plants.

25 MIN

Materials: *Reading: How do we get new tulip variations?*, *Breeding Tulips*, 8.5 Lesson 13 Hand Pollination of Strawberries video, 8.5 Lesson 13 Interview with Strawberry Farmer video (See the **Online Resources Guide** for a link to these items. **www.coreknowledge.org/cksci-online-resources**), 1 half-sheet of copy paper for the Word Wall, projector and speakers for playing video

Read about tulip breeding. Distribute *Reading: How do we get new tulip variations?*.* Have students set a purpose for reading the article (to answer their question about whether and how farmers breed plants or tulips) and write it at the top of the handout. Then allow them time to read.

Once they are finished reading, have them turn and talk with a partner to communicate the information they obtained from the reading.

Ask students to share questions they had from the tulip reading.

Sample student responses

- How do the tulip breeders mate or cross only the flowers they want to try breeding together?
- How do they control which pollen goes to which ovules? They can't just trust pollinators or wind to mix the ones they want, right?
- What's going on with those bulb offshoots? Are they offspring? But their flowers are exactly the same as the first one? That's not sexual reproduction … but what is it, then?

Consider a process for artificially pollinating plants. Say, *OK, so we're wondering how exactly people can be sure they breed the right parent plants together. I have a video we can watch to see more about that. And we'll think more about those offshoots next.*

Show the strawberry pollination video. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Have students share what they notice. Listen for the following comments:

- The flowers have stamens with pollen, and they seem to have a lot of stigmas in the middle. (Validate this observation as being correct. You may want to stop the video and point out the multiple stigmas in the center of the strawberry flower.)
- These are strawberries, not tulips!
- They can take the pollen from one parent plant and transfer it to the other parent plant, so it's kind of like mating.

Ask students if they think the same process could be done with tulips. They should recognize that because tulip flowers have the same structures as strawberry flowers, this process might be a little different but could work with tulips as well.

Highlight similarities between plant breeding and animal breeding. Display **slide Q**. Ask students if this way of mating plants reminds them of anything that breeders did with cattle they wanted to cross. They should recognize that artificial pollination of plants is much like artificial insemination in cattle.

*** Supporting Students in Engaging in Obtaining, Evaluating, and Communicating Information**

Students should obtain information from the text that is relevant to answering their questions using whatever reading strategies work best for them. Refer them to the checklist your class made in Lesson 3 or optional slide P only if needed. Once they have obtained the information from the text, sharing what they learned verbally with a partner will allow them to practice communicating information they have obtained. Even though this is done informally here, the practice of articulating their understanding is an important part of this practice.

Suggested prompts	Sample student responses
How is this way of mating plants similar to what cattle farmers do to select for certain trait variations (like extra-big muscles)?	*They bred specific ones together.* *It's kind of like artificial insemination.*
Where do you think these different variations in the tulips came from in the first place?	*They're probably from different alleles.* *Different alleles originally come from mutations.*

Validate that artificial pollination and artificial insemination are basically using the same process of reproduction and passing on of alleles, it's just being done with different organisms. If necessary, remind students of other similarities between flower and cattle reproduction so the idea of their being an equivalent process is set firmly in their minds.

Compare offspring probabilities in animals and plants. Say, *So if plants and cattle (and humans) reproduce basically the same way, would we be able to predict what the genotypes and phenotypes of offspring plants would be?*

Suggested prompts	Sample student responses
Can our model of inheritance and variation of traits work to explain plant variation, too?	*We know plants have genetic material.* *We know plants reproduce sexually.* *That's just like cattle, so the model should work the same way.*
What strategies do we have to predict the outcome of offspring?	*We used probability calculations.* *We used Punnett squares.*
Can we use those same strategies to figure out about offspring in plants?	*It should work. Let's try it!*

Display **slide R**. Distribute the *Breeding Tulips* handout to each student. They can work individually or in pairs to use the probability calculations or Punnett square strategy developed in Lesson 8 to predict the genotypes of offspring and answer the questions.

Recall asexual propagation of plants. Have a few students share their answer to question 3 on *Breeding Tulips*: If the breeders did produce a new flower that they thought people would like, how would they be able to breed more of that particular variation of flower so they could sell them?

Some students may suggest that growers could just keep breeding the same parents and getting the type of offspring they wanted a certain percentage of the time. Say, *But according to our reading, that's not what they do. What do they do?*

Have students refer to the *Reading: How do we get new tulip variations?* reading if necessary. Then have one or more students summarize how tulip breeders produce the plants they want to produce. Listen for these ideas:

- They keep producing bulbs of the same plant.
- The plant can make new, little bulbs (offshoots) that are the same type of plant.

- There isn't any mating or pollination or even flowers involved.
- They take the bulb offshoots and grow new plants that turn out the same.

Investigate another example of plants reproducing without mating. Display **slide S**. Say, *We read about how tulip farmers are able to generate more tulip plants without using sperm and egg to get the phenotypes that they want to sell. And we saw how farmers pollinated strawberry plants by hand. Do you think farmers grow whole fields of strawberry plants by breeding and producing seeds? We have a video to watch of an interview with a farmer who grows a lot of strawberry plants on his farm.*

Show the video. (See the **Online Resources** Guide for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Alternate Activity

If you have a student who has particular experience or knowledge about ways some plants may reproduce asexually, you might choose to have them share their experience instead of or in addition to the interview with a strawberry farmer. Hearing about the experiences of their peers generally has a positive impact on students' learning. If you can cue students a couple of days ahead of time that they will be sharing information about this with the class, they may even want to bring in cuttings or parts of plants from home to share.

Some of your students may know about how to propagate plants without producing or planting seeds if they or others in their community propagate succulents or other houseplants (using cuttings), or if they garden various types of berries (cuttings or runners) or flowers (bulb offshoots), or if they farm or garden asexually reproduced crops like potatoes, bananas, or apple trees.

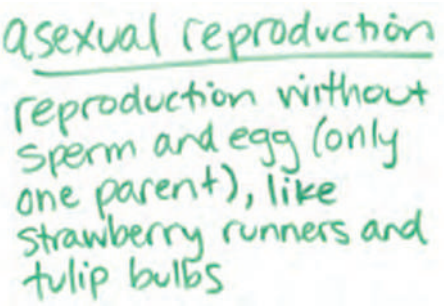
Articulate differences between sexual and asexual reproduction. Facilitate a discussion to articulate that plants can reproduce in ways (asexually) that cattle and humans cannot.

Suggested prompts	Sample student responses
Do plants reproduce sexually?	*Yes. Their flowers have male and female sex cells that combine and produce seeds.*
Is using bulb offshoots or runners or cuttings a way of reproducing?	*Well, it does make more plants.* *We can make more copies of the plants, or the plants can make more copies of themselves, so that must be reproducing.*
Can cattle or humans reproduce this way?	*No, you can't just cut off part of a cow and grow a new cow.* *Parts of us like hair and fingernails regrow after you cut them off, but you can't grow a whole new person from a part of a person.*

Suggested prompt	Sample student responses
What's different from sexual reproduction about this other way of reproducing that plants do?	*It doesn't involve sex cells or flowers.* *You just take a part of the plant and separate it and grow it separately. No egg and sperm or mating is involved.*

Introduce the term "asexual reproduction". Say, *It would be handy to have a quick way to refer to these two different types of reproduction. We know sexual reproduction involves sex cells combining in fertilization. The other way of reproducing does not involve sex cells, so it is refered to as* ***asexual reproduction*** *because adding the "a-" or "an-" as a prefix to the front of a word can be used to make it mean its opposite. Other examples are "symptomatic" and "asymptomatic", or "symmetrical" and "asymmetrical". Can you think of others?*

Add the term "asexual reproduction" to the Word Wall at this time, but it is not necessary to define it any more carefully at this point. Its meaning and distinction will be refined during Lesson 14, and more details can be added to the Word Wall at that time.



7. Explain how plants reproduce.

10 MIN

Materials: science notebook, *Flower Diagram*, *Exit Ticket*, *Peer Feedback Guidelines* (optional)

Prepare students to complete an exit ticket. Say, *This reminds me of the questions we had at the end of Lesson 11. We started out investigating plants because we thought they would be really different from cattle and that explaining their variations might not work using the same model we had for cattle variations. We weren't even sure if plants had genetic information! We have figured out a lot about plants and how they reproduce.*

Suggested prompts	Sample student responses
Would you say plants reproduce in the same way as cattle?	*Mostly. But there are some differences.* *Not exactly the same, but they're similar!*
What are major differences in how plants reproduce compared to cattle?	*Some plants need animals as pollinators to help them.* *Plants can reproduce asexually.*

Say, *Great. It seems like we can explain plant reproduction pretty well. We're going to do an exit ticket to summarize what we've learned about plant reproduction. But we're all in this together, so let's take a minute to share what we know with a couple of elbow partners before we get to doing the exit ticket.*

Formulate an explanation. Display **slide T**. Have students refer to the prompts on the slide, which are also listed below. Allow them to think quietly to themselves for a couple of minutes to come up with responses to the prompts. They can record notes in their science notebook, if they like.

1. What reproductive structures in plants have similar functions to structures in cattle (or humans)?
2. What is similar about their functions in plant reproduction and cattle reproduction?
3. What is similar about the process of reproduction in plants and cattle?
4. What is different about the process of reproduction in plants and cattle?

Additional Guidance

Students are not expected to remember the names of the flower structures that are involved in sexual reproduction. They should be encouraged to refer to their copy of *Flower Diagram* and/or their labeled flower dissection to help identify important structures. The only critical structures involved are the pollen/sperm and ovule/egg. The other structures support the transfer of the pollen to the ovule, sometimes interacting with pollinators.

Share, provide, and receive feedback on explanations. Display **slide U**. Tell students that in a moment, each of them will have an opportunity to be an "explainer" and share with a partner a verbal explanation of how plants reproduce. Everyone will also have a chance to be a "responder" and provide feedback on a different partner's explanation. *Peer Feedback Guidelines* is available to support students if that would be helpful to them.

Organize the class into "inside-outside circles" as described here:

- Students stand in two concentric circles of equal numbers of students with the inside ring facing the outside ring so each student is facing a partner.
- Designate the inside circle as "explainers" first. The outside circle of students will listen carefully and be "responders" to provide feedback after the explainer is finished.

After the first sets of student pairs have a chance to explain and respond, direct every student to take a step to their right (so the inside circle rotates clockwise and the outside circle rotates counterclockwise). Now that all students are facing a new partner repeat the exercise again, but this time, have the pairs switch roles. Direct the outside circle of students to be explainers and the inside circle of students to listen and respond.

Complete an exit ticket. Display **slide V**. Distribute an *Exit Ticket* to each student. Have students respond to the prompts on the exit ticket and turn it in.

Assessment Opportunity

Building towards: 13.A Construct an explanation, using a representation of plant reproductive parts, for how these specialized structures support sexual and asexual reproduction in plants (function).

What to look and listen for: As students are sharing, and giving and receiving feedback on, their explanations, listen for students to make connections between structures and their functions that support sexual reproduction in plants as well as share examples of plant structures involved in asexual reproduction. On the exit tickets that students turn in, look for what they label, draw, and write to explain the process of how plants reproduce, including

- the importance of flowers in reproduction,
- structures and functions of flower parts that indicate sexual reproduction is happening,
- the importance of animal interactions to support plant sexual reproduction,
- the fact that some plants also reproduce asexually, and
- humans may use both sexual and asexual reproduction in plants to obtain plants with desirable traits.

See details on the *Key for Exit Ticket*.

What to do: In conversations, if students struggle to make the structure-function connection for flower parts or to sequence the process in their explanations, remind them of what they may already know about human reproduction and what we have learned about cattle reproduction, specifically the importance of eggs and sperm in sexual reproduction.

8. Navigation

2 MIN

Materials: sticky notes

Summarize what we learned in this lesson. Display **slide W**. Say, *We figured out that plants reproduce sexually using the structures in flowers, sometimes with the help of different kinds of pollinators. And we figured out that plants can also reproduce asexually without sperm or egg involved at all. Can cattle reproduce asexually?* (No.) *What about the other organisms we looked at in Lesson 11?* (If the photo cards of planaria, flamingos, humans, and wheat are posted in your classroom, refer to them.)

Ask new questions. Allow students to share their thinking and wondering about the way other organisms might reproduce or what the offspring of asexual reproduction might be like. Do they always have the exact same phenotype as their parents? Have them add any burning questions to the Driving Question Board.

SCIENCE LITERACY: READING COLLECTION 4

Plants and Variation

1 **Flowering Plant Reproduction**
2 **Pollinating Meyer Lemon Trees**
3 **Trouble in the Banana Plantations**

Literacy Objectives

- ✓ Summarize key points related to plant reproduction.
- ✓ Distinguish cause(s) and effect(s) related to pollination, seed dispersal, and genetic diversity.
- ✓ Write a short summary for a particular audience.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 10–13.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a script for a television science show promo in response to the reading.

Instructional Resources

Student Reader



Collection 4

Science Literacy Student Reader, Collection 4
"Plants and Variation"

Exercise Page



EP 4

Science Literacy Exercise Page
EP 4

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 10: How can we use our model to explain a different trait variation?
- Lesson 11: How can we answer the rest of our questions?
- Lesson 12: Do plants have genetic material?
- Lesson 13: How do plants reproduce?

Standards and Dimensions

NGSS

Disciplinary Core Ideas:
LS1.B: Growth and Development of Organisms Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. (MS-LS1-4) Genetic factors as well as local conditions affect the growth of the adult plant. (MS-LS1-5)

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-LS3-2)

Science and Engineering Practices: Analyzing and Interpreting Data; Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Cause and Effect; Structure and Function

CCSS

English Language Arts

RST.6-8.5: Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

WHST.6-8.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

genetic diversity

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

asexual reproduction
pollination
sexual reproduction
trait variation

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

Exercise Page



EP 4

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Genetics unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
  - *First, you will read a photo essay about plant reproduction that includes interesting examples of adaptations for transferring pollen and dispersing seeds.*
  - *Second, you'll read simulated blog posts from a family that is experimenting with getting three indoor lemon trees to pollinate and produce fruit.*
  - *Lastly, you'll read the fictitious journal of a visitor to Central America who is learning that all is not well for banana farmers—and banana consumers.*
- Distribute Exercise Page 4. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to generate a script for a television promo that advertises a science show based on this collection.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
How do forest fires benefit some plants in reproducing?	*The heat of the fire opens pine cones, so the seeds can be released.*
Which of the three lemon trees in the experiment produced the greatest number of lemons?	*Tree B—the one that the teens helped to pollinate with small paint brushes*
Why are "Gros Michel" bananas no longer available?	*They were wiped out by a soil fungus.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
What evidence did you see or read that leads you to think that bee orchids, monkey flowers, and pine trees carry out sexual reproduction?	*They have structures and processes for pollination and that means they have to move male sex and female sex cells together to produce seeds.*
Where are the ovule/egg structures on a Meyer lemon tree?	*They are at the base of the style on the flowers.*
What trait variation are scientists trying to develop in banana plants?	*resistance to diseases*

- Refer students to the Exercise Page 4. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to develop a script to promote a television science segment based on one of the three selections in this collection.*
  - *Since the promo can only be 30 seconds long, you'll want to read it aloud, time yourself, and make edits as needed.*
  - *If your promo is going to appeal to other middle school students, you'll also need to think of an angle that will capture their attention. One way to do this is to ask questions of the audience, revealing intriguing details of the show.*
  - *Remember, you are selling a product that your audience is not sure it needs, so be engaging.*
  - *Pick a theme for your promo—it may be funny, mysterious, urgent, or serious.*
  - *The important criteria for your work are that the science you describe is accurate, that you engage your audience, and that when delivered, the promo will not exceed 30 seconds.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page



EP 4

4. Facilitate discussion.

(FRIDAY)

Facilitate class discussion about the reading collection and writing exercise. There are three readings in this collection, each very different in style. Students will have chosen one reading as the focus of their TV promo script and should be able to explain what in it appealed to them.

Pages 34–43 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "Flowering Plant Reproduction"?	*It describes adaptations of various kinds of plants for pollination and seed dispersal.*
How do the moth and hummingbird actually pollinate the plants?	*When the animal comes to sip the sweet nectar in the flower, it has to get close enough for its body parts to brush up against the male flower parts. Some pollen from those parts sticks to its body, and as it brushes up against other flowers, the pollen is transferred onto the female plant parts of the same plant or different plants.*
What variations in traits might the offspring dandelion plants have that the parent plant did not have?	*The offspring might be better able to survive in cold or hot weather or with less water or might produce seeds that can travel farther by wind.*
What features of this article make it appealing to promote as the topic of a science TV show?	*It describes some strange plant traits that the audience might find interesting.*
What is the general purpose of the second selection, "Pollinating Meyer Lemon Trees"? How are lemon flowers actually pollinated in nature?	*It is a science investigation report to share how a family experimented to find the best way to get indoor lemon trees to produce more fruit. In natural settings, lemon flowers are pollinated by bees.*
How does the second selection help you build knowledge on top of what you learned in the first selection?	*The first article reveals that wind is needed for pine trees to transfer pollen and then to make seeds. The second article details how it is likely that Meyer lemon trees use wind in the same way.*

Student Reader



Collection 4

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Online Resources



SUPPORT—Point out to students that the moth on page 34 is a hummingbird hawk moth. Have students search online videos of these moths so that they can observe how the insect interacts with flowers to assist in pollination. Point out to students that as the moth touches a flower, some of the pollen may adhere to its body parts. Then, when the moth visits another flower, the pollen may adhere to the female parts of the flower so that fertilization can take place.

Pages 34–43 Suggested prompts	Sample student responses
How did the subheadings in this selection add to your understanding?	*The dates in the subheadings showed how much time it took for the trees to produce fruit once they were pollinated. It also showed the seasons in which the family was trying to get the trees to produce fruit.*
Why did the teens measure the mass of the lemons as well as count them?	*If they want to make lemonade with them, heavier fruit may contain more juice than smaller fruit. So, mass matters.*
What was the average mass of a lemon from each tree, and why are those data significant?	*Tree A: 0.18 kg per lemon* *Tree B: 0.25 kg per lemon* *Tree C: 0.35 kg per lemon* *They're significant because more massive lemons are larger and probably have more juice than less massive lemons.*
Check out the Dig into Data box. What pattern can you find in the data when comparing the three trees, the number of fruits, and the fruits' mass?	*A tree without any outside means to move pollen makes much less fruit, and a tree that has a human pollinator has a greater number of fruits and greater mass of lemons than either wind or no pollinators.*
What features of this article make it appealing to promote as the topic of a science TV show?	*It provides practical information for people who want to grow Meyer lemon trees in their homes.*
What is the general purpose of the third article, "Trouble in the Banana Plantations"?	*It explains why bananas could be wiped out in a pandemic.*
Why do you think farmers and scientists would selectively breed to produce seedless bananas?	*because the seeds don't taste good* *because the seeds are hard to chew and swallow* *Maybe it was a side effect of breeding for large, sweet fruit.*
What is the conclusion of this journal entry? Does the author think people will have bananas to eat in the future? Explain your reasoning.	*The author sounds hopeful but not sure that scientists can come up with disease-resistant varieties.*
What features of this article make it appealing to promote as the topic of a science TV show?	*It explains many facts that most people don't know about how a favorite and delicious fruit is grown.*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 4, students should write a script for a 30-seond television promo for a science show based on one of the three selections in this collection. The word count should be about 70 words and the promo should be as engaging as possible to convince middle school students to watch the show.

For example, if students choose to write their script about a story based on the first selection, it might say something like, "Sometimes the plant and animal kingdoms are very confusing. Do you know there is a plant with flowers that look just like a bee, a moth that behaves just like a hummingbird, and a wildflower named for monkeys? See the wild and crazy ways plants transfer pollen so that they can produce seeds. Then see some unusual ways plants make sure their seeds are spread far and wide."

Use the rubric provided on the Exercise Page to supply feedback to each student.

LESSON 14

(How) do other organisms reproduce without sperm and eggs?

Previous Lesson

We investigated the structures of flowers and their similar functions to human reproductive structures. We observed video footage of flowers and pollinators and shared ideas about how the structures of flowers interact with pollinators. We read text and watched videos to learn about how farmers breed and propagate tulips with a lot of trait variations, and we discovered that some plants can reproduce both sexually and asexually.

This Lesson

Investigation

2 DAYS



We work in small groups to do research about an organism that uses asexual reproduction and then share what we learn with our classmates. We discuss how the genetic information of offspring from asexual reproduction compares to that of the parent. Then, we observe a video of planarian regeneration, and we discover that the resulting planaria don't look identical. We decide we need to figure out what could cause these planaria to look different.

Next Lesson

We will integrate information from images and text about how planaria color was affected by light exposure, and we will consider how environmental factors like light might influence other ranges of variation we've seen. We will obtain scientific information from texts about color variation in apples and flamingos and then use a model to explain the different environmental factors that cause the range of variation we see in apple and flamingo colors.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5

What Students Will Do

14.A Obtain, evaluate, and communicate information about how organisms reproduce asexually and transfer their genetic information to their offspring, which results in offspring with identical genetic information.

What Students Will Figure Out

- Several different methods of asexual reproduction all result in genetically identical offspring.

Lesson 14 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**NAVIGATION AND DIRECTIONS FOR RESEARCH** Plan to research and share, with teacher support, about organisms that reproduce asexually.	A-D	chart or slide from Lessons 3 and 6 listing strategies for evaluating text (optional)
2	35 min	**SMALL GROUP WORK TO OBTAIN INFORMATION AND PLAN COMMUNICATION** Work in small groups to do research about an organism that uses asexual reproduction and plan what they will share with their classmates about that organism.	E-G	computer with internet access, access to presentation software (such as Google Slides or MS PowerPoint), printer (if students need a physical copy of an article to annotate)
				End of day 1
3	20 min	**SHARE ABOUT ASEXUALLY REPRODUCING ORGANISMS** Present slides and take notes about how various organisms reproduce asexually.	H	*Asexual Reproduction Notes*, computer that has access to slide software and projector for presentation of slides
4	5 min	**SELF-ASSESS ABOUT OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION** Self-assess the obtaining and evaluation of information on their asexually reproducing organism and the presenting of their slide.	I	*Self-assessment for Obtaining, Evaluating, and Communicating Information*, transparent tape
5	8 min	**BUILDING UNDERSTANDINGS DISCUSSION ABOUT ASEXUAL REPRODUCTION** Identify in a whole-group discussion that when organisms reproduce asexually, the offspring have identical genetic information to the parent.	J	*Asexual Reproduction Notes*, chart paper or whiteboard, markers, 2 half-sheets of copy paper to update the Word Wall
6	3 min	**UPDATE PROGRESS TRACKER** Summarize today's learning by adding an entry to the Progress Trackers.	K	
7	6 min	**OBSERVE PLANARIAN REGENERATION VIDEO** Predict, based on what we know about asexual reproduction, how planaria will look after they have regenerated. Observe a video of live planaria and their regeneration.	L-N	Want a Whole New Body? Ask This Flatworm How | Deep Look video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Part	Duration	Summary	Slide	Materials
8	3 min	**Navigation** Revisit the planaria images we used in Lesson 11 and wonder what influenced their color variation.	N	

End of day 2

Lesson 14 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**  	• science notebook • computer with internet access • *Asexual Reproduction Notes* • *Self-assessment for Obtaining, Evaluating, and Communicating Information* • transparent tape	• access to presentation software (such as Google Slides or MS PowerPoint) • computer that has access to slide software and projector for presentation of slides	• chart or slide from Lessons 3 and 6 listing strategies for evaluating text (optional) • printer (if students need a physical copy of an article to annotate) • chart paper or whiteboard • markers • 2 half-sheets of copy paper to update the Word Wall • Want a Whole New Body? Ask This Flatworm How | Deep Look video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Materials preparation (30 minutes)

Online Resources



Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare the handouts:

- Make 1 copy of *Asexual Reproduction Notes* for each student.
- Make 1 copy of *Self-assessment for Obtaining, Evaluating, and Communicating Information* for each student and trim it to fit in the students' science notebook.

Plan for how students will share their slides about asexually reproducing organisms, either by attaching their computers to your projector or sharing their slide files with you to present. If students are unable to present by projecting slides, then prepare enough chart paper and markers for each group to use to present their findings to the class.

Be ready to print articles if students need a physical article to annotate and highlight as they read the text.

Have 2 half-sheets of copy paper ready to update your Word Wall definitions of *sexual reproduction* (from Lesson 5) and *asexual reproduction* (from Lesson 13).

Lesson 14 • Where We Are Going and NOT Going

Where We Are Going

This lesson gradually releases scaffolding around obtaining, evaluating and communicating information. As the complexity of the task increases it is important to scaffold other aspects of the task to allow for student success. Here the teacher directly leads the students to their purpose for reading scientific texts, while they need to identify and evaluate sources that would be appropriate so they can communicate these ideas back to the class. In Lesson 15, the class will work on a different aspect of this practice by co-constructing their purpose for reading. The organisms selected for research in this lesson were chosen in an attempt to include a variety of types of asexual reproduction without getting too complicated.

Where We Are NOT Going

This lesson does not expect students to go into detail about how organisms are able to make copies of themselves or their cells (mitosis, meiosis). The discussion about asexual reproduction will not get into its benefits or drawbacks, as that will be covered in *Unit 8.6: How could things living today be connected to the things that lived long ago? (Penguins Unit)*. Students are also not going to discuss the stem cells required by planaria and some other organisms for regeneration. Reproduction via spores was left out because internet searching yielded information that was well beyond the scope of eighth-grade boundaries.

LEARNING PLAN FOR LESSON 14

1. Navigation and Direction for Research

10 MIN

Materials: chart or slide from Lessons 3 and 6 listing strategies for evaluating text (optional)

Set a purpose for today's work. Display **slide A**.

Say, *In the previous lesson we observed that plants have similar structures as animals that function to support sexual reproduction. We also noticed that plants sometimes don't need these stuctures and can produce new plants through a process called asexual reproduction. We know that organisms like strawberries that can reproduce asexually have genetic material. But that left us wondering how asexual organisms pass on genetic information without using sperm and eggs (or pollen and ovules). So today, you're going to work in small groups to do a miniature research project about organisms that reproduce asexually. Your group will be responsible for obtaining information about how a certain asexual organism reproduces, and then you will communicate to the whole class what you've figured out. We have just today's class to do research, and next class each group will have only about two minutes to share, so it's going to be quick, but we'll learn a lot!*

Give specific directions for today's mini-research project. Display **slide B** (or refer to the slide or chart you created in Lesson 3 and used in Lesson 6) about strategies for making meaning from text and evaluating the text.

Say, *We have already had practice during this unit reading and gathering information from scientific text. You have also practiced evaluating sources to consider how reliable they are. For today's research, your group will have a specific organism to research, and you will have to find information online about how that organism reproduces. You will need to ask yourself questions to consider whether the sources you find are reliable. If they are, you will need to read the information in a way that helps you make sense of it. Usually we mark up the text to help us focus on our purpose for reading. How will you read closely and carefully on a screen? What tools or strategies can you use?*

Elicit suggestions such as attending to text features (headings, image captions, and so forth), highlighting the text on the screen to call attention to key details, taking notes on paper to remember main ideas, and so on.*

Safety Precautions



Be sure your students understand the school's policy for safe online searching. You might suggest that groups search the question "How do _____ reproduce?" which usually generates student-friendly results. Searching a specific species name often generates more high-level academic results, which are likely too complex for students to understand.

Say, *But you probably know that scientists don't just learn information and keep it to themselves. Science exploration and learning works because people share their ideas. So today we are going to gather the information so that next class we practice communicating science information with others.*

Display **slide C**. Discuss the questions listed on the slide.

***Attending to Equity**
Universal Design for Learning:
In addition to highlighting the text on the screen, consider providing students access to printouts of articles they find so that they can physically mark them up. Asking students to annotate the readings can help students manage information so that they can *express* their understanding. Different computers and browsers also offer accessibility tools that allow on-screen annotation, zoom capabilities, and text-to-voice read-aloud that supports students of differing abilities.

***Attending to Equity**
If needed, **slide O** is provided as a template that could be shared with students (all or a select few) to support them in including all the expected components.

Suggested prompts	Sample student responses
Who will be your audience for your presentation?	*Us! Our classmates, each other, the other groups.*
What is your purpose for sharing the information you learn?	*Well, each group is going to research a different organism, so we would learn about only one if we didn't share. We have to share so the whole class can learn about more than one living thing.* *We are trying to find out about asexual reproduction and how it works. Maybe different groups will learn different things or have different ideas, and it will be good to compare them. We can look for patterns.*
What are the constraints for your communication about your organism?	*You said we only get two minutes to share.* *We have to be finished with our research and ready to share our presentations in the next class, so we can't make them super-detailed or complex.*
How will you communicate this information? Why have you chosen that method?	*We need something simple, not too fancy.* *Since we already have computers out for research, we could make slides.*
OK, you might not even need multiple slides, one might be enough.	*A photo or drawing of the organism so we can see what it looks like.*
*What will you put on your slide?**	*the name of the organism* *A little bit about the organism: Is it a plant or animal or something else? Where does it live?* *How it reproduces without sperm and egg cells, but just a sentence or two since we don't have long to share.*
But then will you just show your slide or poster to the class? Or do you think we should have you talk about it?	*It would probably help to talk about it. We can make sure we're saying the words correctly, and it might be easier to take notes about important ideas.* *We are doing reading to find our own information; let's hear other groups tell us about theirs.* *Maybe the whole group doesn't have to talk, but at least one person could.*

Alternate Activity

If students do not have access to presentation software such as Google Slides or MS PowerPoint, each group can create a simple poster on chart paper, instead.

Additional Guidance

Be sure students understand your school's policy about crediting sources for photos or other images they use on their slide(s).

Share an example slide. Display **slide D**.

Say, *OK, here's a sample slide I put together about strawberries since we investigated those in a previous lesson. I tried not to put too many words on the slide, but I can explain a little bit more information while I'm sharing about it. Let's see …. Strawberries are plants that typically produce fruit in June. They are native to the United States and can grow from Florida to Alaska. Strawberry plants reproduce asexually by sending out root runners that grow little baby plants. No sex cells are involved in creating these new plants. The connected runners are called "stolons". Farmers will detach the new plants from the runners and replant them to replace older plants that no longer produce as many strawberries. New plants have the same genetic information as the parent. See, I gave just the main ideas and a couple of details about how they reproduce.*

2. Small Group Work to Obtain Information and Plan Communication

35 MIN

Materials: science notebook, computer with internet access, access to presentation software (such as Google Slides or MS PowerPoint), printer (if students need a physical copy of an article to annotate)

Plan for successful collaboration in groups. Display **slide E.**

Say, *We need to make sure everyone in your group gets to participate in this work. How will you be sure everyone gets to contribute?*

Elicit responses such as the following:

- Everyone in the group finds a different source to read, and then members compare ideas.
- The group should find consensus about how their organism reproduces: everyone should share ideas, listen to others, refer to evidence as needed, and be sure all agree when deciding what information to share.
- Google Slides allows for multiple editors, so group members can each be responsible for adding a component to the slide (or poster).
- It might be hard for three or four people to take turns talking (or to talk in unison!) when telling the class about their organism, so take volunteers to speak or play rock/paper/scissors to see who speaks.

Assign organisms to groups and begin research. Create groups of students to research some of the following organisms that reproduce asexually.* Say, *I will help your group self-select which organism you'll be researching and sharing about* (display **slide F**)*, and you can get to work. Some of these organisms can also reproduce sexually, but remember, today's purpose is to find out how they use asexual reproduction—without combining sperm and egg cells—so*

***Attending to Equity**

Universal Design for Learning: Students may benefit from careful planning of groups for this lesson's work rather than numbering off randomly or keeping the same groups they usually have. You might consider grouping students heterogeneously by reading skill or willingness to speak in front of the group to create effective cooperative-learning groups. This can set groups up for success by providing one-on-one peer support and better differentiation. Or, if you have a couple of students who require extra support, you may want to group them together (to make teacher assistance easier)

focus on that. After we're all organized I'll switch to the slide with our constraints and directions so you can refer to that as you work. You have 30 minutes to research and prepare for your presentation which you will present during the next class meeting.

The following organisms are also listed on **slide F**. Allow groups to self-select an organism to research, making sure that one group selects planaria. Keep track of which organisms have been selected so that there isn't any overlap.

- coral
- planaria
- aphids
- potatoes
- hydra
- bacteria
- marbled crayfish (also called marmorkreb)
- spider plants
- banana
- echeveria

and guide them to one of the simpler organisms to research, such as hydra or planaria.

ALTERNATE ACTIVITY

If you have time for more presentations or more in-depth study and/or would like students to work in partnerships or individually, the following are other asexually reproducing organisms that might make good choices for students to research: yeast, ginger, sea stars, sea anemones, sponges, Bdelloidea rotifers, the brahminy blind snake, and the New Mexico whiptail lizard.

After all groups are settled and know their organism, switch to **slide G** so they can refer to the expectations.

After about 20 minutes of work time, announce that groups should be starting to create their slides, if they haven't already.

End of day 1

3. Share about asexually reproducing organisms.

20 MIN

Materials: science notebook, *Asexual Reproduction Notes*, computer that has access to slide software and projector for presentation of slides

Set expectations for communicating information and listening. As students enter the classroom direct students to find their groups. Have students prepare for their presentation by opening up their presentation slide using a computer and look over any presentation notes in their science notebooks. Display **slide H.** Distribute the *Asexual Reproduction Notes* handout.

Say, *As each group tells about their organism, make a few notes to summarize how that living thing is able to reproduce without sex cells. Then consider how the genetic information of the babies compares to the parent. If you're not sure about that second part right now, make a prediction and we will discuss that later in class. Remember that the same expectations we have for listening during discussions—eyes on speaker or notes, one person speaking at a time—apply during this sharing time, too.*

Additional Guidance

If needed, ask the students how they will help make sure everyone hears the information they're communicating. They should have voice volumes that can be heard across the room, and listeners can use a silent signal (such as a hand cupped around an ear) if they cannot hear the speaker.

Share groups' slides about asexually reproducing organisms. Have each group share their presentations. Periodically remind students between presentations that they should be taking a few notes on their *Asexual Reproduction Notes* summarizing each of the organisms in the chart.



Name: _____ Date: _____

Asexual Reproduction Notes

Organism	How does it reproduce asexually?	How does the offspring's genetic information compare to the parent's?
spider plants		
potatoes		
aphids		
hydra		
marbled crayfish		
bacteria		
coral		
planaria		
bananas		
echeveria		

45

Assessment Opportunity

Building towards: 14.A Obtain, evaluate, and communicate information about how organisms reproduce asexually and transfer their genetic information to their offspring, which results in offspring with identical genetic information.

What to look and listen for: Look for students who are using reliable websites and finding just key ideas about asexual reproduction (not getting caught up in the other details of that organism or more-complex mechanisms). Listen for students who are able to communicate effectively: be concise and clear when presenting organized, relevant information.

What to do: If you anticipate that students will struggle to find appropriate, reliable sources of information, you might select a specific website or two for them to use rather than asking them to do a general internet search. If students are struggling to find relevant information about their organism, you might suggest they print out their article and use a highlighter or other way of marking up the text as they read. A group mate or teacher could also read the text aloud for students who are struggling to make sense of the text. In order to scaffold students who might be nervous about sharing, be sure their slide is well written. A template is provided in this lesson's slides if that would be helpful to share with students as a starting point. If you anticipate that students may struggle to present their information clearly, offer an opportunity for a practice run through the presentation before sharing in front of the class. If you would like to make sure that all students get a chance to share with a group (not as big as the whole class), set up a rotation where one group member stays at the computer to present the group's slide while other group members go around to learn from their classmates. Switch often enough that all students have a turn to tell about the slide.

4. Self-assess about obtaining, evaluating, and communicating information. 5 MIN

Materials: *Self-assessment for Obtaining, Evaluating, and Communicating Information*, transparent tape

Complete the *Self-Assessment for Obtaining, Evaluating, and Communicating Information* individually. Display **slide I**. Distribute *Self-assessment for Obtaining, Evaluating, and Communicating Information* to every student. Students

should take the next few minutes to individually reflect on their research and presentation and independently complete the self-assessment. After students finish filling it out, have them tape it in their science notebook to refer to later in the unit.

This assessment is intended as a space for student reflection, but if you are interested in responding to their thoughts, you might ask students to leave their notebooks open to this page at the end of class today as they exit so that you can see it and provide feedback.

5. Building Understandings Discussion About Asexual Reproduction

8 MIN

Materials: science notebook, *Asexual Reproduction Notes*, chart paper or whiteboard, markers, 2 half-sheets of copy paper to update the Word Wall

Lead a Building Understandings Discussion about asexual reproduction. Display **slide J**. Have students bring their copy of *Asexual Reproduction Notes* and their science notebook as they gather in a Scientist Circle. Use prompts such as those that follow to facilitate a Building Understandings Discussion.

Key Ideas

Purpose of this discussion: Confirm that asexual reproduction results in offspring that are genetically identical to the parent.

Listen for this idea:

- Several different methods of asexual reproduction all result in genetically identical offspring.

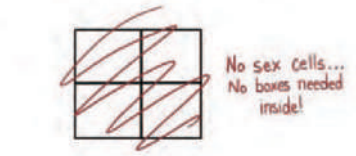
Suggested prompts	Sample student responses
What patterns did you find as you listened to the presentations and took notes about these organisms?	*They only needed one parent, not two.* *Sometimes the females just had egg cells ... no sperm were involved.* *I kept thinking the genetic information would be the same, right? For parents and offspring?*
Let's talk about that genetic information … if there's only one parent or only one parent's sex cell, is the genetic information going to be any different?	*Nope.* *No, not unless a mutation happens.*
And mutations are really, really rare, remember? So, if a mutation doesn't happen, how will the offspring produced by these forms of asexual reproduction compare to the parent?	*The offspring will have exactly the same genetic information as the parent.*

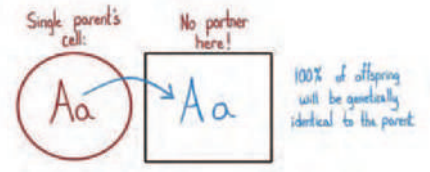
Suggested prompts	Sample student responses
OK, so if the offspring have exactly the same genetic information as the parent, what do you think those offspring would look like compared to the parent?	*They'd look exactly the same!* *There would be no differences at all.* *They're clones, so they're exactly alike.* *We couldn't tell them apart.*
Well, you know we like to find evidence to support what we're figuring out, right? So let's try to collect our own data to determine whether offspring from asexual reproduction look exactly alike. Ready?	*Yes! Let's go!*

Additional Guidance

Some of your students may have read in their research about the pros and cons of asexual reproduction, such as it's easier for a whole population to be wiped out by disease if they all have the same genetic information. If students bring up these ideas during discussion, have them phrase their thinking as a question and add it to the DQB. Then it can be carried over into *Unit 8.6: How could things living today be connected to the things that lived long ago? (Penguins Unit)*.

Use a Punnett square to show that genetic information of offspring from asexual reproduction is identical to the parent's. Draw a Punnett square on chart paper or the whiteboard. Lead a discussion about how this model could apply to asexual reproduction and record the students' thinking on the chart paper or whiteboard as you talk.





Suggested prompts	Sample student responses
What is the purpose of a Punnett square?	*It helps us figure out what the possible genotypes, or variations of alleles, are that offspring could have.*
OK, so what do we put at the top and sides of these boxes?	*That's where we would put the sex cells from the parents: two possible sperm cells on the top, and what allele they'd have, and two possible egg cells along the side.*
So, hang on, what kind of reproduction would that be, though, if we had sperm and eggs cells?	*That's sexual reproduction.*
So what's going to be different if we want to use this model to show asexual reproduction?	*We only have one parent, so there's only one cell.* *Let's put that single cell on the side, because often it's the organism with eggs who's doing the reproducing without sperm.*

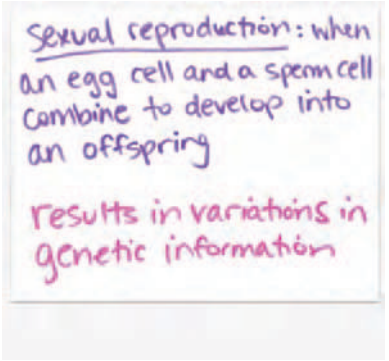
Suggested prompts	Sample student responses
Should we just put the same genotype from the parent on both the top and the side of the box, is that correct for asexual reproduction?	*No, the asexual organisms we studied don't make separate sex cells with only one chromosome each as with sexual reproduction—they keep their pairs.*
What should we change?	*We can cross off the other parent on the side.*
So I think we don't even need the dividing lines here inside, right? We can just have a box with this single cell and its two alleles from its chromosome pairs on top, like you said. So what can we say about the genotype these offspring will inherit?	*It's going to be the same combination as the parent has. That's the only genotype to fill in the box with.* *The offspring will have the exact same genetic information as the parent.*
What percentage of the offspring will have this identical genetic information?	*One hundred percent of the offspring will be genetically identical to the parent.*

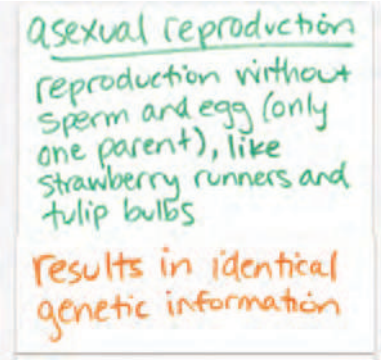
Additional Guidance

If students do not see the value in applying a model to a situation where it doesn't really work, explain that working through this model in a new situation (asexual reproduction) helps us understand and articulate how it does work (for sexual reproduction). Also, it is important to discover the limitations of our models, and we don't figure those out until we try applying the model to different situations.

Update the Word Wall definitions for sexual and asexual reproduction. Include what we know about an offspring's genetic information.

- To asexual reproduction (from Lesson 13), add "results in identical genetic information".
- To sexual reproduction (from Lesson 5), add "results in variations in genetic information".



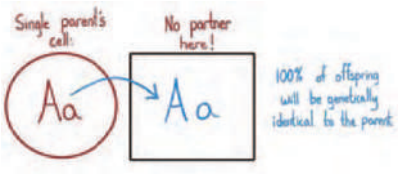


6. Update Progress Tracker.

3 MIN

Materials: science notebook

Update Progress Trackers. Say, *Let's use our Progress Trackers to summarize what we figured out today.* Display **slide K** and give students about 3 minutes to work. In the example two-column Progress Tracker row for this lesson, each of the columns has been completed with *possible* student ideas.

Question	What I figured out in words/pictures
How do asexual organisms pass on genetic information without sex cells?	Asexual organisms (such as planaria, coral, aphids, spider plants, bacteria, and so forth) can make copies of themselves or divide themselves to produce offspring. The genetic information of these offspring is identical to the genetic information of their parent. 

7. Observe planarian regeneration video.

6 MIN

Materials: science notebook, Want a Whole New Body? Ask This Flatworm How | Deep Look video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Navigate to investigating planaria more closely. Display **slide L**. Say, *According to our Punnett square model, organisms that use asexual reproduction should look exactly the same as one another. Let's test this idea by looking closer at planaria, one of the organisms a group of you researched in class.*

Suggested prompts	Sample student responses
What did we learn about how planaria reproduce?	*They can divide and grow from the pieces.*
*Throughout this unit we have discussed different cause-and-effect relationships. How might thinking about cause-and-effect relationships help us make strong predictions about planaria reproducing asexually?**	*Making predictions using cause and effect helps us interpret what the actual results mean when we observe them.*
If a single planarian is divided into multiple pieces then regenerated, would we expect the regenerated planaria to look the same or different? Explain.	*They should look the same because each planarian has the same genetic information.*
What if the regenerated planaria all looked different from each other? What would that mean?	*It would mean that something other than genetic information is affecting the physical appearance of the planaria.*

Display **slide M**. Say, *Before we watch a video with these organisms, we need to talk about how we view and treat living things with respect.*

Read with students the expectations we have as scientists when working with living things. Work to establish in your classroom a culture of appreciation for living things; for example, remind students to say things like "wow" or "interesting" instead of "eww" or "gross."

Say, *So we're going to watch a planarian regenerate today. We'll see how they look when they are divided into pieces and after they regrow.*

***Supporting Students in Developing and Using Cause and Effect**

This prompt foregrounds thinking students have done numerous times in this unit as they have used cause-and-effect framing to discuss these relationships. This is an opportunity to help students predict, using their knowledge of cause-and-effect relationships, about what they might see when planaria regenerate after being divided into multiple pieces. Having students think through the different potential outcomes helps them consider the mechanistic how or why explanations for this relationship. At this point in the unit students should be able to use causal framing themselves. Look for students saying "When a planarian is divided into multiple pieces we will observe _____", then proceed to explain why we should observe their predicted outcome.

Additional Guidance

For students whose views or beliefs make this video uncomfortable for them to watch, be prepared to allow them to step out during the viewing of this video. Depending on your state, students may have the legal right to opt out of viewing the video. If students step out during the video, you can have their classmates summarize what they saw in the video and/or provide some screenshot images from the video to highlight how the offspring planaria look the same as the original planarian.

Observe a planaria regeneration video as a whole class. Display **slide N**. Have students read over the questions on the slide so that they can record their responses in their science notebook as they watch. Play the video Want a Whole New Body? Ask This Flatworm How | Deep Look (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) from 0:00 to 2:39. Then briefly share in a whole-class discussion.

Suggested prompts	Sample student responses
What did you notice when the planaria were growing back?	*After being cut, the planerian's wounds healed.* *The planaria regrew eyes, a head, and a tail.* *It took several days before the pieces looked like a planarian again.*
Was there any new genetic information being introduced? Explain.	*No, because the planarian just grew back after it was divided into four pieces.*
Did the planaria all look exactly the same at the end of the video?	*They looked pretty similar, but they were moving around a lot. It was hard to tell.* *It was difficult to see if they were exactly the same because the planaria were not all lined up next to one another and because that part of the video was short.*

8. Navigation

3 MIN

Materials: science notebook

Reflect on what we know and what we still need to figure out about organisms that reproduce asexually. Say, *OK, since it was difficult to compare all the planaria in the video after they regenerated, let's return to the images of the planaria from Lesson 11.*

Display **slide N** and refer to the posted Lesson 11 pictures of planaria. Say, *These planaria all have the same genetic information too. Just like in our video these planaria were split apart and were able to regenerate. Some of these photos are even of the same individual planarian, just at different times. Let's look closer again to see if these planaria look exactly the same.*

Allow students to individually respond in their science notebook to the slide questions, then have students briefly share with the whole class.

Suggested prompts	Sample student responses
How are the planaria similar to one another?	*They all have a similar shape.* *They have the same physical characteristics like eyes, a head, and a tail.*
How are the planaria different from each other?	*They are different colors, some are lighter than others and some are darker.*
Interesting, these planaria have different phenotypes, yet they have the same genetic information. What could be causing these phenotype differences?	*Something other than genetic information is affecting the physical appearance of the planaria.* *Maybe something about where they're living or what they're eating?* *(Students may also predict other possible environmental factors.)*

Summarize by saying, *We have figured out that there are different ways offspring can inherit genetic information from their parent or parents. We also have figured out that once a baby has that genetic information, that genetic information directs the body to make proteins which then influence the organism's phenotype. But how can we explain phenotype differences in organisms that have the same genetic information for a trait? Let's start there next time.*

ADDITIONAL LESSON 14 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.W.8.8

Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

CCSS.ELA-LITERACY.SL.8.4

Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

In order to complete their research about an asexual organism in this lesson, students must search effectively for multiple sources, evaluate their credibility, and summarize for others what they find. When sharing their findings, students must be concise and clear, speaking so others can understand the key ideas they learned.

LESSON 15

How do we get variations if the genetic information is exactly the same?

Previous Lesson

We worked in small groups to do research about an organism that uses asexual reproduction and then shared what we learned with our classmates. We discussed how the genetic information of offspring from asexual reproduction compares to that of the parent. Then, we observed a video of planarian regeneration, and we discovered that the resulting planaria didn't look identical. We decided that we needed to figure out what could cause these planaria to look different.

This Lesson

Investigation

1 DAY





We consider possible causes for the color variation we saw in planaria (even though they have the same genetic information) and then integrate information from images and text about how the planaria were affected by light exposure. We consider how environmental factors like light might influence other ranges of variation we've seen, and we obtain scientific information from texts about the causes of color variation in apples and flamingos. We work with partners to use a model to explain the different environmental factors that cause the range of variation we see in apple and flamingo colors.

Next Lesson

We will investigate the variation found in wheat kernel coloration as well as human arm span. We will revise our current classroom consensus model to explain the variation in musculature we see in cattle. We will hold a Consensus Discussion about what we figure out and extend our explanation to all trait variation.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5



What Students Will Do

15.A Construct an explanation using a model to explain the influences of environmental and genetic factors on trait variation.

What Students Will Figure Out

- Environmental factors can cause a continuous range of variation.
- We begin to notice that different environmental factors and genetic factors can influence trait variation to different degrees.

Lesson 15 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Recall the question we wanted to answer today about planaria color and consider possible causes.	A	
2	10 min	**GALLERY WALK OF PLANARIA DATA** Circulate around the room to integrate information from images and text about how planaria were affected by light exposure.	B	*Planaria Study Data*, 8.5 Lesson 15 Planarian Movement video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) (optional)
3	7 min	**HOLD A BUILDING UNDERSTANDINGS DISCUSSION ABOUT PLANARIA AND ENVIRONMENTAL EFFECTS** Lead a Building Understandings Discussion to make sense of the information we gathered from text and images about the planaria study.	C-D	chart paper, markers, card sorts from Lesson 11, classroom consensus model
4	8 min	**READ ABOUT VARIATION IN FLAMINGOS AND APPLES** Predict possible environmental factors that could influence color variation in apples and flamingos and then obtain scientific information from texts about those causes.	E-G	*Two Examples of Environmental Influences on Trait Variation*
5	12 min	**EXPLAIN ENVIRONMENTAL EFFECTS ON FLAMINGOS AND APPLES** Work with a partner and use a model to explain the causes of color variation in apples and flamingos.	H	*Explaining Environmental Effects*, *Two Examples of Environmental Influences on Trait Variation*, transparent tape (optional)
6	3 min	**PREDICT FACTORS INFLUENCING OTHER TRAIT VARIATIONS** Look forward to next time's work by suggesting possible causes for the variation we see in wheat kernel color and human arm span.	I	card sorts from Lesson 11

End of day 1

Lesson 15 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Two Examples of Environmental Influences on Trait Variation* • *Explaining Environmental Effects*		• *Planaria Study Data* • 8.5 Lesson 15 Planarian Movement video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) (optional) • chart paper • markers • card sorts from Lesson 11 • classroom consensus model • transparent tape (optional)

Materials preparation (20 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare the handouts:

- Make 1 copy of *Explaining Environmental Effects* for each student.

Gather the color copies of *Planaria Study Data* from your materials kit. Or, if you do not have premade data sheets from the materials kit, see the **Online Resources Guide** for links to these items (**www.coreknowledge.org/cksci-online-resources**), and prepare them as follows:

- Print a color copy on cardstock of all 12 pages of *Planaria Study Data*.
- Consider laminating these data sheets since you will reuse them for each class you teach and can keep them year to year.

Make two copies of *Planaria Study Data*. When these are posted around the classroom, there will be 12 stations. The pages should be spread out so students do not have to huddle together to see them clearly. Post the pages either facedown on tables or counters where students won't be sitting or taped on the wall with the blank side facing out (or wait to have students help post them at the beginning of the gallery walk).

Lesson 15 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students explore how environmental factors impact trait variation to build on what they figured out about diet and exercise in the first lesson set. In comparing the main causes of color variation in planaria (light exposure), flamingos (types of food), and apples (multiple environmental factors, but genetic factors too), students begin to notice that environmental and genetic factors can influence the variation we see to varying degrees. They continue developing this idea in Lesson 16 by investigating the causes of variation in wheat kernel color (influenced by multiple genes) and human arm span (influenced by hundreds of genes and environmental factors) and comparing those ideas to what they figured out in this lesson.

Where We Are NOT Going

When predicting possible causes of color variation in the planaria, students may suggest that they change color in order to blend into their environments like arctic hares or some lizards do. In this lesson, we find out that light exposure leads to loss of pigment in planaria, and students can certainly speculate about why planaria might react to light in this way, but conversations about how it benefits them can continue into the next unit: *Unit 8.6: How could things living today be connected to the things that lived long ago? (Penguins Unit)*. The mechanism for changing color in response to the environment involves gene expression and is beyond the scope of the middle school grade band.

LEARNING PLAN FOR LESSON 15

1. Navigation

5 MIN

Materials: None

Navigate into today's work. Display **slide A**. Use prompts such as the following to discuss possible explanations for the range of color variation we saw in planaria.

Suggested prompts	Sample student responses
Last time, we left off wondering about the range of planaria colors. Who can restate our question from last class?	*If those planaria all reproduced asexually, they should have all the same genetic material, so they should have identical phenotypes. So what would be causing those color differences?*
What ideas do you have about possible causes of that color variation we're seeing?	*Could it be a mutation?* *Could it be something they're eating or something about where they live?*
OK, let's think through those ideas. What about a mutation? What do we know about mutations that could help us think through that possibility?	*We know the extra-big muscles in cattle are caused by a mutation.* *The farmers and scientists noticed it was a big change in the cattle muscles, and there were three groups—typical, with no copies of the mutation; extra-big, with both alleles of that changed gene; or medium muscles, with only one copy of that allele.* *The tulip variations were also caused by mutations that farmers kept selectively breeding for. Some of those variations were round or pointed petals, frilly or smooth edges, and different colors.*
Do we think the continuous range of planaria color could be caused by a mutation?	*Probably not. These planaria aren't in two or three groups like we could categorize those other variations caused by mutations. They're a range.* *Mutations are also really rare. I don't think there were so many mutations for all those planaria to get their different colors.*

Suggested prompt	Sample student responses
So we think not a mutation because we would see specific phenotypes, not a range. What were some of the other causes you suggested?	*What they're eating might be different. Could that influence their colors?* *I don't think they're exercising like we saw with cattle muscles, but maybe there's something else that's different about what they do.* *Maybe where they live causes changes in their colors?*

Say something like, *It sounds like we need some more information about what was going on with these planaria that could cause their color variation. Let's investigate that.*

2. Gallery Walk of Planaria Data

10 MIN

Materials: science notebook, *Planaria Study Data*, 8.5 Lesson 15 Planarian Movement video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) (optional)

Give instructions for a gallery walk through planaria data. Display **slide B**. Explain to students that they will have time to move around the room to read and view images about these planaria. They will work individually and silently, moving to a new page of data whenever they finish with one. They should title the next blank page in their science notebook with the question we're trying to answer and record key information they find.*

Additional Guidance

Post or spread out the gallery walk pages so that students aren't all clustered in one area. A gallery walk is not a move-on-a-timer activity; rather, students move from one page to the next at their own pace and in any order.

It's possible that in the time allotted not every student will get to see every page of data, which will make it that much more important for them to record key ideas to share afterward from those pages they do see.

Gallery walk through planaria data. If you haven't already posted the pages from *Planaria Study Data* around the room, have students help do that as they move to various locations in the room to get ready to begin the gallery walk. Instruct students to move around to review the data at their own pace. Give students about 8 minutes to explore the data and record key ideas in their notebook.

Additional Guidance

If your students are concerned or confused that in the photos of the same planarian (same individual animal) its body shape looks different, you may choose to watch the 12-second video clip of a planarian moving at 8.5 Lesson 15 Planarian Movement (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) (this one happens to be depigmented). Pause the video a few times and ask students to describe and compare the planarian's body shape each time. Guide students to infer that depending on how the planarian was moving when each photo was taken could make its body look different.

***Supporting Students in Engaging in Obtaining, Evaluating, and Communicating Information**

At this point in the unit and year, students should be independent in critically reading scientific texts adapted for classroom use to determine the central ideas and obtain scientific information as well as integrating qualitative scientific information in written text with that contained in visual displays to clarify findings. If your students need more support with this practice, you might choose to have them do the gallery walk in partnerships or work with the *Planaria Study Data* as a whole-class, shared activity.

3. Hold a Building Understandings Discussion about planaria and environmental effects. 7 MIN

Materials: science notebook, chart paper, markers, card sorts from Lesson 11, classroom consensus model

Bring the class back together for a Building Understandings Discussion. Display **slide C**. Use prompts such as those that follow to facilitate a discussion about the planaria data. Capture the class's thinking on chart paper in a model with different-sized arrows showing the influences on the planaria's color variation.

Key Ideas

Purpose of this discussion: to (1) share take-aways from the planaria data gallery walk, establishing that light exposure can cause variation in planaria color, (2) co-construct a model to explain the influences on planaria color variation, and (3) motivate investigating other organisms' variations that could be caused by environmental factors.

Listen for these ideas:

- These planaria were all genetically identical, so the variation we're seeing is caused by light exposure, not genetic information.
- Light exposure causes pigmentation loss in planaria, so we see a range of colors depending on the timing and amount of the exposure.
- This amount of light exposure and color variation is not likely to happen in the wild.
- We can call influences like light exposure, diet, and exercise "environmental factors" as opposed to genetic factors.

At the beginning of the discussion, refer to a few of the images from the gallery walk, also shown on **slide C**, to establish that these animals have the same genetic information. Point to the image sets for Planarian A and Planarian B and ask, *Are these animals the same one or different?*

Confirm with the class that Planarian A and Planarian B are different individuals that were repeatedly photographed.

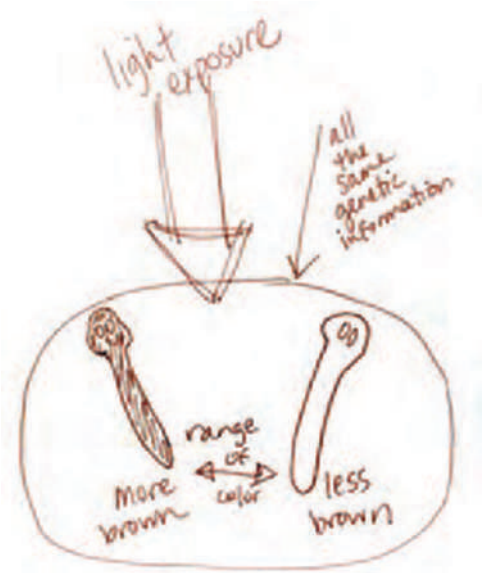
Suggested prompts	Sample student responses
Do Planarian A and Planarian B have the same genetic information?	*Yes, the study said all the planaria we saw were from the same asexual population, so both A and B have the same genetic information.*
*What did you figure out from integrating the information in text and images about those planaria? What caused their color variation?**	*The planaria lost their pigment when they were exposed to a lot of bright light.* *We saw a range of colors depending on the timing or amount of light they were exposed to.* *The study said this amount of light exposure and color variation was not likely to happen in the wild.*

***Supporting Students in Developing and Using Cause and Effect**

Students should be explaining cause-effect relationships independently at this point in the unit, but if needed, you can provide the framing used in earlier lessons: When the scientists ___ *(caused a change to the system)*___, they observed __(*effect on the system*)_____.

Suggested prompts	Sample student responses
This study focused on pigments in the planaria. Can you infer from the study information what pigments are?	*Something in their bodies that causes their color.* *Pigments were related to certain molecules, so are they molecules too?*
Pigments are molecules in living things that cause colors, and they need to interact with certain proteins to do that. What directs the production of those proteins, then?	*The organism's genetic information gives instructions for making proteins.*

See the sample model shown here:



Compare the arrow you've drawn for light exposure on this model with the arrows you have for exercise and diet on the original classroom consensus model explaining cattle muscles. Ask, *How are these causes similar? What do light exposure for planaria and diet and exercise for cattle have in common?*

Sample student responses

- They don't have anything to do with genetic information or genetic material.
- They're influencing the animals after they've been born.

Say, *Since influences like light, exercise, and diet are from an organism's environment, we can call them "environmental factors" to help us distinguish them from how an organism's genetic information is influencing its growth, which we can call "genetic factors".*

Navigate to investigating other variations. Display **slide D**. Refer to the card sorts from Lesson 11 displayed in the room. Say, *We noticed that for these planaria, light exposure had a big effect on their color. If we want to investigate another variation that's influenced by environmental factors, which of our organisms might be good to investigate next?*

Decide as a class that apples and flamingos would be good to investigate next. (We will investigate wheat kernels and human arm span in Lesson 16.)

4. Read about variation in flamingos and apples.

8 MIN

Materials: *Two Examples of Environmental Influences on Trait Variation*

Predict what environmental factors could influence color in apples and flamingos. Display **slide E**. Ask, *What environmental factors do you think could be influencing the range of color variation we see in apples? Flamingos?*

Sample student responses:

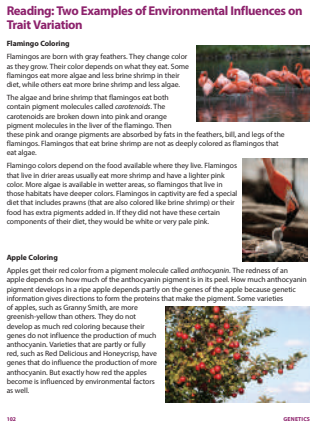
- Apples don't exactly eat, so it wouldn't be diet like we saw with cattle muscles, but maybe the amount of water or rain the trees get? Or what nutrients are in the soil?
- Maybe the weather is different in different places where apples grow.
- Maybe light exposure influences apples or flamingos like it did for the planaria, but it would be from the Sun.
- What do flamingos eat? Could their color depend on the food they eat?

Additional Guidance

If your students suggest that genetic factors could also influence color variation in apples and flamingos, refer back to the classroom consensus model to acknowledge that yes, since birds reproduce sexually and apples can reproduce sexually (although again, not always, if farmers want a consistent type), genetic factors could also be influencing the variation we see. Remind students that we have also noticed a range of color in apples and flamingos rather than just a few distinct categories like we had when we learned how genotype was influencing phenotype in cattle musculature or goldfish colors, and we want to explain that range too. We will continue to investigate the differing impacts of genetic and environmental factors in Lesson 16 as well.

Distribute *Two Examples of Environmental Influences on Trait Variation* and give students time to read. Display **slide F**. Say, *Let's read to find out what's causing the ranges of variation we see in flamingo and apple colors. Do what you need to do to make sense of the text and find key ideas while you read.**

Give students 5-7 minutes to read the article.*



Reading: Two Examples of Environmental Influences on Trait Variation

Flamingo Coloring

Flamingos are born with gray feathers. They change color as they grow. Their color depends on what they eat. Some flamingos eat more algae and less brine shrimp in their diet, while others eat more brine shrimp and less algae.

The algae and brine shrimp that flamingos eat both contain pigment molecules called *carotenoids*. The carotenoids are broken down into pink and orange pigment molecules in the liver of the flamingo. Then these pink and orange pigments are absorbed by fats in the feathers, bill, and legs of the flamingos. Flamingos that eat brine shrimp are not as deeply colored as flamingos that eat algae.

Flamingo colors depend on the food available where they live. Flamingos that live in drier areas usually eat more shrimp and have a lighter pink color. More algae is available in wetter areas, so flamingos that live in those habitats have deeper colors. Flamingos in captivity are fed a special diet that includes prawns (that are also colored like brine shrimp) or their food has extra pigments added in. If they did not have these certain components of their diet, they would be white or very pale pink.

Apple Coloring

Apples get their red color from a pigment molecule called *anthocyanin*. The redness of an apple depends on how much of the anthocyanin pigment is in its peel. How much anthocyanin pigment develops in a ripe apple depends partly on the genes of the apple because genetic information gives directions to form the proteins that make the pigment. Some varieties of apples, such as Granny Smith, are more greenish-yellow than others. They do not develop as much red coloring because their genes do not influence the production of much anthocyanin. Varieties that are partly or fully red, such as Red Delicious and Honeycrisp, have genes that do influence the production of more anthocyanin. But exactly how red the apples become is influenced by environmental factors as well.

102 GENETICS

*Supporting Students in Engaging in Obtaining, Evaluating, and Communicating Information

If your students still need support with critically reading scientific texts adapted for classroom use to determine the central ideas and obtain scientific information, you could refer to the checklist your class created in Lesson 3 and/or Lesson 6, or display optional **slide G** to support them while they read.

*Attending to Equity

Universal Design for Learning: If you anticipate that some students would benefit from an alternate *representation* of this text, consider pairing students to have one person read aloud and one person listen. The listener could begin to sketch ideas for a model or jot notes. You could also assign different parts of the article to different students to read to themselves or aloud. The flamingo section is a less complex text than the apple section.

5. Explain environmental effects on flamingos and apples. 12 MIN

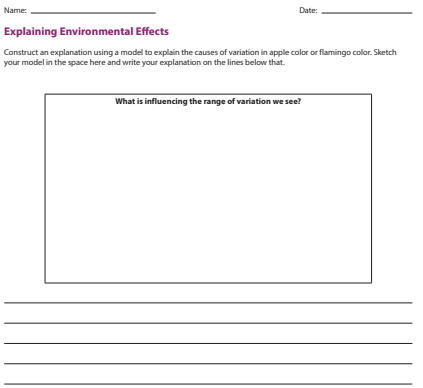
Materials: *Explaining Environmental Effects*, *Two Examples of Environmental Influences on Trait Variation*, transparent tape (optional)

Work with a partner to use a model to explain the causes of color variation in apples and flamingos. Display **slide H**. Distribute *Explaining Environmental Effects*. If you plan to collect this page as a formative assessment, do not have students add it to their notebooks yet. Assign partnerships and give directions for modeling the influences on color in apples and flamingos like we did earlier for planaria.

- Work together to construct explanations using models.
- Have one partner record your explanation for flamingo color and the other for apple color.
- Be sure your explanations communicate the relationships involved: use your model to explain the causes for the range of color variation we see and then listen while your partner explains theirs.

After 5-7 minutes of work time, remind students to take turns using their model to explain to their partner the causes of color variation.





Name: _____ Date: _____

Explaining Environmental Effects

Construct an explanation using a model to explain the causes of variation in apple color or flamingo color. Sketch your model in the space here and write your explanation on the lines below that.

What is influencing the range of variation we see?

Assessment Opportunity

Building towards: 15.A Construct an explanation using a model to explain the influences of environmental and genetic factors on trait variation.

What to look and listen for: While students work on *Explaining Environmental Effects* and share their explanation with their partner, listen for the following ideas:

- Flamingo color is influenced by the environmental factor of the foods they eat: eating more algae results in deeper pink-orange color and eating more shrimp results in lighter pink-orange color.
- Apple color is influenced by genetic and environmental factors: temperature and sun exposure to a greater extent and stressors such as lack of water or nutrients and insect activity to a lesser extent.

As you review the models students use along with their written explanations, look for arrows of varying size and/or words that indicate how much effect some factors have relative to others.

What to do: If students need help using a model to explain, walk them through an example using the model the class constructed to explain the causes of planaria coloration. If students need support making sense of the texts before constructing their explanation, walk through developing a model with them first. Refer to the model of the influences on planaria color and have students represent the components of a similar model for flamingos (darker to lighter pink) or apples (more green to more red). They can then find the causes of those color differences in the text and write those labels on the model before they draw the arrows representing the relative amounts of influence on the variation. After developing their model, have students use it to explain the causes of the variation. Consider having students explain orally rather than in writing so you or a partner can prompt them as needed.

6. Predict factors influencing other trait variations.

3 MIN

Materials: card sorts from Lesson 11

Summarize today's work and look ahead to next time. Display **slide I**. Refer to the card sorts from Lesson 11 displayed in the room and consider the other ranges of variation we haven't yet investigated. Say, *You were able to explain that the ranges of variation in apple color and flamingo color are caused by environmental factors, along with genetics for apples. What do you predict is causing the variation we see in wheat kernel color and human arm-span length? Why do you think that?*

Sample student responses

- Since those are ranges of variation, we couldn't put them into specific groups or categories, so we think they're caused by environmental factors too.
- Maybe the wheat is influenced by the temperature or sunlight or rain like other plants.
- People definitely have different arm spans depending on how old they are, and I bet like with muscles if you didn't have enough healthy food you wouldn't be able to grow as much.
- But there are patterns in people's families about how big or small they are too, so I don't think it's just environment that causes that variation.

Summarize by saying, *Let's investigate those ideas next time.*

ADDITIONAL LESSON 15 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.SL.8.1.A

Come to discussions prepared, having read or researched material under study; explicitly draw on that preparation by referring to evidence on the topic, text, or issue to probe and reflect on ideas under discussion.

In this lesson, students are responsible for reading about, thinking about, and sharing about the causes of variation in a trait. When explaining these causes to their partner, students are expected to refer to ideas they obtained from that reading.

LESSON 16

How much of trait variation in a population is controlled by genes or by the environment?

Previous Lesson

We integrated information from images and text about how planaria color was affected by light exposure, and we considered how environmental factors like light might influence other ranges of variation we've seen. We obtained scientific information from texts about color variation in apples and flamingos and then used a model to explain the different environmental factors that cause the range of variation we see in apple and flamingo colors.

This Lesson

Investigation

2 DAYS



We investigate the variation found in wheat kernel coloration to learn this trait is controlled by more than one pigment-producing gene. We use this new idea in addition to what we learned about environmental factors in Lesson 15 to update our classroom consensus model explaining variation we see in cattle musculature. We investigate the distribution of the human arm span trait and independently use our model to explain which factor(s) affect arm span. Finally, we share our models in small groups and hold a Consensus Discussion about what we figured out about these influences on all traits.

Next Lesson

The class will revisit its Driving Question Board to evaluate and answer their questions. Students will use this time to ask any clarifying questions to refine their understanding about their models for how living things are different from one another. Then students will demonstrate understanding on a summative assessment transfer task involving redwood trees.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5

What Students Will Do

16.A Analyze and interpret patterns in data to provide evidence that a combination of genes and environment is causing the variation we see in traits.

16.B Develop and use models to show multiple causes of variation within a trait.

What Students Will Figure Out

- Different traits and variations are influenced differently by genes and environment.
- Most trait variations are influenced by a combination of multiple genes and the environment and to varying degrees, depending on the trait.
- It is rare to have a single gene influence a trait variation.

Lesson 16 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	2 min	**NAVIGATION** Think back to the last class to remember that we were interested in investigating the last two remaining examples from Lesson 11.	A	
2	3 min	**DISCUSS EVIDENCE THAT COULD BE USED TO MAKE PREDICTIONS** Discuss the idea that examples of traits that seem to have a range of variation with no clear ways to group them are more difficult to categorize.	B	
3	10 min	**ANALYZE DISTRIBUTION OF COLOR VARIATION FOR WHEAT KERNELS** Attempt to categorize the wheat and then make a claim about whether wheat kernel color is influenced more by the environment or by genes. Propose an investigation that could provide evidence to support that claim.	C-E	*Data Collection: Wheat Kernels*, 1 set of photo cards from *Wheat Kernel Photos* (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)
4	10 min	**INVESTIGATE WHEAT KERNEL COLOR** Analyze results of investigations that cross plants that have different colors of wheat kernels and raise offspring plants in either similar or different environments.	F-M	*Wheat Kernel Environmental Factors Investigation*, *Data Collection: Wheat Kernels*, *Steps for Using Probability to Make Predictions* (optional)
5	10 min	**OBTAIN INFORMATION ABOUT HOW WHEAT KERNEL COLOR IS DETERMINED** Read independently an article about the causes of varied wheat kernel colors, then share key ideas with the class.	N-O	*Color of Wheat Kernels*
6	10 min	**MAKE PREDICTIONS ABOUT KERNEL COLOR** Use what we know about genetic influences on wheat color to predict phenotypes based on genotypes and compare these patterns to what we have figured out about cattle musculature.	P-T	*Color of Wheat Kernels*
				End of day 1
7	10 min	**COLLECT AND ORGANIZE ARM SPAN DATA** Introduce students to the data we have about arm spans and add to the data set our own class data about arm spans.	U-V	*Arm Span Histogram Instructions* (optional), 1 tape measure, 1 meterstick or other measuring tool (optional), clear packing tape (optional), 1 set of *Arms Photos* cards from Lesson 11, table on chart paper or shared spreadsheet for collecting arm span data
8	5 min	**VISUALIZE DATA USING A WEB-BASED GRAPHING TOOL** Explore how changing the interval size affects how the data are represented.	W-X	computer (optional), *Arm Span Histogram Instructions* (optional), *Arm Span Data Set* (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Part	Duration	Summary	Slide	Materials
9	10 min	**READ AND MODEL INDIVIDUALLY ABOUT THE IMPACT OF GENES AND ENVIRONMENT** Recall strategies for reading critically, make a plan for communicating via models, then independently read and create a model explaining the genetic and environmental influences on arm span.	Y-Z	*Arm Span Length*, *Arm Span Reading and Modeling*
10	5 min	**SHARE STUDENT MODELS AND EXPLANATIONS IN SMALL GROUPS** Meet in small groups to share and compare models and explanations; exchange models to provide peer feedback.	AA-BB	2-3 sticky notes, *Arm Span Reading and Modeling*
11	7 min	**CONSENSUS DISCUSSION ABOUT THE IMPACT OF GENES AND ENVIRONMENT ON TRAITS** Participate in a Consensus Discussion to share what they learned about the impact of genes and environment on different traits.	CC	*Arm Span Reading and Modeling*
12	8 min	**REVISE CLASSROOM CONSENSUS MODEL TO INCLUDE ENVIRONMENTAL FACTORS AND MULTIPLE GENES** Work together as a class to revise the classroom consensus model to reflect the different impacts of genes and environment on phenotypes.	DD-FF	*Arm Span Reading and Modeling*, classroom consensus model, markers, chart paper (optional), *Cattle Photo Cards* from Lesson 1 (optional)
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 16, students are ready to read Student Reader Collection 5 and then respond to the writing exercise.		Student Reader Collection 5: *Making New Individuals*

Lesson 16 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• *Data Collection: Wheat Kernels* • *Wheat Kernel Environmental Factors Investigation* • *Steps for Using Probability to Make Predictions* (optional) • *Color of Wheat Kernels* • *Arm Span Histogram Instructions* (optional) • computer (optional) • *Arm Span Length* • *Arm Span Reading and Modeling* • 2-3 sticky notes • science notebook	• 1 set of photo cards from *Wheat Kernel Photos* • 1 tape measure • 1 meterstick or other measuring tool (optional) • clear packing tape (optional)	• 1 set of *Arms Photos* cards from Lesson 11 • table on chart paper or shared spreadsheet for collecting arm span data • *Arm Span Data Set* (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • classroom consensus model • markers • chart paper (optional) • *Cattle Photo Cards* from Lesson 1 (optional)

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare the handouts:

- Make 1 copy each of *Data Collection: Wheat Kernels*, *Arm Span Reading and Modeling*, *Wheat Kernel Environmental Factors Investigation*, *Color of Wheat Kernels*, and *Arm Span Length* for each student.
- If you think it would be helpful, print 1 copy per student in your largest class of the optional handout *Steps for Using Probability to Make Predictions*, which can be collected and reused in each class.

Prepare to redistribute a set of *Wheat Kernel Photos* cards from Lesson 11 to each small group.

Gather 8-10 72" tape measures (one per group of 3-4 students in your largest class) for students to measure each other's arm spans. Alternatively, you may choose to tape meter sticks or measuring tapes on the walls of your classroom so students can easily measure their own arm spans.

Before the lesson, practice using the Arm Span Data Set and accompanying online graphing tool (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) as outlined in the Teacher Guide and in *Arm Span Histogram Instructions*.

This data set includes the opportunity to contribute your class's arm span data to the set to improve the experience for other students. If you would like your students' anonymous data to be added to the online set, share this Google form Arm Span Data Survey: (See the **Online Resources Guide** for a link to this item.

Online Resources



www.coreknowledge.org/cksci-online-resources) They will enter only a number: their arm span in centimeters. No other information will be collected. Since it is imperative that only accurate numbers (reasonable arm spans in centimeters) be entered into the form, you may choose to have students report their measurements to you and have you enter them. Please note that the website does not automatically or immediately upload your data to the shared set. It is refreshed periodically and all new data entered will be displayed at that time.

If you choose to have students explore the Arm Span Data Set and graphing tool on their own before discussing it as a class, have computers available and print a set of *Arm Span Histogram Instructions* for your largest class to collect and redistribute.

If the shared Arm Span Data Set and graphing tool are not working for you, the teacher reference *Alternate Histogram Tool Instructions* provides instructions for using a different web-based histogram creator. However, this tool does not already include an arm span data set; you will need to enter your own class data and bear in mind that with a smaller data set, results may be different than expected.

Lesson 16 • Where We Are Going and NOT Going

Where We Are Going

Since this is the penultimate lesson of the unit, the classroom consensus model is quite complex after this lesson's revision. The goal of this lesson's revision is to help students represent the different relative impacts of genetic and environmental factors on the varying musculature of cattle. The sample model shown in this *Teacher Guide* did not have room for all the details of inheritance patterns or the gene-protein-trait causal chain that we added to the classroom consensus model in Lesson 7, but follow your students' ideas: if they suggest a way of better linking all those models together without hindering this lesson's work, see what you can do to be creative about incorporating their ideas.

Note that there are seven colors named for the wheat kernels students investigate in this lesson. From lightest to darkest, they are as follows:

1. lightest cream color
2. lightest red
3. medium-light red
4. medium red
5. medium-dark red
6. dark red
7. deep red

Where We Are NOT Going

It may be tempting to think that one can actually separate environmental and genetic influences on traits. But it is too simple to say that a certain percentage of a trait is influenced by the environment and a certain percentage is influenced by genetics. Rather, all traits are mutually influenced by genes and environment in an integrated way. It is not correct to think that there are two influences that are independent of each other. Instead, it is genes *interacting* with the environment that determines an organism's traits. The notion of heritability as a measure of how much

genes versus environment influence a trait is therefore misleading. Our take-away in this lesson is that both genes and environment are always at play—we are not getting into how these factors interact.

More information about environmental factors can be found in the Teacher Background Knowledge section titled "What are some frequently asked questions about genetics?" Also, do not confuse the way we approach the role of environmental factors (e.g., local conditions such as diet) in the growth of organisms with epigenetics. Gene expression is beyond the scope of this unit and beyond the target DCIs for middle school.

As is explained in the Teacher Background Knowledge section, this unit does not introduce students to the classical dominant/recessive inheritance patterns because they are rare in nature. However, if your state assessment will expect students to recognize that vocabulary and name those patterns, you may choose to introduce them during this lesson in the context of wheat kernel color. You can discuss why the alleles that lead to red pigment would be considered dominant to the alleles that do not lead to production of that pigment and how that relationship results in a classical dominant/recessive pattern. However, resist the urge to equate "makes a product or protein" with "dominant" because this is not always the case (such as with Huntington's disease).

Also note that if you are considering exposing students to other examples of human traits, many that were previously thought to have simple dominant/recessive inheritance patterns are, in fact, more complex. There is more information about these examples traditionally used in classrooms that you may want to consider at this link: (See the **Online Resources Guide** for a link to this item.) **www.coreknowledge.org/cksci-online-resources**.)

LEARNING PLAN FOR LESSON 16

1. Navigation

2 MIN

Materials: None

Navigate to investigating the other trait variation examples. Display **slide A**. Say, *Last time, we learned that the environment has an effect on trait variation as much as genes do. Even when two or more organisms have the exact same genetic information due to asexual reproduction, they can still look different because of the environment's effects, like we saw in the planaria example. We still have some examples of variation we have not investigated yet. What did you predict is causing the variation we see in wheat kernel color and human arm-span length? Why?* Give students a moment to discuss this question with a partner and then come back and share ideas with the class.

2. Discuss evidence that could be used to make predictions

3 MIN

Materials: None

Share and discuss observations about traits with variations that are difficult to categorize. Show **slide B**. As a class, make some observations about the wheat kernels in the image on the slide. Allow students to predict whether they will be easy to categorize into groups based on their color.

Suggested prompts	Sample student responses
What patterns do you notice about the different colors of wheat?	*It looks like some of the wheat is darker and some is lighter.*
Do you think you could sort this wheat into categories by color?	*We're not sure. It looks like some would be easy to separate, but others look pretty close in color.*
Think back to the variation you noticed in the planaria, flamingos, and apples. Were the differences among individuals easily put into categories? Were any of the examples of variation easy to categorize?	*Planaria, flamingos, and apples were difficult to put into categories because the differences had a large range.* *Cattle were easier to put into categories, but they were hard sometimes too.*

3. Analyze distribution of color variation for kernels.

10 MIN

Materials: *Data Collection: Wheat Kernels*, 1 set of photo cards from *Wheat Kernel Photos*

Sort the wheat kernels by color. Display **slide C**. Organize students into groups of 3 or 4. Pass out a set of cards from *Wheat Kernel Photos* to each group and a copy of *Data Collection: Wheat Kernels* for each student.

Have students attempt to group and sort the different colors of wheat from *Wheat Kernel Photos* and record their ideas to the first prompt on *Data Collection: Wheat Kernels*. Circulate among groups to ask questions about what "rules" or

criteria they are using to make each category of color. As you circulate, identify groups that have evidence that the wheat kernel colors fall into categories and the groups that do not think they can be categorized.

Share ideas about whether these wheat kernel colors have categories. Give students time in a whole-class discussion to share ideas about whether the wheat can be categorized by color. Accept all answers and challenge students to support their ideas with evidence from their experience sorting the cards.

Prepare to further investigate the wheat kernel colors. Direct students to respond with their group to prompts 2-4 on *Data Collection: Wheat Kernels*. They will use these ideas to support their work in the next step.

Additional Guidance

Ideally, some groups will argue that the wheat can be categorized, and others will argue the wheat cannot be categorized. If there are no groups that authentically think that wheat kernel color falls into categories, you may need to problematize the next step by showing an image of how someone did categorize the wheat, such as is shown on optional **slide D**.

Plan a possible investigation to collect data as evidence for what is influencing wheat kernel color. Show **slide E** and say, *Discuss with your small group what you would expect to see as a result of these three crosses if the color was determined solely by genes and what you would expect to see if the color was determined only by the environment.*

After students have had time to discuss their ideas, come back together to share ideas with the class.

Suggested prompts	Sample student responses
If the wheat kernel color trait is controlled only by genes, what do you expect the results of these crosses to look like?	*If genes were totally controlling that trait, we would expect to see only two or three types of offspring, like we had with the cattle muscles.* *No matter what environment they were grown in, the offspring from those crosses would be the same two or three types.*
What evidence would we need to see to help us know that the environment was having an effect on the color of the wheat kernels?	*We would see different-color kernels based on whatever the environment was.* *Maybe if kernels get a lot of light, they will be lighter, or maybe they will get darker—like a tan!* *The color might change based on temperature like we saw with the apple example.*

4. Investigate wheat kernel color.

10 MIN

Materials: *Wheat Kernel Environmental Factors Investigation*, *Data Collection: Wheat Kernels*, *Steps for Using Probability to Make Predictions* (optional)

Present students with the results of an investigation that tested different crosses under different environmental effects. Pass out *Wheat Kernel Environmental Factors Investigation* showing the results of exposure to different environments to demonstrate that these distributions are the same regardless of environment.

Show **slide F** to remind students about the steps of the I^2 strategy.*

Direct students to work individually for a few minutes to analyze the data set using the I^2 strategy. When you see that most students have written their statements, direct the class to discuss their ideas with their small group.



Assessment Opportunity

Building towards: 16.A Analyze and interpret patterns in data to provide evidence that a combination of genes and environment is causing the variation we see in traits.

What to look and listen for: While students are using the *Wheat Kernel Environmental Factors Investigation* data sets, look for students to be able to determine that the results do not match what they predicted on *Data Collection: Wheat Kernels* (for either an environmental or genetic cause) based on what they know so far.

What to do:

- If you anticipate that a student may struggle to understand how to read the graphs in this lesson, you may choose to walk through the first pair of Identify and Interpret statements with all students since we haven't used this strategy yet in this unit.
- While students are working with *Wheat Kernel Environmental Factors Investigation*, take note of students who might be having trouble finding patterns or associating them with the other causes we've seen for this kind of range of variation. As needed, refer students to the Progress Tracker section of their science notebook to look for examples of similar patterns and their notes about what caused those.

Make sense of the investigation results. Display **slide G**. Bring students together to share ideas as a class using prompts such as the following.

***Attending to Equity**

Universal Design for Learning: Using the I^2 sensemaking strategy will help all students comprehend this relatively complex set of data. This strategy helps students identify and interpret important features of each graph and will allow students to see and make sense of the patterns in the data. Consider modeling one observation (WIS - What I See) and one interpretation (WIM - What It Means) with your students before they begin to work on their own.

Suggested prompts	Sample student responses
What did you notice about the data set?	*When a plant with the deepest red kernels was crossed with another plant with the deepest red kernels, all the offspring plants had kernels that were the deepest red color.* *When plants with cream-colored kernels were crossed with plants with the same kernels, all the offspring plants had cream-colored kernels.* *When a deepest red kernel plant was crossed with a cream-colored kernel plant, the offspring were plants that had medium-red kernels.*
Does this support the idea that the environment influences this trait or the idea that the alleles influence this trait?	*It seems like the alleles are influencing the trait because when the environment changed, we did not really see a change in the trait distribution.* *Plants with kernels that are deep red, medium red, or cream colored remind me of the pattern we saw with the three kinds of cattle muscles, and that trait was really heavily influenced by the alleles for the myostatin protein, so it looks like alleles are influencing these colors too.*

Make a prediction based on your claim. Display **slide H**. Say, *We saw that when we crossed plants that have cream-colored kernels with plants that have the deepest red kernels, the resulting offspring were mostly all plants that had medium-red kernels.*



Alternate Activity

If you think your students would benefit from seeing the two algorithms we can use to determine offspring probabilities while you walk through these steps as a class, you can decide to distribute optional handout *Steps for Using Probability to Make Predictions* to some or all of your students.

Suggested prompts	Sample student responses
Do you think we could use what we learned about how to predict an offspring phenotype with cattle musculature to make a prediction about parental crosses in wheat? *For example, can we use what we learned to make a claim about what alleles might be present in the plants that make medium-red wheat kernels?*	*The medium-muscled cattle had one of each type of allele.* *Maybe the plants with the medium-red kernels also have two different alleles like the medium-muscled cattle did.*

Suggested prompts	Sample student responses
*OK great, so if that is the case and if we were to cross two of the plants that have medium-red kernels, what can we predict about the offspring? (Show **slide I**.) Let's start by determining what kind of sex cells each plant can make.*	*If they have one of each allele to make their color medium red, then both can make two different kinds of sex cells.* *Half of the sex cells would have one allele, and the other half would have the other allele.*
*(Show **slide J**.) Great, how does this help us make some predictions about the offspring?*	*We could use a Punnett square to see how they would combine during fertilization.* *We could also use the probability calculations to see the probability of each kernel color variation.*
*(Show **slide K**.) So what does this mean about what you think we will see? What is the probability that an offspring would produce medium-red kernels? Deepest red kernels? Lightest cream-colored kernels?*	*We should see some plants that have dark-red kernels, some that have cream-colored kernels, and some that have medium-red kernels.* *About half of the plants should have the medium-red kernels and 25 percent should have cream-colored kernels and the other 25 percent should have dark-red kernels.*
*(Show **slide L**.) OK, I agree that those predictions make a lot of sense. Let's check the results of the cross. (Show **slide M**.) Were these the results we predicted?*	*No!* *Almost all the offspring were still producing medium-red kernels!*

5. Obtain information about how wheat kernel color is determined.

10 MIN

Materials: *Color of Wheat Kernels*

Read about how wheat color is determined. Display **slide N**. Pass out the *Color of Wheat Kernels* reading that gives an explanation that three genes, with three pairs of alleles that lead to the production of a red pigment or not, contribute additively to red coloration in wheat kernels. Instruct students to highlight important ideas as they read so they are prepared to share them with the rest of the class.

Discuss what we learned from the reading. Ask students to turn and talk to share a few of the key ideas before coming together as a class to share what we learned.

Suggested prompts	Sample student responses
What did you learn about how the color of wheat kernels is determined?	*Wheat plants have three different chromosomes with genes that contribute to the red coloration in wheat kernels.* *There are two forms of the allele for each of the genes, one that will lead to making a red pigment and the other that does not.* *Plants have six total alleles that help determine the color, from the lightest cream to the deepest red.*
*How did having more than one gene contributing to the phenotype affect the pattern of trait distribution? (Show **slide O**.)*	*The more versions of the allele that makes pigment a plant has, the more red the kernels are.* *Plants that have all pigment-making alleles are the darkest. The ones that don't have any pigment-forming alleles have the lightest cream-color kernels.* *Different combinations of pigment- producing alleles make the different medium shades of red.* *There were a lot of different possible combinations of the alleles.*
When we look at the results of the wheat crosses shown on the slide, are there the same number of plants in each of the kernel color categories? Can you explain why that is?	*No, there are many more plants that are in the medium-red color ranges.* *There are more combinations of alleles that can make a medium-red color than there are for the lightest cream color or the deepest red, so plants with those kernel colors are not as common.*

Additional Guidance

If your state assessment will expect students to recognize the terms *dominant* and *recessive* and name the patterns of inheritance tied to these words, you may choose to introduce them during this lesson in the context of wheat kernel color. You can discuss why the alleles that lead to red pigment would be considered **dominant** to the alleles that do not lead to production of that pigment and how that relationship results in a classical dominant/recessive pattern. However, resist the urge to equate "makes a product or protein" with "dominant," because this is not always the case (such as with Huntington's disease).

6. Make predictions about kernel color.

10 MIN

Materials: *Color of Wheat Kernels*

Use what we learned to make some predictions. Show **slide P** and ask students to turn and talk about the question posed on the slide: Can you use what you learned to make a reasonable determination about which of these plants would produce kernels that are more red? Encourage students to use *Color of Wheat Kernels* reading to help them make sense of the images.

Key Ideas

Purpose of this discussion: To explore an example of a trait variation where multiple genes contribute to a wider range of phenotypic outcomes than we saw with the single-gene influence of the two alleles for myostatin.*

Listen for these ideas:

- It is possible for organisms to be different genetically but still have the same phenotype.
- It is possible for organisms with different phenotypes to look different but still have very similar genes.

Bring the class back together to discuss these ideas and give students space to share.

Suggested prompts	Sample student responses
What predictions did you have about the phenotype of these two plants?	*Both plants have three versions of the alleles that would lead to the production of pigment, so they should be the same shade of red.*
So are you saying the two plants have the same genes?	*No, they actually have different alleles on each chromosome, but they still will look the same.*

Show **slide Q** so students can visualize the connection between the genotype and relative production of pigment.

Then show **slide R** so students can see another example (plants 3 and 4). Have students turn and talk again to make predictions then share ideas with the class.

Suggested prompts	Sample student responses
What predictions did you have about the phenotype of these two plants?	*Plant 3 has five chromosomes with the allele that will lead to pigment production, and Plant 4 has only four.* *Plant 4 will not make as much pigment, so it will be slightly lighter red.*
*(Show **slide S**.) So we are seeing a different genotype which led to the phenotype being different. But how many of the genes were different?*	*Only one was different. They actually have the same version of the alleles on most of the chromosomes.*

*** Attending to Equity**

We acknowledge that a polygenic trait is more complex than might be expected for students to explore in the middle school grade band, but we felt strongly about giving students a concrete example of genotype influencing phenotype differently than they saw with myostatin. Beginning to explain the effect of multiple genes on the range of wheat kernel color allows students to identify that organisms can have different genotypes but have the same phenotype or that organisms could look quite different and have quite similar genes. This additional angle impacting how genetic factors can influence the range of variation we see in living things (such as musculature beyond animals influenced by the myostatin mutation), in addition to the many environmental factors students are considering, is important for students to understand to have a fuller understanding of the complexity of these interactions.

Suggested prompt	Sample student responses
That is interesting. The last set of examples had plants with kernels that were the same color, but most of their chromosomes had different alleles. What do you think that means for how our genes impact phenotypic variation?	*Two organisms might be pretty different genetically but still have the same phenotype.* *Two organisms with different phenotypes may look different but still be practically the same genetically.*

Connect what we learned to our existing explanation for musculature in cattle. Show **slide T** and facilitate a discussion to surface the idea that there is more variation in general cattle musculature than we could really explain with only one gene.

Suggested prompts	Sample student responses
Since we used what we know about genetics to help us figure out wheat, let's think about this a little more. How are the patterns we saw in wheat coloration and alleles similar to the patterns we saw in offspring of crossing cattle that were both medium muscled? How are they different?	*Both wheat kernel color and cattle muscularity have specific genes and alleles associated with those traits.* *There were only two alleles that contributed to the trait for cattle muscularity.* *There were three different combinations of those alleles in cattle.* *There were three different phenotypes in the cattle—heavily muscled, medium muscled, and typically muscled.*
But if you look at the cattle shown on this slide, does it seem like there are really only three categories of muscularity?	*Well, it is definitely easy to tell which are the heavily muscled cattle, but some cattle look pretty well muscled even when they have both alleles for typical muscles.* *It is kind of difficult to tell the difference between some of the typical cattle and cattle with one copy of the allele that causes extra-big muscles.*
What could be a reason that not all the cattle that have the same alleles look exactly the same with regard to their musculature?	*Maybe there is a difference between the cattle who are doing heavy work and those that just lay around.* *Maybe some are not getting enough food to be able to build bigger muscles even if they have an allele that would make them bigger.* *Maybe there are more alleles that affect what the muscles look like than just the one that causes myostatin.*

Navigate to explaining our final example using our model. Say, *We have made good progress today on figuring out how genotype can be even more complicated when we start considering the ways different genes can interact to give a range of phenotypes. But what about the final unexplained trait we looked at in Lesson 11—the length of a person's arm span? Do you think we can use what we have learned so far to explain the variation in this trait? Will we be able to use our classroom consensus model to completely explain the variation in arm span? That is what we will investigate next time.*

End of day 1

7. Collect and organize arm span data.

10 MIN

Materials: *Arm Span Histogram Instructions* (optional), 1 tape measure, 1 meterstick or other measuring tool (optional), clear packing tape (optional), 1 set of *Arms Photos* cards from Lesson 11, table on chart paper or shared spreadsheet for collecting arm span data

Navigate into today's work. Display **slide U**. Lead a quick discussion to surface the ideas we figured out last time. Establish that we wanted to investigate the different impacts of genes and environment on arm span. Refer to the *Arms Photos* card set from Lesson 11 and use prompts such as the following to navigate into today's work.

Suggested prompts	Sample student responses
When some of you sorted and tried to categorize arm spans in Lesson 11, what did you figure out?	*They were hard to categorize—there were a variety of different lengths.* *Arm spans come in a range, not just specific lengths.*
Do you think arm span length is influenced by environmental factors or genetic factors?	*I think genes influence your body size—like my whole family is really tall and we have long arms.* *It might be related to the environment, too—you can't grow well if you don't have healthy food to eat.* *Aren't there some health conditions that affect a person's size? Are those related to genes or environment?* *I think it might be both—genes and environment could play a role.*
We already have some arm span data from the Lesson 11 cards, but why would it be helpful to have more than just those dozen or so measurements in our sample?	*If we have more data, we can better understand the similarities and differences between people's arm spans.* *It's hard for a small sample size to fairly represent a large group, so if we have a larger sample size, we would know better if what we're figuring out applies to more people than only those folks in the photos.*

Introduce the idea of collecting and using more arm span data. Show **slide V** and say, *We can collect arm span data from our own class. Other middle schoolers around the country who are using this unit have also been measuring their arm spans. We can combine our data with theirs so other students using this unit have a nice large sample to explore.*

Give directions for measuring arm spans. Have volunteers help you demonstrate how to work as a group to measure arm span in one of two different ways, depending on how you planned to collect this data (see the Materials Preparation section for more instructions).

- For one option, have the person being measured stand back against the wall where you have taped meter sticks and/or other measuring tools, with one middle fingertip at zero and arms stretched as far as they will reach, and read the measurement at the other middle fingertip.
- For another method, away from the wall, have one helper hold a tape measure at the back of one arm being measured (starting at the middle fingertip) and have another helper stretch it across the person's back to their other middle fingertip, again, with arms stretched as far as they will reach. Refer students to the images shown on **slide V** for a visual representation of the measurement.

Give directions for recording data. If you would like your students' anonymous data to be added to the Arm Span Data Set (which students will use in the next step), share this Google form link Arm Span Data Survey (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) They will enter only a number: their arm span in centimeters. No other information will be collected.

Distribute tape measures to groups, if needed, or direct them to the measuring tools taped to the walls. Instruct students to efficiently collect and record their data.

Alternate Activity

Body size and stature can be a sensitive topic for people of any age, but especially for middle schoolers. We have provided the Arm Span Data Set (to which students can anonymously add their data) so future students using this unit will be more likely to see the shape of the curve we are looking for when they graph the data, but also because more data points can help students be less likely to feel like the rest of the class is noticing their personal measurements. However, if you have concerns about asking your students to collect their arm span data, feel free to skip taking measurements and just analyse the data provided in the data set.

If you do have students collect their arm span data, but you do not want to contribute to the data set, simply have students list their arm spans on a white board, chart paper, or shared spreadsheet for discussion before you go on to use the data set and tool to visualize the variations in arm span lengths.

Once students have collected their data and recorded the measurements, discuss as a class how they might represent their data in order to best examine the patterns of variation.

Suggested prompt	Sample student responses
We collected a list (or we have a list, if you did not collect your own) of numbers representing our arm spans. Is it very easy to notice any patterns that might help us understand this trait better?	*Not really, especially if the numbers aren't even in order.* *We could tell there are many different sizes, but we cannot really see how many individuals have each size.*

Suggested prompts	Sample student responses
What would be our first step in organizing the data?	*We need to decide how many categories of the trait there are so we can count how many people are in each category and create a graph.*
How can we decide how to make the categories? Will how we decide that have an effect on the patterns we can see from our data? For example, what if we decided we want only two categories? How would that affect the patterns that emerge?	*Well, if we only had two categories we wouldn't really see a pattern.* *We would not be able to see whether there is a lot of variation because it would look like there are only two versions of arm-span length, and that is not true.*
OK, so what if we had fifty categories?	*That is a lot, so it would show the variation.* *It depends on how large our sample is—that would probably be better, but it would take a lot of time to organize the data into that many groups.*

Say, *When working with large sets of data it can be really cumbersome to figure out how to make our categories. Luckily there are tools to help us do this.*

8. Visualize data using a web-based graphing tool.

5 MIN

Materials: computer (optional), *Arm Span Histogram Instructions* (optional), *Arm Span Data Set* (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Use an online tool to co-construct a histogram of middle-schoolers' arm span data. Show **slide W** and open the Arm Span Data Set and graphing tool. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Follow the steps after the "Key Ideas" box to work together as a class to create and modify a histogram of the arm span data.

Alternate Activity

The graphing tool available for this data set allows students to interact with this data set in many fun ways. If time and computer access allow, let your students explore the Arm Span Data Set and graphing tool on their own before discussing it as a class. The instructions found here in this Teacher Guide are available as a handout (*Arm Span Histogram Instructions*) for you to print and distribute.

Key Ideas

Purpose of this discussion: Work together as a class to adjust the interval sizes on the histogram of arm-span lengths, trying to find a representation that reflects the variation we see in this trait.

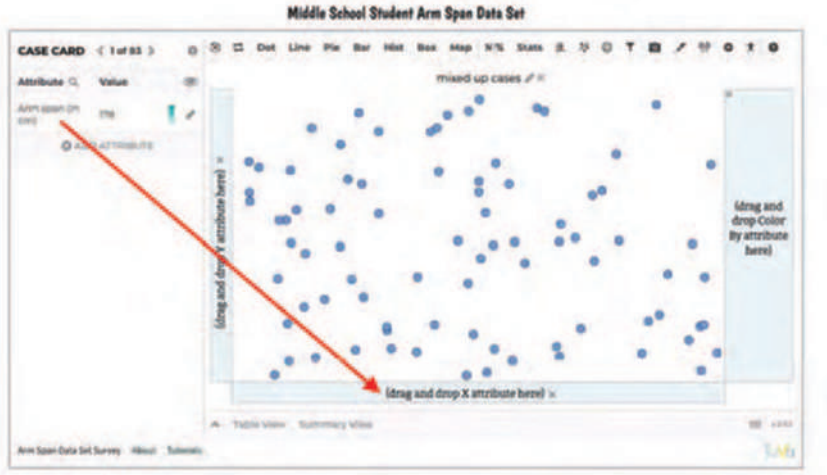
*** Supporting Students in Engaging in Using Mathematics and Computational Thinking**

As we analyze the data as a class by creating a histogram, this online tool helps students get an immediate visual representation of how our data change when we change the interval size. Be sure to use the suggestions of the class to change the sizes and pause to ask students to reflect on how the different representations may be more or less useful with regard to understanding the trait variation in a population.

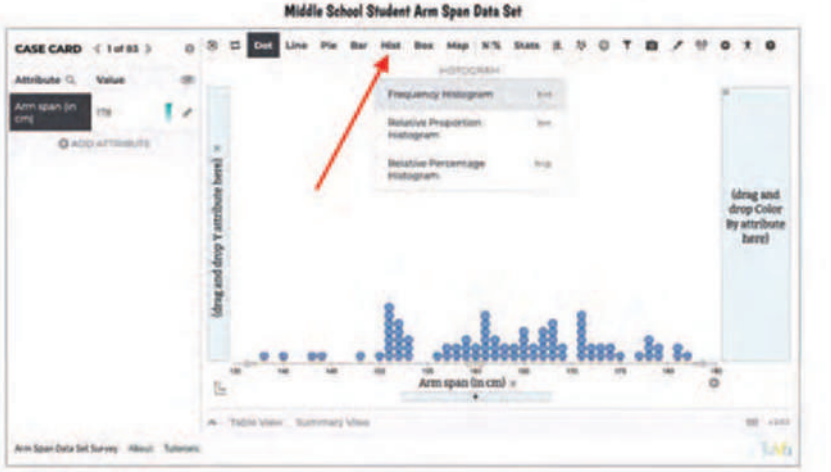
Listen for these ideas:

- When the histogram's intervals ("bin" sizes) are smaller, it's easier to see the distribution of lengths throughout the range—we can see that the middle or medium lengths are most common and the shortest and longest lengths are less common.
- When the histogram's intervals are larger, it's harder to see the range of variation.
- Even with the help of a digital tool, it's difficult to categorize arm-span lengths into groups. The divisions between groups are so arbitrary—is the longest length in one bin really very different from the shortest length in the next bin?

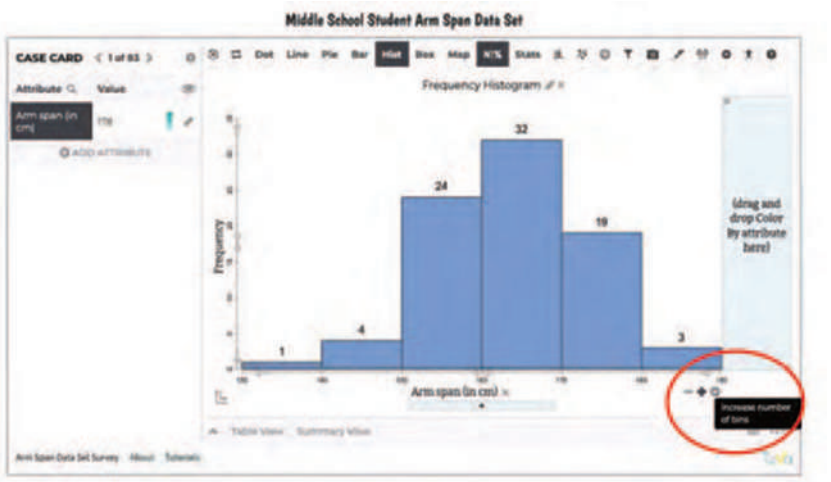
1. When you first open the data set in the online graphing tool, data points will be scattered on the field. Your first step is to drag the "Arm span (in cm)" attribute to the X-axis.



2. The graphing tool will default to organizing data in a dot plot, but we want to use a histogram. So, choose "frequency histogram" from the top toolbar.



3. The histogram will default to 6 bins (the minimum number the tool will allow). You can adjust the number of bins using the gray minus and plus buttons in the lower-right corner of the graph. Think aloud as you are taking student ideas and using them to modify the interval sizes.*



Suggested prompts	Sample student responses
Hmm, this histogram with six groups (called "bins") looks like the wheat histogram we saw last time. What do you think about that?	*Are wheat colors and human arm span lengths the same categories?* *Are there only six?* *Would it be influenced by three genes like wheat color?* *Can we look at the data differently?*
Are there only six different arm span lengths?	*No, we know we had more than six just in our class (or on the cards).* *I think the tool is just grouping by easy intervals, like 140-149, 150-159, 160-169, etc.*
Let's see what this cool tool can do to help us see the variations better. Do you see how we can adjust how the histogram is set up? What happens when we make the bins smaller?	*With more/smaller "bins" the mountain shape looks "smoother."* *It seems to show the variety of arm span lengths better when we have the smaller bins.* *With more bins, it reminds me of the continuous range like we saw with planaria colors (even though we didn't graph those), but with fewer bins, it looks like what we saw with wheat kernels.*
What had more influence on wheat kernel color: genetic or environmental factors? How about planaria?	*Genetics affected the wheat kernel colors more—light and temperature differences did not.* *Environmental factors influenced the planaria colors—they were a continuous range, like our arm span measurements.*

Optional **slide X** is provided if you would like to save a screenshot of the histogram your class decided best represented the arm-span data.

Transition to obtaining information about the causes of arm-span length variation. Say, Now that we've analyzed a large sample of arm span data, think back to your predictions about the causes of this variety of arm span lengths. *We have observed examples of this kind of range of variation in a trait being caused by different factors. Has your thinking changed about what you think causes the range of variation we see in arm spans?*

Accept all responses.

9. Read and model individually about the impact of genes and environment.

10 MIN

Materials: *Arm Span Length*, *Arm Span Reading and Modeling*

Introduce the independent work of obtaining, evaluating, and communicating information. Say, *Next, you will work by yourself to read an article and obtain information about what is known about this arm-span-length trait. Then create a model with different-sized arrows—like we have in our consensus model—to show the impact of those factors on this trait. You each use your model to communicate with your small group, and your group mates will share their models and information with you. We will read, draw models, and share all during today's class.*

Review expectations for obtaining, evaluating, and communicating information. Display **slide Y**.

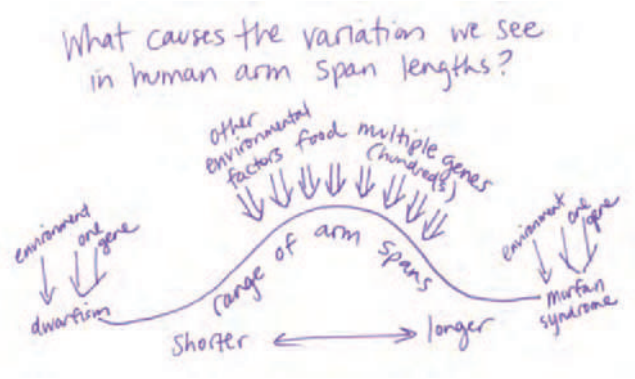
Say, *You've had practice obtaining information from scientific text and evaluating sources for reliability. You also had a chance to practice communicating with others when you created and shared your slides about organisms that reproduce asexually. Today you will be working more independently to practice these skills, but we will also be giving and receiving feedback about our models to help one another create the most clear explanations we can. See if you can give me a recap about the communicating part for today's work.*

Suggested prompts	Sample student responses
Who will be your audience today?	*Ourselves, but just a small group, not the whole class.*
What is your purpose for sharing the information you learn?	*Each of us will explain the causes of arm-span trait variation that we obtained from the article.* *Sharing and hearing from others will let us check to make sure we understood the information in the article.* *We will also help one another improve or clarify our models with the feedback we share.*
What are the constraints for your communication today?	*You said you already have an article for us, so we are not looking around the whole internet for information.* *We're reading, drawing a model, sharing, and giving feedback all in today's class, so it needs to be pretty quick.* *Everyone in the group will need time to share.*

Suggested prompt	Sample student responses
How will we communicate this information? Why have we chosen this method?	*We are drawing models, and we should use the same convention about the sizes of arrows showing how much influence a factor has.* *Everyone using the same style of model will help us compare the different factors.* *We will also have to talk a little bit—not too long, but just enough to explain why we made the arrows the sizes we did.* *We will use sticky notes to add feedback on each other's models so we are not writing directly on their stuff but they can still see the feedback easily.*

Distribute the *Arm Span Length* text and *Arm Span Reading and Modeling* handout to everyone. Display **slide Z** and direct students to work quietly and independently for 10 minutes.

An example of one way students might model their ideas about the causes of variation in arm span is shown here. Your students' models might look different but represent similar ideas.



Assessment Opportunity

Building towards: 16.B.1 Develop and use models to show multiple causes of variation within a trait.

What to look and listen for: Students should be able to draw their own model on *Arm Span Reading and Modeling*, following the same different-sized-arrow convention, to show the approximate relative amounts of genetic and environmental causes of arm span variations.

What to do: If students are struggling to draw different-sized arrows to represent the different causes, ask if they would be more comfortable with another indicator of the relative impact of each factor; maybe the size or thickness of the lettering they're using, or heavy underlines or boxes around the more-impactful factor(s) would make more sense to them.

10. Share student models and explanations in small groups. 5 MIN

Materials: 2-3 sticky notes, *Arm Span Reading and Modeling*

Meet in small groups to share and compare the models and explanations they created. Direct students to circle up in their small groups. Display **slide AA** and review the instructions for sharing:

1. Lay your handout with your model in front of you so others in your group can see it.
2. Find and discuss similarities and differences among the models in your group.
3. Turn and talk with a neighbor in your group to explain the reasoning behind your model.
4. Exchange models with that same neighbor and use 2-3 sticky notes to provide feedback and ask clarifying questions.

After students have had a few minutes to carry out steps 1-3, advance to **slide BB** to show guidance about providing feedback. Ask students to provide feedback that might help their partner's model clearly show the cause-and-effect relationships that result in the phenotype.

Say, *Consider the feedback you got from your partner as we discuss how to revise our classroom consensus model about cattle muscles to represent the idea of differing impacts of genetic and environmental factors.*

11. Consensus Discussion About the Impact of Genes and Environment on Traits 7 MIN

Materials: *Arm Span Reading and Modeling*

Hold a Consensus Discussion about the impact of genes and environment on different traits. Display **slide CC**. Bring the class together into a Scientists Circle with their *Arm Span Reading and Modeling* handout.

Key Ideas

Purpose of this discussion: Students share their evidence about different influences on variations of traits in order to find consensus about how genes and environment impact trait variation differently.

Listen for these ideas:

- Different traits and/or variations within a trait are influenced differently by one or more genes and by environmental factors, such as diet, temperature, or amount of sunlight.

Suggested prompts	Sample student responses
What did you learn from your group discussions about the role of genes or environmental factors on the arm-span trait?	*The reading about peoples' arm span said the length of your limbs is influenced more by genes, but it is so many different genes they are still trying to figure out how most of them work. They said over 700 genes play a role in arm-span length!* *The environment also influences limb length—people's bodies won't grow as well if they're not eating nutritious food or if they're getting sick all the time.* *Scientists know of some single genes that can cause very rare disorders where people have shorter arms or longer arms than usual, but those are really uncommon. In those cases, like with our cattle, the environment would not matter as much as having that gene. But for most people, it is both genes and environment that affect limb length.*
Before this lesson, you also read about flamingo coloration and about the color of apples. How do those traits compare to what we learned about here with arm-span length?	*Flamingo coloring is based almost entirely on what they eat: flamingos are born gray and would be white or pale pink if they did not eat certain algae and shrimp—the pigment in their food turns them bright pink or orange.* *Apple coloring seems to be maybe half and half genes and environment. Certain apples are always green because of their variety's genes, like Granny Smith, so the environment does not matter so much for them. But most apples have genes that can get them to turn red, but they need the right temperature and the right amount of sunlight to actually get that red color to happen.*
So how could you summarize what all these different examples show about the role of genetic and environmental factors on trait variation?	*It is always some of both—more or less depending on the trait—but organisms grow the way they do because of both genetic and environmental factors.*

Additional Guidance

If students have asked deterministic-like questions (e.g., "Are genes my destiny?"), you could come back to them now that students have figured out how genetic and environmental factors both influence traits.

12. Revise classroom consensus model to include environmental factors and multiple genes.

8 MIN

Materials: *Arm Span Reading and Modeling*, science notebook, classroom consensus model, markers, chart paper (optional), *Cattle Photo Cards* from Lesson 1 (optional)

Consider the range of muscle variation in cattle. Display **slide DD.** Say, *Let's revise our classroom consensus model to show this understanding we've built about the differing influences of environmental and genetic factors on a trait. One of the things we figured out is that the causes of trait variations can be different for different positions along a range of variations.*

You may choose to reference the *Cattle Photo Cards* from Lesson 1 as the class considers the range of cattle muscles in all kinds of cattle.

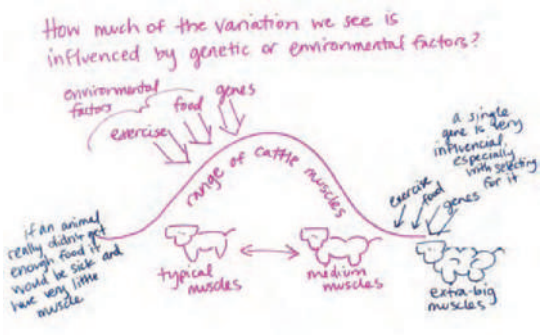
Suggested prompts	Sample student responses
There are 93.6 million cattle in the United States. If we imagined a graph of the distribution of cattle musculature, what do you think it would look like? Why?	*We would have the muscle sizes along the bottom of the graph, from typical (or even smaller than typical?) on one side and heavily muscled on the other side.* *I've seen a lot of cattle, but I hadn't seen the heavily muscled ones until we started investigating them in class, so I think they're pretty uncommon. I think the graph would dip way down on the heavily muscled end—they're on the extreme.* *Most of the cattle being typically or medium muscled would mean a wider and higher bump in the middle of the graph.* *There might be a few smaller-than-typical-muscled cattle at the other end, too, like if they were sick and not getting enough food or exercise.*
I hear you describing a curved shape, rather than distinct "bins"—what makes you think that?	*There's a range of cattle muscles, like we had a range of arm spans.* *We looked really carefully to identify the muscle types of the collection of cattle we were studying, but those were only 35 or 40 cattle out of the 93.6 million in the United States, and they had the allele for the different myostatin.* *Cattle that don't have that different allele will probably have a range of sizes and muscles like we saw with people's arms because the environmental factors will affect them more.*

Turn and talk about how we should revise our classroom consensus model. Display **slide EE**. Direct students to turn and talk with a partner about how we could revise our classroom consensus model to show the different impacts of genetic and environmental factors on cattle musculature.



Bring the class together to revise the consensus model to reflect our ideas about the different impacts of genes and environment on an organism's phenotype. As you elicit ideas from the class, look for a thumbs up or thumbs down indication of group consensus before making those changes on the classroom consensus model.

See the example here of what a final classroom consensus model may look like, and on the next page how you might place it in relation to the other models the class has developed during the unit.





Assessment Opportunity

Building towards: 16.B.2 Develop and use models to show multiple causes of variation within a trait.

What to look and listen for: When suggesting revisions to the model, students should point out the need to show multiple causes of both the heavily muscled and typically muscled phenotype in cattle. These causes do not carry the same weight of influence on the different phenotypes, so students should suggest a way (such as larger or smaller arrows) to represent these different causes.

What to do: Refer students to previous versions of the classroom consensus model to see how we have used different-sized arrows to communicate different weights of influence.

Additional Guidance

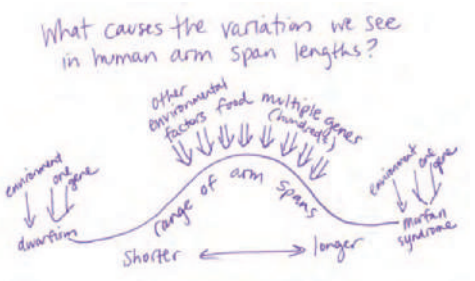
There are many possible ways to create this final class consensus model. The most important element is to have some way to clearly show that (1) traits have multiple environmental factors and multiple genetic factors causing variation and (2) for any given trait each of these factors may have more or less of an impact. Encourage students to describe various options for representing these ideas, asking follow-up questions, inviting other students to rephrase ideas being shared, and offering the marker to students to sketch on the chart paper, as needed. Do your best to use their ideas to make the model come to life.

If time allows, update Progress Trackers. Say, *Let's use our Progress Trackers to summarize what we figured out in this lesson. Pick any of the examples we have studied, or choose an example of your own, and use our model to explain the variation found in that organism.*

Display optional **slide FF** and give students about 5 minutes to work.

In the example two-column Progress Tracker row for this lesson, each of the columns has been completed with *possible* student ideas.

Question	What I figured out in words and/or pictures
How much of trait variation in a population is controlled by genes or the environment?	• Some trait variations, such as heavily muscled animals, are much more influenced by genes than environmental factors. • Traits are also influenced by many genes that can result in a range of variation. • Other trait variations, such as the color of a flamingo, depend more on environmental factors, such as what they eat. • We used bigger or smaller arrows to show relatively how much influence different factors have on variations of a trait. • The sizes of the arrows can be different depending on the trait.



ADDITIONAL LESSON 16 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.SL.8.1.A Come to discussions prepared, having read or researched material under study; explicitly draw on that preparation by referring to evidence on the topic, text, or issue to probe and reflect on ideas under discussion.

In this lesson, students are responsible for reading about, thinking about, and sharing about the causes of variation in a trait. When communicating this information to their peers, students are expected to refer to evidence in the text they read to support their ideas.

Supporting Students in Making Connections in Math

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

Students co-develop and analyze a histogram of arm span data.

CCSS.MATH.CONTENT.7.SP.C.5 Understand that the probability of a chance event is a number between 0 and 1 that expresses the likelihood of the event occurring. Larger numbers indicate greater likelihood. A probability near 0 indicates an unlikely event, a probability around 1/2 indicates an event that is neither unlikely nor likely, and a probability near 1 indicates a likely event.

CCSS.MATH.CONTENT.7.SP.C.7 Develop a probability model and use it to find probabilities of events. Compare probabilities from a model to observed frequencies; if the agreement is not good, explain possible sources of the discrepancy.

Again in this lesson, as in Lessons 8 and 13, students use probability calculations to predict the outcomes of certain parental crosses.

Making New Individuals

1 Reproduction: A Comparison
2 When Is an Offspring Just Part of the Parent?
3 A Shark Reproduction Whodunit
4 Nature and Nurture: Checking In with the Dunking Duo

Literacy Objectives

- ✓ Summarize key points related to asexual reproduction and traits.
- ✓ Organize related details about clones and cloning.
- ✓ Contrast pros and cons of asexual and sexual reproduction.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 14–16.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a well-reasoned paragraph in response to the reading.

Instructional Resources

Student Reader



Collection 5

Science Literacy Student Reader, Collection 5
"Making New Individuals"

Exercise Page



EP 5

Science Literacy Exercise Page
EP 5

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 14: (How) do other organisms reproduce without sperm and eggs?
- Lesson 15: How do we get variations if the genetic information is exactly the same?
- Lesson 16: How much of trait variation in a population is controlled by genes or by the environment?

Standards and Dimensions

NGSS

Disciplinary Core Idea LS1.B: Growth and Development of Organisms Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (secondary to MS-LS3-2)

Science and Engineering Practices: Analyzing and Interpreting Data; Obtaining, Evaluating, and Communicating Information

Crosscutting Concept: Patterns

CCSS

English Language Arts

RST.6-8.5: Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6- 8 text complexity band independently and proficiently.

WHST.6-8.2.B: Develop the topic with relevant, well-chosen facts, definitions, concrete details, quotations, or other information and examples.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

clone

epigenetic

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

genet

parthenogenesis

ramet

skeptic

stressor

viable

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Genetics unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.

- *First, you will interpret a table that describes the advantages and disadvantages of two forms of reproduction—sexual and asexual.*
- *Next, you'll read the transcript of a conversation between a fictitious brother and sister about redwood trees and the meaning of life and death.*
- *Then, you'll read an article about shark reproduction and learn that some species can reproduce by both sexual and asexual reproduction.*
- *Finally, you'll catch up with the high school basketball buddies, Isaiah and Gabe, from this unit's preface. After two years, have they decided who was right about what it takes to dunk a basketball?*

- Distribute Exercise Page 5. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to generate an informative paragraph on the topic of cloning that contains supporting details from the readings in Collection 5.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

Exercise Page



EP 5

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What type of reproduction leads to greater genetic diversity—sexual or asexual reproduction?	*sexual*
What do genets and ramets have to do with cloning?	*They are the names of the parent and offspring when a redwood tree clones itself.*

Suggested prompts	Sample student responses
What kinds of ocean-living organisms can reproduce by parthenogenesis?	*sharks and other cartilaginous fish*
What evidence did Gabe give that the exercise app helped him?	*He said he added more inches to his vertical leap than his friend Isaiah did.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
How would the genotype and phenotype of the offspring of a bacterium compare to that of its parent?	*The genotype would be identical and so would the phenotype.*
How does the genotype of a cut-down redwood tree compare to the genotype of the ring of offspring that grow from its roots?	*They have the same genotype.*
How do environmental factors affect a zebra shark's method of reproduction?	*When there are no male sharks around, a female shark can switch to asexual reproduction.*
Would a clone of a basketball player be able to dunk equally as well as the "parent"?	*Not necessarily. Environmental factors such as practice are needed to be a good dunker, too.*

- Refer students to the Exercise Page 5. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to develop a well-constructed paragraph discussing the topic of cloning and using details from as many of the readings in Collection 5 as you can.*
  - *The term* clone *is informally defined in the collection, and we've also done so in our class discussions.*
  - *While there is some discussion of human cloning in the last reading, you should look elsewhere in the collection for details about the costs and benefits of cloning.*
  - *The important criteria for your work are that you define cloning accurately, use supporting details from the selections in Collection 5, and write clearly and understandably.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page



EP 5

4. Facilitate discussion.

(FRIDAY)

Facilitate class discussion about the reading collection and writing exercise. There are four readings in this collection, each having one or more details related to clones or cloning. Students will need to synthesize what they learn about this topic to complete their writing exercise.

Pages 44–53 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "Reproduction: A Comparison"?	*It compares the costs and benefits of these two methods of reproduction.*
If there are more disadvantages than advantages to sexual reproduction, why do so many species use it?	*because the one advantage—greater genetic diversity in a population—must be more important for the survival of the species than all the disadvantages*
What is a clone?	*It is the offspring produced by asexual reproduction and has all the same traits as the parent it came from.*
What is the general purpose of the second selection, "When Is an Offspring Just Part of the Parent?"	*It compares two ways of thinking about the relationship between a fallen redwood tree and the offspring that grow from its roots.*
How would you summarize the disagreement between the brother and sister about the nature of the redwood ramets?	*The brother thinks the ramets are part of the parent tree, not offspring. The sister thinks the ramets are offspring, or the next generation.*
What environmental stressors might result in a redwood tree producing clones?	*if the parent tree is burned down, cut down, or has some other kind of damage*
After a wildfire, where should foresters check to see if a redwood tree will be able to produce ramets? Explain.	*They should check underground and see if the roots are still healthy, because the ramets grow from the roots.*
What is the general purpose of the third article, "A Shark Reproduction Whodunit"?	*It describes scientists' observations of female sharks reproducing when no males are around and then explains how it happened.*
How were you able to use context to infer the meaning of the word viable *in the timeline?*	*I could tell the word means "alive" or "healthy" because the next sentence said four shark pups hatched.*
How are shark parthenogenesis and redwood fairy circles similar and different?	*They are both examples of asexual reproduction, but parthenogenesis produces offspring from an unfertilized egg, and fairy circles are trees that are produced from the budding tissue in the parent's tree roots.*
What is the general purpose of the fourth article, "Nature and Nurture: Checking In with the Dunking Duo"?	*It continues the story from the Preface about two friends and compares the progress they made in their growth and vertical leap abilities.*

Student Reader



Collection 5

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—If students are unfamiliar with the term *cartilaginous fish*, explain that this class of organisms includes sharks, skates, rays, sawfish, and ghost sharks. Point out that, instead of bone, their skeletons are made entirely of cartilage. Have students feel the tips of their noses and notice that the cartilage below their skin gives shape to their nose but is also flexible.

CHALLENGE—Students may be intrigued by the idea that humans may someday be cloned. Scientists, medical doctors, philosophers, ethicists, and legal scholars agree that the risks are too great to allow human cloning. Challenge students to use credible sources to learn what the potential benefits and risks are of human cloning and share their findings with classmates as a T-chart or concept map.

Pages 44–53 Suggested prompts	Sample student responses
What does the phrase "Nature and Nurture" mean?	*"Nature" is the traits that come from your genes, and "nurture" is traits influenced by your environment.*
Why is it probably a good idea to be skeptical about apps that have monthly fees?	*The people who make and sell the apps want to make money, so they may be exaggerating claims about the benefits of using their app.*
Do you agree or disagree that buying the VertiCalisthenics app was a good deal for Gabe? What data support your answer?	*agree, because Gabe increased his vertical leap by four inches using the app, while Isaiah increased his leap two inches at best without the app*
Gabe has read about epigenetic factors that affect the expression of genes. What reliable sources could you use to learn more about this topic?	*ask a medical doctor* *interview a geneticist* *ask a reference librarian for materials* *read articles in online encyclopedias* *read online articles posted on college, university, hospital, science museum, or government websites*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 5, students should write a well-constructed paragraph about the topic of cloning that includes the details requested in the bulleted list on Exercise Page 5.

- The content of the paragraph's topic sentence is left up to the students. It should summarize the paragraph to come, for example, "Cloning is a very interesting science topic, but whether it should be used on humans is uncertain."
- A description should include that a clone is an exact copy of a single parent. Look for evidence throughout the paragraph that students understand that a clone is a product of asexual reproduction.
- Organisms mentioned in the collection that can clone themselves include bacteria, strawberry plants, redwood trees, and zebra sharks.
- The benefits and costs of human cloning can draw on the detailed costs and benefits of asexual reproduction in the first reading selection.

Use the rubric provided on the Exercise Page to supply feedback to each student.

LESSON 17

Why are living things different from one another?

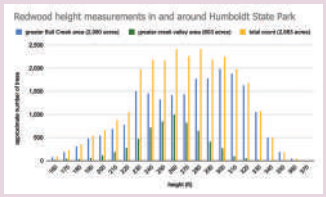
Previous Lesson

We investigated wheat kernel coloration to learn this trait is controlled by multiple genes. We updated our classroom consensus model to include this idea and the roles of environmental factors to help explain the variation we see in cattle musculature, and after learning about human arm span we extended our model to explain all trait variation.

This Lesson

Putting Pieces Together

2 DAYS



Data Source: Canopy height distribution in old growth redwood forests from www.verylargeandtallredwoods.com

The class revisits its Driving Question Board to evaluate and answer their questions. The students use this time to ask any clarifying questions to refine their understanding about their models for how living things are different from one another. Then students demonstrate understanding on a summative assessment transfer task involving redwood trees.

Next Lesson

There is no next lesson.

Building Toward NGSS

MS-LS1-2, MS-LS1-4, MS-LS1-5, MS-LS3-1, MS-LS3-2, MS-LS4-5

What Students Will Do

17.A Ask questions to clarify and refine our model explaining what causes living things to be different from one another.

17.B Construct an explanation about how environmental and genetic factors influence the growth of organisms and how organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring.

What Students Will Figure Out

- All living things have genetic information.
- Genetic information is passed from parents to offspring either sexually (which can result in variations) or asexually (the offspring get exactly the same genetic information as the parent).
- Genetic information has instructions to put together building blocks to make different-shaped proteins.
- The shape of a protein influences its job.
- Differences in those proteins in combination with environmental factors (to varying degrees depending on the trait) result in the variations that exist among living things.

Lesson 17 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Work with the class to navigate to the work in this lesson.	A	
2	15 min	**EVALUATE OUR QUESTIONS ON THE DQB** Evaluate our list for questions we have made progress on and choose three questions to answer with evidence. Use dot stickers to mark progress on the DQB.	B-D	*Questions and Answers from Our DQB*, 5 dot stickers, transparent tape
3	25 min	**REVISIT THE DRIVING QUESTION BOARD** Revisit the DQB and take stock of all the questions we've now answered. Ask new questions to clarify class models in preparation for the assessment on day 2 of this lesson.	E	*Questions and Answers from Our DQB*, chart paper, markers
4	5 min	**UPDATE OUR PROGRESS TRACKERS** Update students' 2-column Progress Trackers.	F	
				End of day 1
5	10 min	**BUILD BACKGROUND ABOUT REDWOOD TREES** Share and discuss facts about coast redwood trees in order to set the context for the summative assessment.	H-M	science notebook (optional), *Redwoods Assessment*
6	30 min	**DEMONSTRATE UNDERSTANDING ON AN ASSESSMENT TASK** Demonstrate individual understanding on an assessment about redwood trees.	N-O	*Redwoods Assessment*, class-created student-facing rubric (optional)
7	5 min	**QUICK WRITE: REFLECT ON OUR EXPERIENCES (OPTIONAL)** Complete a quick write and then discuss what was challenging and rewarding about this unit.	P	
				End of day 2

Lesson 17 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Questions and Answers from Our DQB* • 5 dot stickers • transparent tape • science notebook (optional) • *Redwoods Assessment*		• chart paper • markers • class-created student-facing rubric (optional)

Materials preparation (25 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Create the *Questions and Answers from Our DQB* handout for your class:

- Use a digital copy of *Questions and Answers from Our DQB* as a template. List on the bottom of the handout all the questions students posted on the Driving Question Board and added to the classroom consensus model in Lesson 11. You may or may not choose to include the questions your class identified as already answered on *Questions from Our DQB* in Lesson 11.
- For ease of reference you can number each of the sticky note questions and make sure the handout has the corresponding number next to that question.
- Then, print a copy for each student.
- Trim the handouts to fit into science notebooks.

Each student will need 5 dot stickers on day 1; consider cutting strips of 5 from dot sticker sheets for easy distribution.

The *Redwoods Assessment* includes color-coded maps. These maps are provided in color on **slide K** and in the *Student Edition Reference Images for Redwoods Assessment*. So, decide if you will print *Redwoods Assessment* in color or if the other color versions of the maps will be sufficient and you will print the assessment in black and white. Print one copy of *Redwoods Assessment* for each student.

You might choose to take time before the end-of-unit assessment to co-create with the class a student-facing rubric. (The provided *Rubric for Redwoods Assessment* is teacher-facing and not intended for student use during the assessment.) To develop a rubric with the class, create a table on chart paper or in a digital document with the three dimensions students will use on the assessment listed across the top, such as is shown on optional **slide G**:

- Constructing explanations
- Science ideas around variation and why living things are different
- Cause and effect

Lesson 17 • Where We Are Going and NOT Going

Where We Are Going

This is the last lesson in this unit, and students will be using the knowledge they gained to demonstrate understanding on a summative assessment. In the assessment students will be using the DCI elements LS1.B: "Genetic factors as well as local conditions affect the growth of the adult plant" and LS1.B "Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring" in the context of redwood trees.

Explaining the variety in the heights of coast redwoods gives students the opportunity to articulate one of the key science ideas they have built in this unit: the variation we see in traits is caused by both genetic and environmental factors.

If you plan to follow this unit with *Unit 8.6: How could things living today be connected to the things that lived long ago? (Penguins Unit)*, consider setting aside unanswered DQB questions from this unit that students could make progress on in that unit. Wait to re-post these questions until you're creating the DQB for that unit (or even later in the unit), when students or you recall that they had been previously wondering about an idea.

Where We Are NOT Going

Note that the *Redwoods Assessment* focuses on coast redwoods, not giant sequoias.

On the *Redwoods Assessment*, students do explain how environmental factors affect redwood growth, but they do not specifically consider the effects of climate change on the redwoods. If time and interest allow, there is an alternate extension offered toward the end of this lesson where students can obtain, evaluate, and communicate information and make connections to ideas they built in *Unit 7.6: How do changes in Earth's system impact our communities and what can we do about it? (Droughts and Floods Unit)* in the context of the effects of climate change on redwood trees.

Although redwood trees were chosen as the context for this assessment because they have not been selectively bred by humans (a contrast to many of the organisms students investigated in this unit), the work students do on the assessment does not specifically introduce ideas about natural selection. However, we anticipate that students will bring ideas from this unit and this assessment into *Penguins Unit* and build on them there.

LEARNING PLAN FOR LESSON 17

1. Navigation

5 MIN

Materials: None

Navigate to the purpose of today's class. Display **slide A.** Have students turn and talk to a partner about what the class figured out last time. Ask for a few volunteers to share their ideas. Say, *Wow, we figured out so many different pieces to help answer our big question, "Why are living things different from one another?" Let's take some time to revisit our questions on our DQB to see if we've answered any of them.*

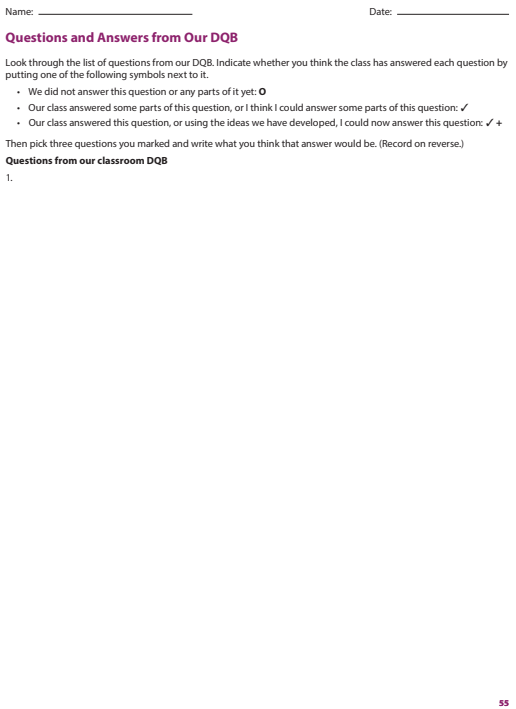
2. Evaluate our questions on the DQB.

15 MIN

Materials: science notebook, *Questions and Answers from Our DQB,* 5 dot stickers, transparent tape

Evaluate individually what questions the class has answered from the DQB. Display **slide B.** Provide students with *Questions and Answers from Our DOB,* which you created to contain all the student questions from the DQB, and have students tape it into their science notebook. Have students work individually to mark whether they think the class has answered each question, using this key:

- We did not answer this question or any parts of it yet: O
- Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
- Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓+



Name: _____ Date: _____

Questions and Answers from Our DQB

Look through the list of questions from our DQB. Indicate whether you think the class has answered each question by putting one of the following symbols next to it.

- We did not answer this question or any parts of it yet: **O**
- Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
- Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓ +

Then pick three questions you marked and write what you think that answer would be. (Record on reverse.)

Questions from our classroom DQB

1.

55

Answer three questions from the DQB using evidence. Have students choose three questions they think the class answered. Tell students to use the space on the *Questions and Answers from Our DQB* handout to write the answers to those questions and back up their reasoning with evidence from the unit.

Review and share the questions that students think we have answered. Present **slide C** and have students share with a partner their answers to the three questions. Pairs should help each other refine their answers using evidence. This is a good way for students to practice sharing responses with a partner before sharing the responses out loud to the whole group, which happens in the next activity section.

*** Attending to Equity**

Revisiting the Driving Question Board is important for students to feel as though their questions are valued and recognized. While not all questions will have been addressed (it's more likely that 60–75 percent will be at least partially answered), this helps students see that they have done this hard work to answer many of their own questions.

Mark questions on the DQB with dot stickers. Display **slide D.** Direct students to bring their handout as they walk up to the DQB and put their dot stickers on five questions they think the class made progress on.*

As they finish, have students move into their Scientists Circle. While they're waiting for classmates to join them, have students

- prepare to share evidence for answers to the questions they marked and
- look for patterns to identify which questions have the most dots.

3. Revisit the Driving Question Board. 25 MIN

Materials: science notebook, *Questions and Answers from Our DQB,* chart paper, markers

Look for patterns using the dot stickers. In the Scientists Circle, focus on the questions that have the most dot stickers.

Discuss as a class the questions the class can now answer. Present **slide E.** Have the class discuss the answers to these questions as a group. Create a Take-Aways poster to create a record of the answers the class comes up with.*



Encourage students to ask questions to help clarify the models the class has built so far. Work through these questions together to clear up the partial understandings.

Assessment Opportunity

Building towards: 17.A Ask questions to clarify and refine our model explaining what causes living things to be different from one another.

What to look and listen for: Listen for students asking questions to clarify their models and explanations for how living things are different from one another. When working through to answer questions on the DQB, new questions may arise that help clarify the models students have been developing for how genetics and environment affect trait variation. Take the time to work through these new questions as it will help students prepare to demonstrate understanding in the assessment on day 2.

What to do: If students struggle as you are discussing the various answers to DQB questions, support them with questions such as the following:

- Do *you have any questions about what _____ just said?*
- *What questions do you have that can help us make our model more clear to everyone?*

You can also give students question stems such as these:

- *How does X part of our model affect Y?*
- *What evidence can you present for _____?*
- *Why is _____ significant?*

*** Supporting Students in Engaging in Asking Questions**

Revisiting the DQB at the end of the unit helps students see the progress they have made toward answering questions that were important to them at the onset of the unit. Through the investigations in the unit and individual and whole-group sensemaking, they can now answer many of the questions.

This final visit to the DQB also allows students to ask additional questions to seek to clarify the several models the class has built over the unit to answer the driving question, "Why are living things different from one another?" This is an opportunity to help students deepen their understandings as we finish the unit and they prepare for the summative assessment.

4. Update our Progress Trackers. 5 MIN

Materials: science notebook

Add any new insights to the Progress Trackers. Present **slide F.** During the time students were revisiting the Driving Question Board and working together to answer questions, new ideas or insights may have surfaced for individual students. Have the class update their 2-column Progress Tracker in their science notebook with any additional ideas they think are important.

Close today's work. Say, *We have made so much progress figuring out why living things are different from one another. Next time, you'll have a chance to demonstrate what you've figured out.*

Additional Guidance

In order to prepare for the end-of-unit assessment on day 2 of this lesson and to support your students while they work on it, you may take time before the assessment to co-create with the class a student-facing rubric. (The provided *Rubric for Redwoods Assessment* is teacher-facing and not intended for student use during the assessment.) To develop a rubric with the class, create a table on chart paper or in a digital document with the three dimensions students will use on the assessment listed across the top, such as is shown on optional **slide G**:

- Constructing explanations
- Science ideas around variation and why living things are different
- Cause and effect

Have students discuss and work together as a class to list what they expect to do and words or ideas they expect to use when constructing an explanation about what causes variation in living things. Then you could display or print this rubric for students to use as a tool during the assessment.

End of day 1

5. Build background about redwood trees. 10 MIN

Materials: science notebook (optional), *Redwoods Assessment*

Introduce the assessment goal. Say, *We have looked at many interesting organisms during our study of why living things are different from one another. Today you will be presented with an organism that we haven't investigated yet and is one that humans have not selectively bred. You'll be asked to explain the variation in one of its traits. This scenario is our end-of-unit assessment, which will be an opportunity for you to demonstrate what you have figured out in this unit.*

Distribute the *Redwoods Assessment*, which includes the information you're about to share with the class and space for students to take notes during these discussions, if they wish.

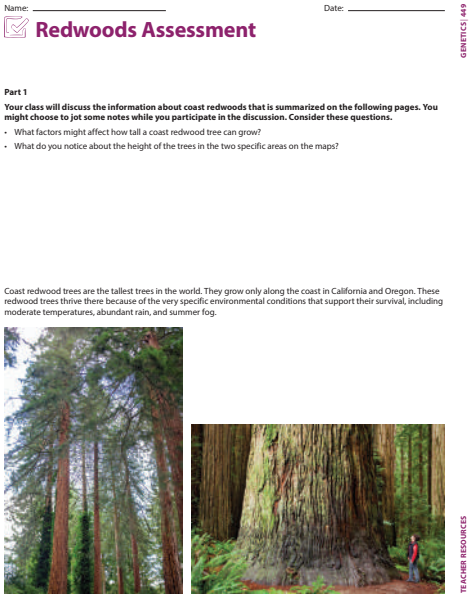
Orient students to the context of the assessment. Display **slide H**. Explain that today's assessment task focuses on coast redwood trees.

Say, *I have some information to share with you about redwoods and how they reproduce so you have some background knowledge about these trees. We'll have some discussion about this information, but it will also be available to you for reference on your assessment, so you don't need to worry about remembering all these details—just start thinking about how they might connect to what you've figured out in this unit.*

Share the following information with the class to build their background knowledge about these trees.

Say, *Coast redwood trees are the tallest trees in the world. For context, that person in the photo is six and a half feet tall. These trees grow only along the coast in California and Oregon. Redwoods thrive in that location because of the very specific environmental conditions that support their survival, including moderate temperatures, abundant rain, and summer fog.*

Display **slide I**. Read aloud the information about redwoods' characteristics on the slide (also shown below). As a class, you may choose to do a quick search for frames of reference for those heights (e.g., buildings or other landmarks).



Name: _____ Date: _____

Redwoods Assessment

GENETICS | 449

Part 1

Your class will discuss the information about coast redwoods that is summarized on the following pages. You might choose to jot some notes while you participate in the discussion. Consider these questions.

- What factors might affect how tall a coast redwood tree can grow?
- What do you notice about the height of the trees in the two specific areas on the maps?

Coast redwood trees are the tallest trees in the world. They grow only along the coast in California and Oregon. These redwood trees thrive there because of the very specific environmental conditions that support their survival, including moderate temperatures, abundant rain, and summer fog.

TEACHER RESOURCES

Characteristic	Information
Range	Along the Pacific coast from the middle of California to the southwest corner of Oregon
Average height	200 to 240 ft (60-70 m) tall, some around 350 ft (100 m)
Lifespan	800 to 1,500 years, some live up to 2,000 years
Genetic information	Almost the largest set of genetic information cataloged by scientists, coast redwoods contain 9 times the genetic information a human has.

Display **slide J**. You may choose to read this information about how redwoods reproduce (also shown below) aloud to students, ask for student volunteers to read it, or have students read it silently to themselves.

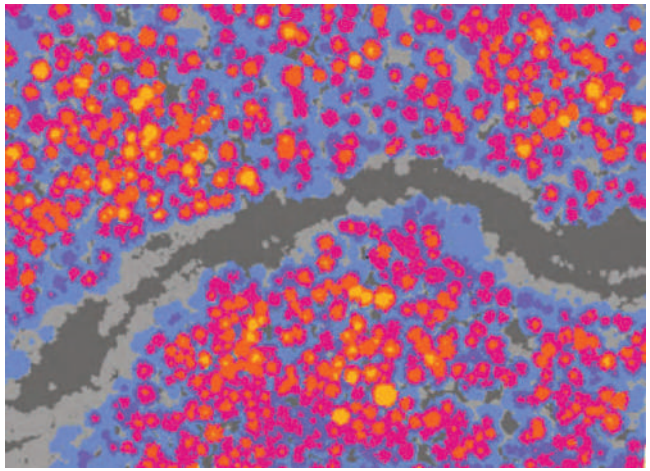
Sexual reproduction	Asexual reproduction
• Many seeds are produced in cones and drop from the tree. • Up to 75% of the seeds cannot actually produce seedlings.	• The parent tree sprouts new trees from its roots near the trunk. • This allows offspring trees to use resources from the parent's roots.

Sexual reproduction	Asexual reproduction
• Even if a seed might be able to produce a seedling, ground conditions often prevent growth (e.g., not enough light, too difficult to get roots into the soil).	• This next generation of offspring trees forms a circle around the parent tree.
• Trees with the most successful seeds are between 250 and 1,200 years old.	• Asexual reproduction is usually more successful than sexual reproduction.

Discuss maps of redwood heights. Display **slide K**. Say, *Why redwoods grow so very tall is a mystery in science. In the Humboldt Redwoods State Park in California, scientists examined how tall the coast redwood trees are in different areas of the park to try to understand why some trees were taller in some areas of the park than in others. They used a technology called LiDAR that allowed them to use laser sensors from the sky to measure the height of the trees off the ground. When they used this technology in the park, they created maps showing the heights of the trees.*

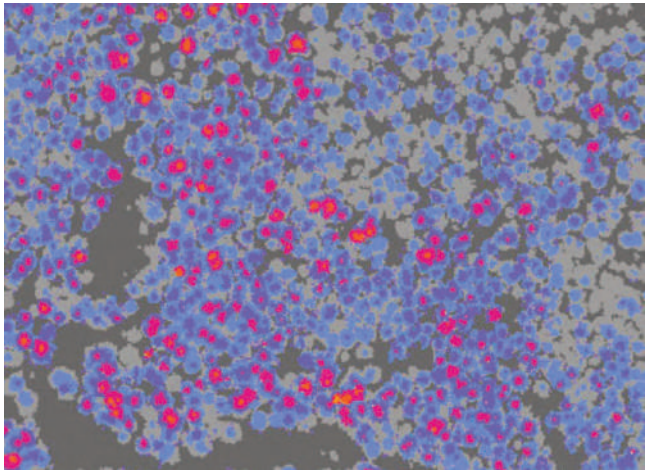
Continue explaining, *These maps show two different areas of about the same size—around 62 acres. Both maps show old-growth areas where the trees are more than 100 years old and do not get much taller each year.*

Map 1: Along Bull Creek



Mark Graham

Map 2: In a creek valley



Mark Graham

map key

yellow	orange	pink	purple	blue
over 328 ft (100 m) tall	over 295 ft (90 m) tall	over 262 ft (80 m) tall	less than 262 ft (80 m) tall	

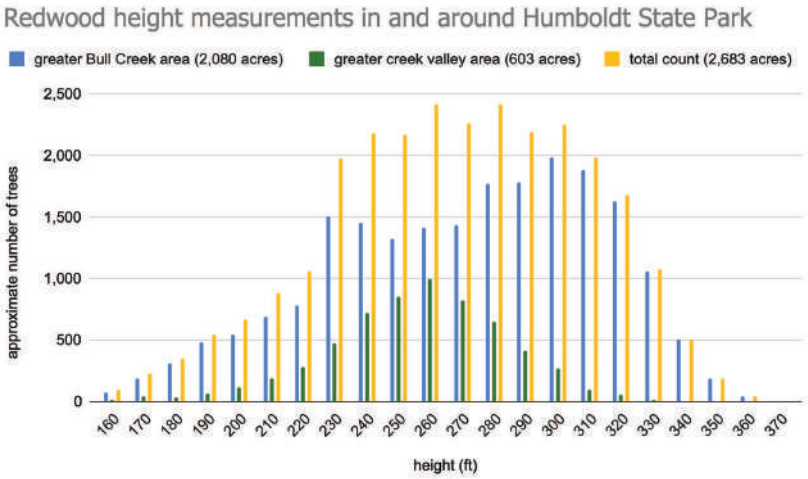
Ask, *What do you notice about the heights of the trees in these two areas?*

Sample student responses

- There are way more supertall trees by Bull Creek.

- There are only a couple orange trees in the creek valley map.
- I'm guessing the purple and blue areas are average. A previous slide said redwoods are usually 200-240 feet, so even the pink ones are taller than average.
- Yellow-height trees appear to be more common around Bull Creek.
- The supertall yellow trees are kind of clumped together. I'm guessing a larger spot of yellow means more trees are together there, and even the spots of yellow are kind of gathered in some areas.

Discuss a histogram of redwood heights. Display **slide L** and explain to students that the two maps we just saw were only two sections of larger LiDAR-scanned areas. The Bull Creek area studied includes 2,080 acres of redwood forest, and the creek valley area is 603 acres. This graph shows the data from those wider areas. Give students a moment to see what they notice about this graph and then ask them to share what they see.



Data Source: Canopy height distribution in old growth redwood forests from www.verylargeandtallredwoods.com

Discuss possible causes for this variation. Display **slide M**. Say, *We've noticed a lot of variation in the heights of these redwood trees. What factors might affect how tall a redwood tree can grow, in general?*

Sample student responses

- what's in their genetic information (Are there specific genes related to that supertallness and some trees have different alleles for those?)
- whether they have enough water (from rain and fog)
- whether they get enough light
- if the soil conditions are right for them
- if the temperatures are right for them
- whether humans are helping them (protecting them, caring for them) or harming them (pollution, damaging them when they visit)

To support this discussion, you might refer students to the models and notes they have in their Progress Tracker and science notebook and ask, *What factors have affected the variation in other organisms we've investigated?*

- *For cattle muscles?* (A single gene caused extra-big muscles, and diet and exercise can also contribute to variation.)
- *For strawberries?* (genes, location, fertilizer, water, frost, pollinization)
- *For planaria?* (light)
- *For apples?* (genes, temperature, light, stress—not enough water or nutrients, insects eating it)
- *For flamingos?* (food)
- *For wheat kernels?* (multiple genes)
- *For arm span?* (multiple genes, general health)

6. Demonstrate understanding on an assessment task. 30 MIN

Materials: *Redwoods Assessment*, class-created student-facing rubric (optional)

Administer *Redwoods Assessment* individually to students. You may choose to display **slide N** if it's helpful. This assessment will probably take students the rest of the class period to complete.

Assessment Opportunity

Building towards: 17.B Construct an explanation about how environmental and genetic factors influence the growth of organisms and how organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring.

What to look for and listen for: See detailed responses in *Key for Redwoods Assessment* and scoring guidance in *Rubric for Redwoods Assessment*.

What to do: If students need extra support you can choose to allow them to use their science notebook or classroom consensus models to help them on this task. Since the phenomenon of height variation and reproduction in redwood trees is new, they will not find exact answers to the assessment in their notes. You can also help students refer to the information the class discussed in this lesson's slides, which is summarized for students at the beginning of the assessment.

Alternate Activity

Extension opportunity: Climate change is affecting redwood trees. Your students might be interested in obtaining and evaluating more information about how these amazing trees can sometimes but not always contend with changes to their environment. Students may also be able to connect to their knowledge from *Unit 7.6: How do changes in Earth's system impact our communities and what can we do about it? (Droughts and Floods Unit)*. Then, they can communicate with others about steps we can take to protect redwood trees and their environment. Students could choose to communicate with policy makers about large-scale changes and/or communicate with peers and other community members about actions individuals can take to reduce the effects of climate change and ensure that redwoods are around for the future. Optional **slide O** is provided to support students in thinking about this extension opportunity.

7. Quick Write: Reflect on our experiences (optional). 5 MIN

Materials: science notebook

Reflect on experiences with the unit. Display **slide P**. Direct students to complete a quick write in their science notebook about any or all of these questions and then discuss them with the whole class.

- What was most challenging in this unit?
- What was most rewarding?
- Think about how you engage in sensemaking discussions and experiences with classmates. How would you want to engage with those experiences the next time around?
  - What would you do the same?
  - What would you do differently?

ADDITIONAL LESSON 17 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.W.8.2

Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

On *Redwoods Assessment* students write an explanation of how genetic and environmental factors influence the growth of redwood trees, articulating cause-and-effect relationships and organizing their writing in a way that clearly conveys their ideas.

Teacher Resources

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Assessment System Overview

Each unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self assessment. Formative assessments are embedded and called out directly in the lesson plans. Please look for the "Assessment Icon" in the teacher support boxes to identify places for assessments. In addition, the table below outlines where each type of assessment can be found in the unit.

Overall Unit Assessment

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 1	Initial models in science notebooks Driving Question Board	**Pre-Assessment** The student work available for assessment in Lesson 1 should be considered a pre-assessment. It is an opportunity to learn more about the ideas your students bring to this unit. Revealing these ideas early can help you be more strategic in how to build from and leverage student ideas across the unit. The initial models developed during Lesson 1 are a good opportunity to pre-assess student understanding of genetics. The two most important times to do this are (1) after students have developed their initial models and (2) during the Consensus Discussion. Refer to assessment guidance sections listed in the Lesson-Level Assessment table below and in the Lesson 1 *Teacher Guide*. The Driving Question Board is another opportunity for pre-assessment. Reinforce for students to generate open-ended questions, such as how and why questions, to post to the board, but celebrate any questions students share even if they are close-ended questions. Make note of any close-ended questions and use navigation time throughout the unit to have your students practice turning these kinds of questions into open-ended questions when they relate to the investigations underway.
Lesson 4	Progress Tracker update	**Formative** This is a key formative assessment moment because students are capturing their ideas about how the environmental factors (though we don't yet call them that) of diet and exercise can influence muscle growth.
Lesson 7	*Revise Your Model* *Key for Gotta-Have-It Checklist*, *Key for the "Revise Your Model" Assessment*, and *Rubric for the "Revise Your Model" Assessment*	**Formative or Summative** Students independently revise their original models from Lesson 1 to explain how an animal other than cattle got extra-big muscles. This is an opportunity for students to articulate the chain of cause-effect relationships in the genotype-to-protein-tophenotype process. *Key for Gotta-Have-It Checklist*, *Key for the "Revise Your Model" Assessment*, and *Rubric for the "Revise Your Model" Assessment* are available to support you in providing feedback to students, which can inform their work in the coming days. They will have another opportunity to be assessed on these practices and ideas in the Lesson 10 *Goldfish Assessment*.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 10	*Goldfish Assessment* and *Checklist for Obtaining and Evaluating Information from Scientific Text* *Key for Goldfish Assessment*, *Key for Checklist for Obtaining and Evaluating Information from Scientific Text*, and *Rubric for Goldfish Assessment*	**Summative** Students use a checklist to critically read and evaluate a research study adapted for classroom use to determine how the brown, speckled, and transparent trait variations of goldfish scales are inherited. They use this information to develop models explaining the inheritance patterns of this trait variation and to give a recommendation for selective breeding of the speckled phenotype. They also apply mathematical concepts of probability and use basic operations to calculate the chances of various goldfish phenotypes resulting from certain matings. This summative assessment ends the first lesson set and will allow you to provide feedback to your students about their work with several key ideas and practices in this unit. *Key for Goldfish Assessment*, *Key for Checklist for Obtaining and Evaluating Information from Scientific Text*, and *Rubric for Goldfish Assessment* are available to support you in providing this feedback.
Lesson 13	Slide T *Peer Feedback Guidelines*	**Peer Feedback** In this lesson students explain to a partner the process of how plants reproduce sexually and an example of how plants reproduce asexually. Their partner then offers constructive feedback about their explanation. Specific instructions including sentence starters for offering feedback are provided to students in the lesson slide and on *Peer Feedback Guidelines*.
Lesson 14	*Self-assessment for Obtaining, Evaluating, and Communicating Information*	**Self-Assessment** After participating in a small-group research activity about organisms that reproduce asexually, students complete *Self-assessment for Obtaining, Evaluating, and Communicating Information*. Since students have been building their independence with this practice throughout the unit, this is an important opportunity for them to be metacognitive, prompting students to reflect and also plan for how they can continue to improve in Obtaining, Evaluating, and Communicating Information. This assessment is intended as a space for student thinking, but if you are interested in responding to their thoughts, you might ask students to leave their notebooks open to this page at the end of class so that you can see it.
Lesson 17	*Redwoods Assessment Key for Redwoods Assessment* and *Rubric for Redwoods Assessment*	**Summative** This lesson includes a transfer task to give students an opportunity to use the 3 dimensions to make sense of a different phenomenon. In the context of redwood tree heights, students construct an explanation about how environmental and genetic factors influence the growth of organisms and how organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. This summative assessment ends the unit and will allow you to provide feedback to your students about their work with several key ideas and practices from the second lesson set. *Key for Redwoods Assessment* and *Rubric for Redwoods Assessment* are available to support you in providing this feedback.

When	Assessment and Scoring Guidance	Purpose of Assessment
After each lesson	Lesson Performance Expectation Assessment Guidance	**Formative Assessment** Use the Lesson-Level table below to see which parts of each lesson can be used as embedded formative assessments.
Occurs in most lessons	Progress Tracker	**Formative and Student Self-Assessment** The Progress Tracker is a thinking tool that was designed to help students keep track of important discoveries that the class makes while investigating phenomena and figure out how to prioritize and use those discoveries to develop a model to explain phenomena. It is important that what the students write in the Progress Tracker reflects their own thinking at that particular moment in time. In this way, the Progress Tracker can be used to formatively assess individual student progress or for students to assess their own understanding throughout the unit. Since the Progress Tracker is meant to be a thinking tool for students, we strongly suggest it is not collected for a grade other than for completion.
Anytime after a discussion	Student Self-Assessment Discussion Rubric	**Student Self-Assessment** The student self-assessment discussion rubric found in the *Teacher Handbook* can be used anytime after a discussion to help students reflect on their participation in the class that day. Choose to use this at least once a week or once every other week. Initially, you might give students ideas for what they can try next time to improve, such as sentence starters for discussions. As students gain practice and proficiency with discussions, ask for their ideas about how the classroom and small-group discussions can be more productive.
After students complete substantial, meaningful work	Peer Feedback Facilitation: A Guide	**Peer Feedback** In addition to the specific use in Lesson 13, there will be times in your classroom when facilitating students to give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback from others. We suggest that peer review happen at least two times per unit. This guide found in the *Teacher Handbook* is designed to give you options for how to support this in your classroom. It also includes student-facing materials to support giving and receiving feedback along with self-assessment rubrics where students can reflect on their experience with the process. Peer feedback is most useful when there are complex and diverse ideas visible in student work and not all work is the same. Student models or explanations are good times to use a peer feedback protocol. They do not need to be final pieces of student work, rather, peer feedback will be more valuable to students if they have time to revise after receiving the peer feedback. It should be a formative, not a summative, type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities where they can use these experiences as evidence for their feedback.

For more information about the approach to assessment and general program rubrics, visit the Teacher Handbook.

Lesson-by-Lesson Assessment Opportunities

Every lesson includes one or more lesson-level performance expectations (LLPEs). The structure of every LLPE is designed to be a three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts. The font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to Science and Engineering Practice(s), alignment to Cross-Cutting Concept(s), and alignment to the Disciplinary Core Ideas.

The table below summarizes opportunities in each lesson for assessing every lesson-level performance expectation (LLPE). Examples of these opportunities include student handouts, home learning assignments, progress trackers, or student discussions. Most LLPEs are recommended as potential formative assessments. Assessing every LLPE listed can be logistically difficult. Strategically picking which LLPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher's discretion.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 1	**1.A** Develop and/or use a model to predict what is causing these animals to have extra-big muscles. **1.B** Ask questions that arise from careful observation of pictures of animals with different musculature to seek information about what causes these variations in populations.	**1.A Developing and Using Models; Cause and Effect** **When to look for it:** On *Initial Model* while students share their initial models with partners and during the Consensus Discussion about initial models **What to look and listen for:** Look at students' initial models so you can highlight the range and diversity of ideas the whole class has. See more information about how to use initial models as a pre-assessment in the Overall Unit Assessment table. Also, use the Consensus Discussion about the initial class model to listen for ideas students bring up to explain the possible causes of these muscle differences. Look for the following ideas as components of the models: (1) exercise, (2) diet, and possibly (3) other animals in that individual's family might share this feature. **1.B Asking Questions; Cause and Effect** **When to look for it:** While students write and share their questions for the Driving Question Board **What to look and listen for:** The Driving Question Board is another opportunity for pre-assessment. Look for "how" or "why" questions about phenomena that seek to investigate possible causes for not only these extra-big muscles but the variety of features found within living things that are otherwise generally the same.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 2	**2.A** Obtain, evaluate, and communicate information about muscles in various media and visual displays, including models of complex protein structures, to describe (1) how the function of those proteins depends on their shape and (2) how the muscle cells of extra-big-muscled animals compare with those of typical animals.	**2.A Obtaining, Evaluating, and Communicating Information; Structure and Function** **When to check for understanding** 1. During students' work on *Muscle Protein Questions* 2. In students' Progress Tracker entries 3. During the Building Understandings Discussion after the gallery walk **What to look and listen for** 1. See *Key for Muscle Protein Questions* for sample student responses. In general, look for responses that articulate how students' understanding improved from initially watching the video animations to watching the video animations a second time after reading printed text with labeled diagrams, specifically in regard to how integrating these different sources of information helped them understand the structure and function of the muscle cells and proteins. 2. A quick glance at students' Progress Tracker entries will give you insight into their understanding of myosin and actin's structure-and-function relationship. 3. After the gallery walk, look for students who can integrate information to describe differences between the extra-big and typical muscle tissue photos or graphs. Listen for comments that synthesize the information from the various media in this lesson to explain the structure and function of muscle cells and proteins.
Lesson 3	**3.A** Obtain, evaluate, and communicate information to determine the effects of exercise and diet in the development of muscle tissue.	**3.A Obtaining, Evaluating, and Communicating Information; Cause and Effect** **When to check for understanding:** At the end of the lesson, in students' responses to the exit ticket **What to look for:** Look to see if students synthesize information presented in the lesson via images, readings, and data to identify the role of diet and exercise in building muscles. Look to see if students use specific pieces of information to support the claim that protein consumption can positively influence muscle growth but that exercise is key in building larger muscles. Look for questions that ask about the diet of the cattle with extra-big muscles and how they exercise.
Lesson 4	**4.A** Develop and use a model to construct a scientific explanation based on evidence for how different environmental factors (cause) influence variation in a trait (effect).	**4.A Developing and Using Models: Cause and Effect** **When to look for it:** After updating the classroom consensus model as students are working on their Progress Tracker **What to look for:** Look to see if students are able to make connections between the updates the class made to the consensus model and how these components can change or influence musculature. Look to see if students are providing the proper evidence to support why these components were added to our model. See possible student responses in the Progress Tracker activity of the lesson for details.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 5	**5.A** Use a model to describe and predict the patterns in variations in traits between parents and offspring in a pedigree. **5.B** Develop and use a model to describe the unobservable mechanism of fertilization, in which parents each contribute half of the chromosomes an offspring has, by discerning patterns in the number and types of chromosomes in the sex cells of parents and the body cells of offspring.	**5.A Developing and Using Models; Patterns** **When to check for understanding** 1. On day 1 on the *Family Phenotype Graphic Organizer* 2. On day 1 during the Building Understandings Discussion **What to look/listen for** 1. Listen for students using evidence from the images to support the assignment of phenotype symbols on *Family Phenotype Graphic Organizer*. Also look for the pattern to emerge that offspring who are heavily muscled must have both parents with extra-big or medium muscles. 2. Listen for students using evidence from the images to support the assignment of phenotypes and listen for students to support their predictions of what offspring may look like using reasoning that includes offspring inheriting the phenotype from at least one parent. **5.B Developing and Using Models; Patterns** **When to check for understanding:** On day 2 during partner work with the *Chromosomes in Sex Cells* handout and the *Karyotype of Lorenc's Muscle Cell* handout **What to look/listen for:** Listen for students using evidence from the images of chromosomes to support the idea that one chromosome from each pair in the karyotype came from a parental egg and one came from a parental sperm cell. Look for annotations in the science notebook that link the parental and offspring chromosomes to each other.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 6	**6.A** Develop and use a model to describe correlational relationships among chromosome pairs containing two variants, specific proteins, and the trait of musculature. **6.B** Critically read scientific texts to obtain evidence that a distinct gene is the cause for the production of a specific protein related to the trait of musculature.	**6.A Developing and Using Models; Cause and Effect** **When to check for understanding:** On the models students develop in their small groups and then in the whole-class discussion of correlations **What to look and listen for:** Students should identify the correlational relationships listed in the assessment guidance in the Teacher Guide. In all these cases, even though they appear together we do not know if one of these components is causing the other(s). Students' models may predict which component in the pattern is "first," "next," or "last," but question marks or other indicators should show that this thinking has not been supported. **6.B Obtaining, Evaluating, and Communicating Information; Cause and Effect** **When to check for understanding:** When students are discussing *Version 1: New Protein Linked to the Heavily Muscled Phenotype* and *Version 1: Function of the Myostatin Protein* **What to listen for:** Students should give reasons supporting their evaluation of both articles as credible sources. They should indicate vocabulary that is new to them (specifically, *gene*, *allele*, *genotype*, and *receptor*), including definitions from context. Students' questions about the text should be relevant and show their comprehension, even partially, of the text. When focusing on cause-effect relationships, students should make cause-effect statements such as those listed in the assessment guidance in the Teacher Guide.
Lesson 7	**7.A** Develop a model to show how genetic factors influence (cause) variation in a trait (effect) by controlling the production of specific proteins.	**7.A Developing and Using Models; Cause and Effect** **When to check for understanding:** When students complete the midpoint assessment *Revise Your Model* **What to look for:** See *Key for the "Revise Your Model" Assessment* for sample student responses and *Rubric for the "Revise Your Model" Assessment* for scoring guidance.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 8	**8.A** Use mathematics and computational thinking to find patterns about genotypic and phenotypic outcomes resulting from crossing individuals with specific genotypes. **8.B** Plan and carry out an investigation to collect data and uncover patterns that support the idea that chromosome pairs separate when sex cells form and then recombine at fertilization, so each parent contributes half of the genes acquired (at random) by the offspring.	**8.A Using Mathematics and Computational Thinking; Patterns** **When to look for it** 1. Day 1: During the individual calculation of genotype proportions that result from certain crosses and consequent small-group talk related to the patterns uncovered in *Using Pedigrees to Make Predictions* 2. Day 2: As they turn and talk with a partner or as you flip back through the slides to review the steps with them during the class discussion of algorithms 3. Day 2: In their science notebook as they practice calculating probabilities and on the exit ticket they turn in near the end of the lesson **What to look and listen for** 1. Day 1: Listen for students identifying groups with clear patterns of genotypes. 2. Day 2: Listen for students to identify and sequence explicit steps in determining the probability of offspring genotypes and to describe these steps as constituting an algorithm. 3. Day 2: Look for students to demonstrate their mastery of one or both of the algorithms (probability calculations or Punnett squares) used to correctly predict the proportion of offspring with different genotypes when we know the genotypes of the parents. **8.B Planning and Carrying Out Investigations; Patterns** **When to look for it:** When students are recording in their science notebook the genotypes generated from the coin toss simulation activity and again when they compile all the data as a class **What to look and listen for:** Students should be organizing their results in groups based on the genotypes of the parents that mated. They should be focused on looking for the patterns of genotype distribution they are generating with the simulation to see if the patterns are the same as what they found when they looked at the distribution of phenotypes that correspond to these genotypes in existing cattle families.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 9	**9.A** Obtain, evaluate, and communicate information regarding the effect of selective breeding in one type of sexually reproducing organism. **9.B** Use mathematics and computational thinking to determine the beneficial and harmful effects of selective breeding in sexually reproducing organisms by examining the frequency of certain trait variations and combinations in a population over time.	**9.A Obtaining, Evaluating, and Communicating Information; Cause and Effect** **When to look for it:** During the Building Understandings Discussion about selective breeding in cattle **What to look and listen for:** Listen for students to identify the conclusions in the readings are valid because of their use of data and firsthand knowledge. Listen for students to identify that selective breeding causes changes over time in the frequency of beneficial trait variations in a population of organisms. **9.B Using Mathematics and Computational Thinking; Cause and Effect** **When to look for it:** When students update their Progress Trackers after running the computer simulation **What to look and listen for:** Look for students to identify that because of selective breeding of organisms with beneficial trait variations, the frequency of individuals with those trait variations increases in the population over time as evidenced by information found in the readings and data from the computer simulation. Look for students to cite specific data from either the readings or computer simulation to support their understanding. **What to do:** If students are struggling, ask probing questions and refer them to the data they recorded and analyzed in the computer simulation or information from the readings.
Lesson 10	**10.A** Critically read scientific texts and construct an explanation using models and math to describe how sexual reproduction results in offspring with genetic variation in the context of goldfish coloration.	**10.A Developing and Using Models; Cause and Effect** **When to look for it:** On *Goldfish Assessment* and *Checklist for Obtaining and Evaluating Information from Scientific Text* **What to look for:** See *Key for Goldfish Assessment* and *Key for Checklist for Obtaining and Evaluating Information from Scientific Text* for expected student responses and *Rubric for Goldfish Assessment* for scoring guidance.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 11	**11.A** Ask questions to refine our model explaining the causes of trait variations we see in other organisms.	**11.A Asking Questions; Cause and Effect** **When to look for it:** During the Initial Ideas Discussion **What to listen for:** Students should raise questions that connect components or interactions in our model to the causes of ranges of trait variations in these other organisms. Example questions include the following: • Do these organisms have genetic material? • Do they have sperm and eggs? • Do they have parents? (What do the parents look like?) • Is this range of variations caused by something different happening with the chromosomes and alleles? • Is there a protein involved? What's its function? • What environmental factors might be influencing this trait?
Lesson 12	**12.A** Plan and carry out an investigation to produce data to serve as the basis for evidence that plants have genetic material inside their cells that can be visualized (scale).	**12.A Planning and Carrying Out Investigations; Scale, Proportion, and Quantity** **When to look for it** 1. Initial Ideas Discussion in the Brainstorm Ideas for How to Get at the Genetic Material activity 2. After the lab investigation in students' data tables and answers to making sense questions in *Lab v1: Extracting Genetic Material* as well as information collected in the class data table 3. Progress Tracker update **What to look and listen for** 1. Listen for students talking about the location of the chromosomes in cells and using what they know about cells to think about how to get the chromosomes out of the nuclei. Students should also surface the idea that cells are small (microscopic), and so the genetic material would also be microscopic. They should make the connection that because it is so small you need a lot of it together to visualize it. 2. Look for students' answers to list evidence that the material was isolated from all types of cells (egg cells, muscle cells, and plant cells) but not from any nonliving things (water or protein drink) and that the material had similar properties. Students' answers should also demonstrate that they must break open and collect genetic material from many cells in order to visualize it because the genetic material from only one cell would be much too small to see. 3. Students should populate their Progress Tracker with ideas that demonstrate that evidence collected during the investigation supports the claim that genetic material is also found in plant cells. However, while every cell has genetic material, cells are very small, so to visualize the genetic material we need to extract it from many cells and separate the genetic material from the other cell parts.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 13	**13.A** Construct an explanation, using a representation of plant reproductive parts, for how these specialized structures support sexual and asexual reproduction in plants (function).	**13.A Constructing Explanations; Structure and Function** **When to check for understanding:** At the end of day 2 during an explanation and peer feedback opportunity and in written form on an exit ticket **What to look and listen for:** Listen for students to make connections between structures and their functions that support sexual reproduction in plants, as well as give examples of plant structures involved in asexual reproduction. On the exit tickets, look for what they label, draw, and write to explain details of the process of how plants reproduce.
Lesson 14	**14.A** Obtain, evaluate, and communicate information about how organisms reproduce asexually and transfer their genetic information to their offspring, which results in offspring with identical genetic information.	**14.A Obtaining, Evaluating, and Communicating Information; Cause and Effect** **When to look for it:** When students are researching and then sharing what they've learned about asexually reproducing organisms **What to look and listen for:** Look for students who are using reliable websites and finding just key ideas about asexual reproduction (not getting caught up in the other details of that organism or more-complex mechanisms). Listen for students who are able to communicate effectively: be concise and clear when presenting organized, relevant information.
Lesson 15	**15.A** Construct an explanation using a model to explain the influences of environmental and genetic factors on trait variation.	**15.A Constructing Explanations; Cause and Effect** **When to check for understanding:** on *Explaining Environmental Effects* **What to look and listen for:** While students work on *Explaining Environmental Effects* and share their explanation with their partner, listen for the following ideas: • Flamingo color is influenced by the environmental factor of the foods they eat: eating more algae results in deeper pink-orange color, eating more shrimp results in lighter pink-orange color. • Apple color is influenced by genetic and environmental factors: temperature and sun exposure to a greater extent and stressors such as lack of water or nutrients and insect activity to a lesser extent. As you review the models students use along with their written explanations, look for arrows of varying size and/or words that indicate how much effect some factors have relative to others.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 16	**16.A** Analyze and interpret patterns in data to provide evidence that a combination of genes and environment is causing the variation we see in traits. **16.B** Develop and use models to show multiple causes of variation within a trait.	**16.A Analyzing and Interpreting Data; Patterns** **When to look for it:** While students are using the *Wheat Kernel Environmental Factors Investigation* data sets to determine if the results match their predictions based on the ideas they have so far **What to look and listen for:** Look for students to be able to determine that the results do not match what they would predict (for either an environmental or a genetic cause) based on what they know so far. **16.B Developing and Using Models; Cause and Effect** **When to look for it** 1. On *Arm Span Reading and Modeling* 2. During the revision of the classroom consensus model **What to look and listen for** 1. Students should be able to draw their own model on *Arm Span Reading and Modeling*, following the same different-sized-arrow convention to show the approximate relative amounts of genetic and environmental causes of the trait variation they read about. 2. When suggesting revisions to the model, students should point out the need to show multiple causes of both the heavily muscled and typically muscled phenotype in cattle. These causes do not carry the same weight of influence on the different phenotypes, so students should suggest a way (such as larger or smaller arrows) to represent these different causes.
Lesson 17	**17.A** Ask questions to clarify and refine our model explaining what causes living things to be different from one another. **17.B** Construct an explanation about how environmental and genetic factors influence the growth of organisms and how organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring.	**17.A Asking Questions; Cause and Effect** **When to look for it:** While the class is revisiting the Driving Question Board on day 1 **What to look and listen for:** Listen for students asking questions to clarify their models and explanations for how living things are different from one another. When working through to answer questions on the DQB, new questions may arise that help clarify the models students have been developing for how genetics and environment affect trait variation. Take the time to work through these new questions as it will help students prepare to demonstrate understanding in the assessment on day 2. **17.B Constructing Explanations; Cause and Effect** **When to look for it:** During the student assessment *Redwoods Assessment* on day 2 **What to look for and listen for:** See detailed responses in *Key for Redwoods Assessment* and scoring guidance in *Rubric for Redwoods Assessment*.

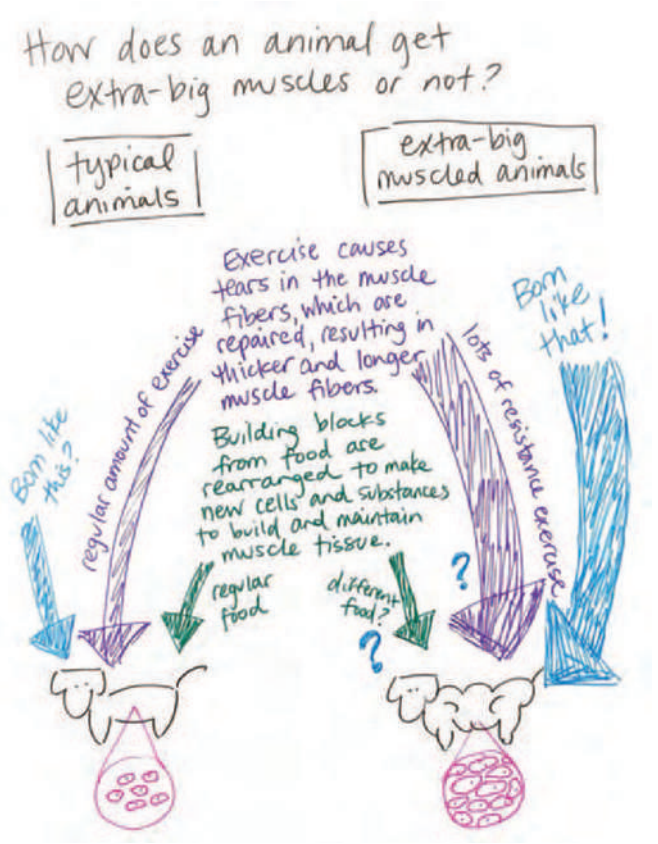
LESSON 1: TEACHER REFERENCE 1

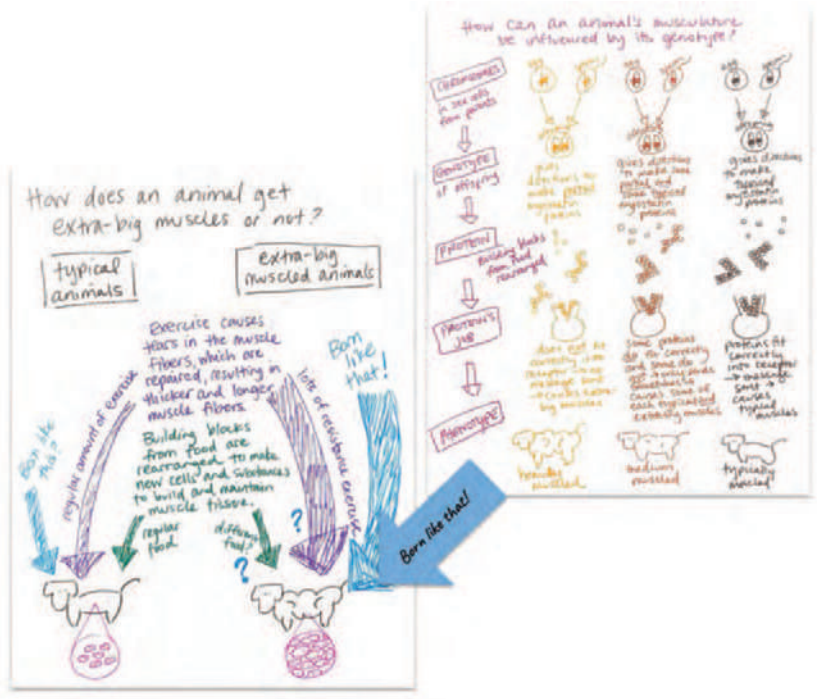
Unit-Wide Lesson-by-Lesson Model Resource

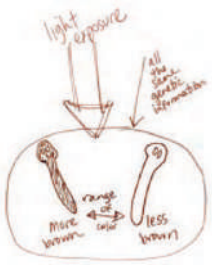
The following chart is intended to help you plan space in your classroom and organize additions to the classroom consensus model throughout the unit (not all in Lesson 1!). Keep in mind that your classroom consensus models may look slightly different than these samples.

Lesson and question	Description of the model updates	Sample image of the updated/revised classroom consensus model
1. How do organisms get their differences?	In this lesson, students co-construct their initial consensus model. The class will not all agree on all aspects of the model; instead, creating this model will surface areas of disagreement and questions to pursue.	

Lesson and question	Description of the model updates	Sample image of the updated/revised classroom consensus model
2. How do extra-big muscles compare to typical ones up close?	In this lesson, students figure out the differences between typical and extra-big muscles at the cellular level. Add sticky notes with zoomed-in drawings of the cells in each muscle type to the classroom consensus model to show these differences.	
3. How do diet and exercise affect muscle size?	The classroom consensus model is not updated in this lesson. The class will create an updated version of the classroom consensus model with ideas from Lesson 3 at the beginning of Lesson 4.	

Lesson and question	Description of the model updates	Sample image of the updated/revised classroom consensus model
4. What is different about the food and exercise for cattle with extra-big muscles?	At the beginning of the lesson, the class creates an updated version of the classroom consensus model to include these ideas from Lesson 3: (1) dietary protein is necessary to maintain muscle tissue and (2) exercise builds bigger muscles. Later in the lesson, students update the model to include ideas the figure out in Lesson 4. The image shown here is an example of the classroom consensus model updated to represent what students figure out by the end of Lesson 4 (that cattle with extra-big muscles are born like that).	
5. Where do the babies with extra-big muscles get that trait variation?	The classroom consensus model is not updated in this lesson.	
6. How do chromosomes cause cattle to be born with extra-big muscles?	The classroom consensus model is not updated in this lesson.	

Lesson and question	Description of the model updates	Sample image of the updated/revised classroom consensus model
7. How does an animal get extra-big muscles?	In Lesson 7, students put the pieces together from Lessons 5 and 6. They create an additional part of the classroom consensus model that shows how an animal's phenotype can be influenced by its genotype. Place this additional model part next to the first part of the classroom consensus model. Connect the two parts of the model with an arrow to indicate that the genotype-to-phenotype model is detailing how an animal can be "born like that." A larger version of the new addition can be found in the Lesson 7 Teacher Guide.	
8. Why don't offspring always look like their parents or their siblings?	The classroom consensus model is not updated in this lesson. However, if it is helpful to your students to post representations of their probability work predicting outcomes of certain crosses, that work can go above or to the right of the genotype-to-phenotype model addition from Lesson 7.	
9. How do farmers control the variation in their animals?	The classroom consensus model is not updated in this lesson.	
10. How can we explain a different trait variation?	The classroom consensus model is not updated in this lesson.	

Lesson and question	Description of the model updates	Sample image of the updated/revised classroom consensus model
11. How can we answer the rest of our questions?	The classroom consensus model is not updated in this lesson. However, make space in your classroom to post the card sorts that students do for reference during Lesson Set 2.	
12. Do plants have genetic material?	The classroom consensus model is not updated in this lesson.	
13. How do plants reproduce?	The classroom consensus model is not updated in this lesson.	
14. (How) do other organisms reproduce without sperm and eggs?	The classroom consensus model is not updated in this lesson.	
15. How do we get variations if the genetic information is exactly the same?	In this lesson, the class models the genetic and environmental influences on planaria. Since this model does not specifically address cattle, post it near the planaria card sort instead of near the classroom consensus model.	 

Lesson and question	Description of the model updates	Sample image of the updated/revised classroom consensus model
16. How much of trait variation in a population is controlled by genes or by the environment?	The class creates a new classroom consensus model to show varying influences of genetic and environmental factors on the range of variation we see in cattle musculature. Post this updated model below and/or overlapping the original classroom consensus model. A larger version of the new addition can be found in the Lesson 16 Teacher Guide.	
17. Why are living things different from one another?	The classroom consensus model is not updated in this lesson, but keep it posted to help students reflect on and celebrate everything they have figured out in this unit.	

LESSON 2: ANSWER KEY 1

Key for Muscle Protein Questions

Part 1: Use words and/or drawings to record ideas from the video animation and the written text (with diagrams).

	Video animation	Written text with labeled diagrams
What ideas about muscles do we figure out from this source?	Muscle cells are made from strands of proteins called actin and myosin. In order to contract (pull together) the whole muscle, actin and myosin strands pull along each other. Several bundles of strands contracting together pull the muscles tighter so you can move.	The actin and myosin strands are made of individual myosin and actin proteins. Each protein molecule is made of many atoms arranged in a particular shape.
How does the structure (shape) of the myosin and actin proteins affect their function (how they do their jobs)?	The myosin and actin strands work together to make the muscle contract (pull together).	The specific shapes of the myosin and actin proteins allow them to do the job of hooking together and pulling so the muscle can move.

Part 2: Integrate ideas from both sources to answer these questions.

1. After reading the text, watch the video a second time. Did you notice or understand any part(s) of the video better the second time because of something you read or saw in the text? If yes, what?

Answers will vary, but they may include clearer understanding of how the myosin and actin strands move, such as how their specific shapes help them "grab on."

2. What new ideas do you have about proteins now?

Answers will vary based on students' prior knowledge of proteins.

3. In one or two sentences of your own words, summarize how muscle cells contract (pull together): What is a claim you can make about how muscles contract?

Muscles contract when the nerves send a signal and the myosin proteins "grab on" to the actin proteins and pull them along. Since they're in strands together, the myosin strand moves past the actin strand. They're anchored at the ends of the strands, and there are so many strands working together in each bundle that they can pull the whole muscle together.

Part 3: Consider how integrating information from both sources helped clarify your understanding of how muscles work.

4. What is an idea you would have missed about muscle cells and how they function if you had used only one source?

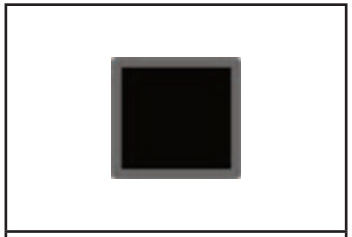
Answers will vary, but they may include realizing that the actin and myosin strands are composed of smaller individual proteins working together or that they are specifically shaped molecules made of atoms.

5. Tell one advantage of using multiple sources, both video and text, that helped you deepen your understanding of this information.

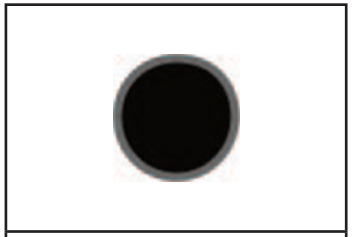
Answers will vary.

Key to Family Phenotype Graphic Organizers

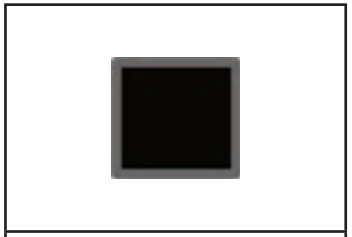
Family 1: Rob's Pedigree



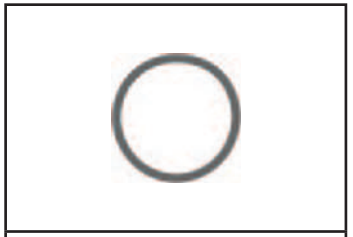
Roe



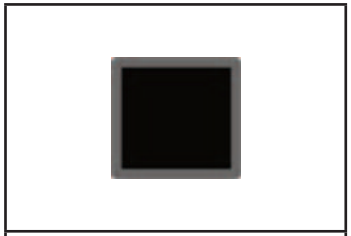
Clancy



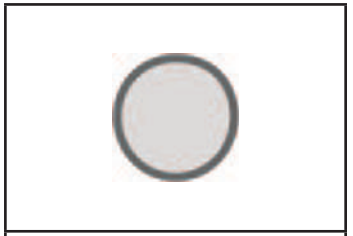
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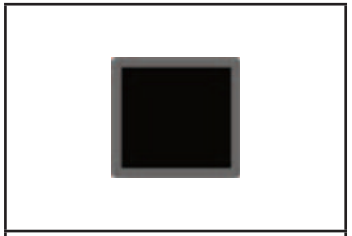
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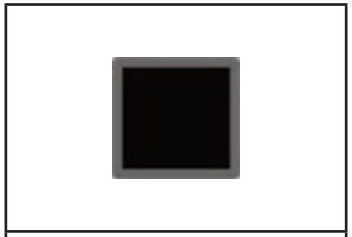


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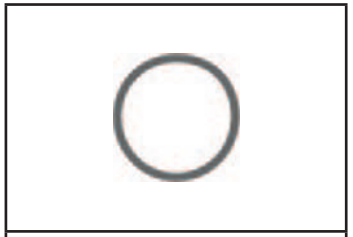


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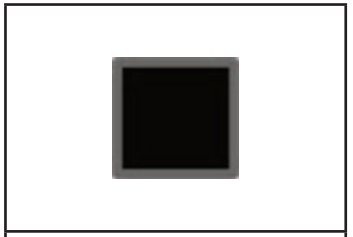
Family 2: Sasson's Pedigree



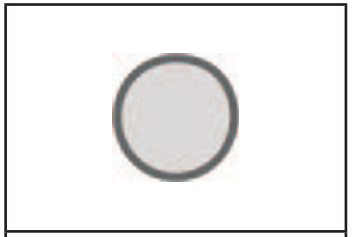
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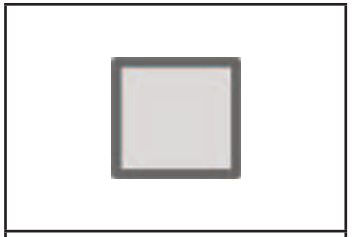
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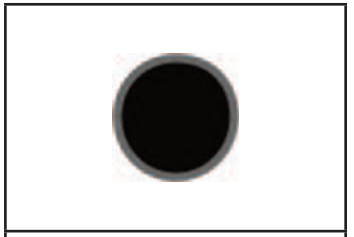
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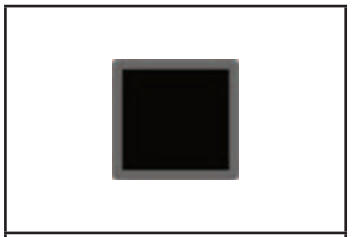
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Hoss

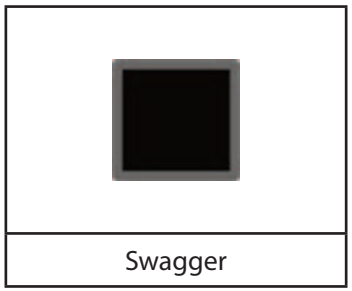


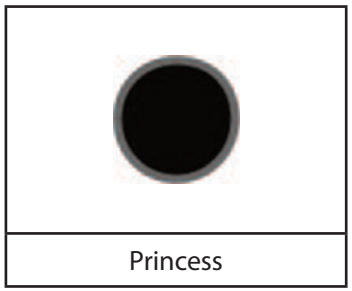
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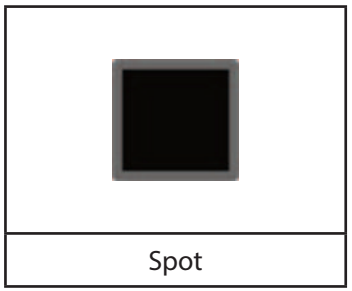


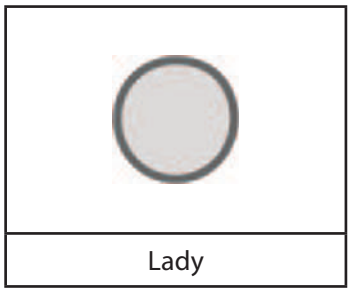
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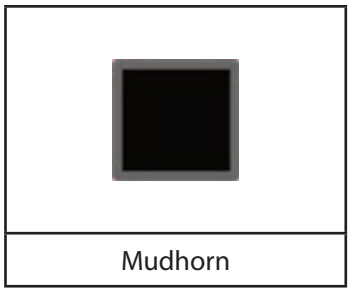
Family 3: Conrad's Pedigree

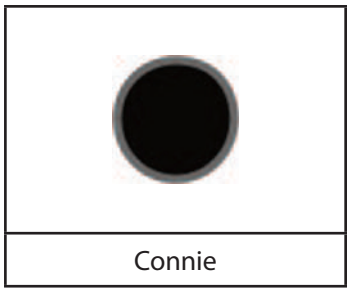

Swagger

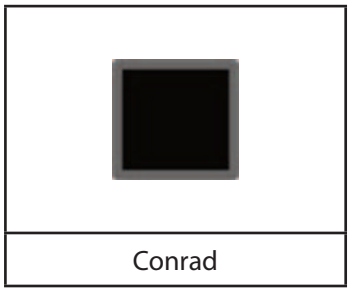

Princess


Spot

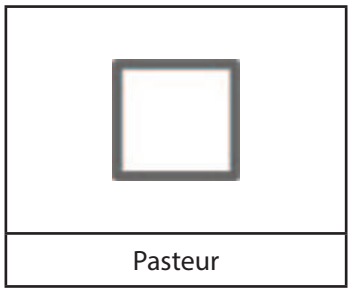

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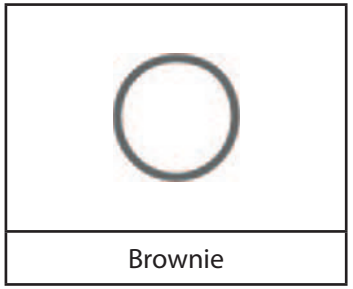

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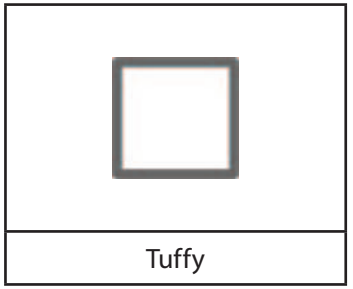

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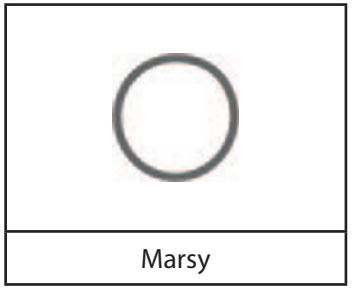

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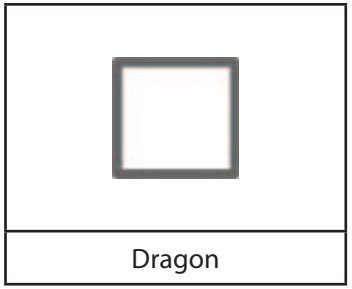
Family 4: Dressy's Pedigree

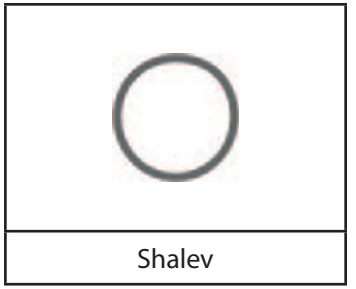

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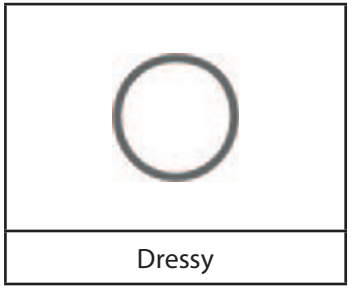

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Tuffy

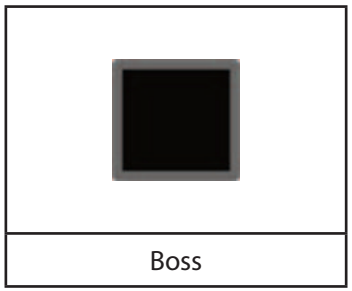

Marsy


Dragon

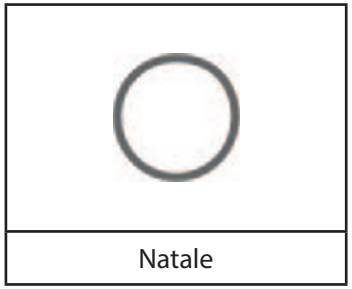

Shalev


Dressy

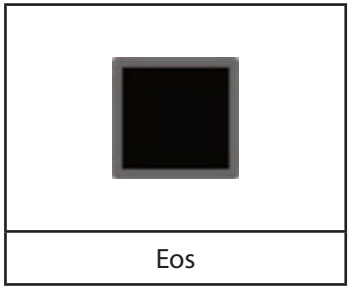
Family 5: Uncanny's Pedigree



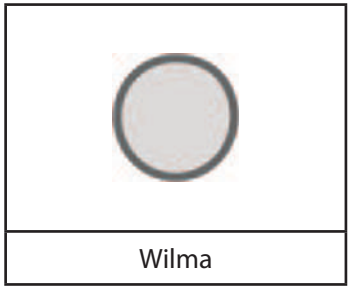
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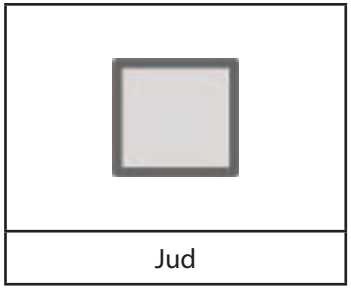
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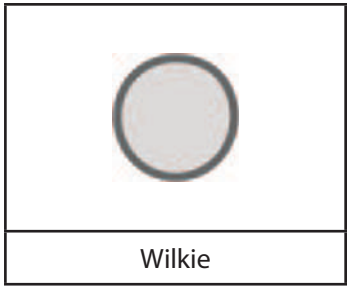
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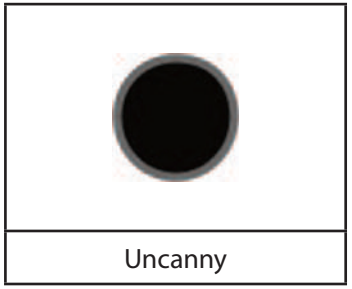
Wilma



Jud



Wilkie



Uncanny

Rubric for the "Revise Your Model" Assessment

Directions: The alignment table shown here indicates how student work on *Revise Your Model* supports each element of this three-dimensional, lesson-level performance expectation. The descriptors listed with the elements describe possible evidence that the element is used effectively in the student's model (or written explanation of that model).

The rubric that follows offers the same descriptors as the alignment table but in a format that may allow you to more-easily record student progress and/or communicate feedback to students. This rubric does not attempt to predict all the possible ways students may still show that they are developing their understandings and use of practices, nor does it attempt to forecast all the possible ways students may show they have advanced understanding and/or especially deep use of practices. Instead, you may mark examples of evidence you see and jot notes about where specifically a student has room for improvement or has shown above-and-beyond understanding. This feedback can then be shared with students (in writing or in a conversation) to support their learning.

This rubric is intended for teacher use, not for students to use as a checklist while developing their responses.

7.A Develop a model to show how genetic factors influence (cause) variation in a trait (effect) by controlling the production of specific proteins.

SEP Elements	DCI Elements	CCC Elements
2.4 Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. Student model shows the cause-effect relationships among genotype, protein, and phenotype for typically muscled and heavily muscled animals other than cattle. (Note that some students may have chosen to write an explanation of the model they have developed instead of drawing it.)	LS1.B Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. LS1.B Genetic factors as well as local conditions affect the growth of the adult plant. LS3.A 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. Model (or written explanation) includes the following: • sperm and egg • which contain chromosomes (genes and alleles) • from the parents transferred to offspring • Offspring's genotype is a pair of alleles—one from the sperm and one from the egg. Model (or written explanation) shows how an animal's genotype can affect its phenotype via proteins. Building blocks to produce these proteins come from the animal's food. Model (or written explanation) includes the following for the typically muscled individual: • representation of a chromosome pair with homozygous alleles, different from the heavily muscled individual's alleles • This pair of alleles results in the production of full myostatin proteins. • The shape of the full myostatin protein allows it to fit correctly into cells' receptors, causing typical muscles to develop. • We see the typically muscled phenotype. Model (or written explanation) includes the following for the heavily muscled individual: • representation of a chromosome pair with homozygous alleles, different from the typical individual's alleles • This pair of alleles results in the production of partial myostatin proteins. • The shape of the partial myostatin protein does not allow it to fit correctly into cells' receptors, causing extra-big muscles to develop. • We see the heavily muscled phenotype.	2.2 Cause and effect relationships may be used to predict phenomena in natural or designed systems. 6.1 Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function. Model (or written explanation) shows the cause-and-effect chain from genotype to protein to phenotype. Look for any of the following: • the words "cause", "effect", "influence", "because", and so forth • arrows between elements in the sequence of genotype and alleles to protein to protein's job to phenotype Model (or written explanation) represents the different structures of the two myostatin proteins and shows or explains how their shape is related to their function. • The shape of the full myostatin protein allows it to fit correctly into cells' receptors, causing a message to be sent. • The shape of the partial myostatin protein does not allow it to fit correctly into cells' receptors, so no message is sent.

Element of CCC, SEP, and DCI being assessed	Evidence that element is used effectively	Evidence of development or extension
2.4 Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.	Student model shows or writing explains the cause-effect relationships among genotype, protein, and phenotype for typically muscled and heavily muscled animals other than cattle.	
LS1.B Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring.	Model (or written explanation) includes the following: • sperm and egg • which contain chromosomes (genes and alleles) • from the parents transferred to offspring • Offspring's genotype is a pair of alleles—one from the sperm and one from the egg.	
LS1.B Genetic factors as well as local conditions affect the growth of the adult plant.	Model or written explanation shows how an animal's genotype can affect its phenotype via proteins. Building blocks to produce these proteins come from the animal's food.	
LS3.A 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.	Model (or written explanation) includes the following for the typically muscled individual: • representation of a chromosome pair with homozygous alleles, different from the heavily muscled individual's alleles • This pair of alleles results in the production of full myostatin proteins. • The shape of the full myostatin protein allows it to fit correctly into cells' receptors, causing typical muscles to develop. • We see the typically muscled phenotype. Model (or written explanation) includes the following for the heavily muscled individual: • representation of a chromosome pair with homozygous alleles, different from the typical individual's alleles • This pair of alleles results in the production of partial myostatin proteins. • The shape of the partial myostatin protein does not allow it to fit correctly into cells' receptors, causing extra-big muscles to develop. • We see the heavily muscled phenotype.	

Element of CCC, SEP, and DCI being assessed	Evidence that element is used effectively	Evidence of development or extension
2.2 Cause and effect relationships may be used to predict phenomena in natural or designed systems. 6.1 Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function.	Model (or written explanation) shows the cause-and-effect chain from genotype to protein to phenotype. Look for any of the following: • the words "cause", "effect", "influence", "because", and so forth • arrows between elements in the sequence of genotype and alleles to protein to protein's job to phenotype Model (or written explanation) represents the different structures of the two myostatin proteins and shows or explains how their shape is related to their function. • The shape of the full myostatin protein allows it to fit correctly into cells' receptors, causing a message to be sent. • The shape of the partial myostatin protein does not allow it to fit correctly into cells' receptors, so no message is sent.	

LESSON 7: ANSWER KEY 1

Key for Gotta-Have-It Checklist

Directions: Use our classroom consensus model, your Progress Tracker, and your science notebook to make a checklist of the components and interactions that need to be in our model to explain how an animal's musculature can be influenced by its genotype. You may or may not use every row.

Sample student responses are included below. Note that your students may have separated or named elements or interactions differently than is shown here.

What our model needs to have in order to answer the question, "How can an animal's musculature be influenced by its genotype?"	***Check off pieces of the model as you use them.***	
	used	***did not use***
Sex cells (egg and sperm) from parents		
Genotype of the individual—same alleles as sperm and egg		
Genotype gives directions for what protein to make—specific alleles that correspond with different versions of the myostatin protein		
Protein (myostatin)—partial/nonfunctional and/or full/functional to result in the corresponding phenotype		
The job or function of the protein—it does not fit into receptors on cells, which causes extra-big muscles, or it does fit, which causes typical muscles		
The phenotype of the individual—heavily muscled, medium-muscled, or typically muscled		

Name: _____ Date: _____

Revise Your Model

Directions: Choose one of the following ways to explain how an animal's genotype can influence its phenotype of musculature.

Choice 1: Develop a model in the space below to explain how an animal's genotype can influence its phenotype of musculature.

- Choose an animal other than cattle that we have seen with extra-big muscles, such as sheep, dogs, pigs, or fish.
- Label the components of your model in the column on the left. Be sure to indicate cause-and-effect relationships.
- Show how these components influence the phenotype we see for both a typically muscled animal and a heavily muscled animal.
- You may choose to use words from the following list to make your ideas clear, but you may not need to use all of them: genotype, phenotype, sperm, egg, allele, protein, myostatin, receptor, gene, food, chromosomes, offspring.

How does an animal's genotype influence its phenotype?

Component	Animal other than cattle with typical musculature	Heavily muscled animal
sex cells from parents ↓		
Resulting phenotype we see		

Choice 2: Explain in writing how an animal's genotype can influence its musculature.

- Include explanations for both a typically muscled animal and heavily muscled animal.
- Be sure to describe cause-and-effect relationships.
- You may choose to use words from the following list to make your ideas clear, but you may not need to use all of them: genotype, phenotype, sperm, egg, sex cells, allele, protein, gene, food, chromosomes, parents, offspring, myostatin, receptor.

LESSON 7: ANSWER KEY 2

Key for the "Revise Your Model" Assessment

The scoring guidance provided here uses a + notation that can help you identify different ideas that students should include in their responses.

- If several of the ideas marked with a + are missing from a student's response, this may indicate the student has not yet mastered the science ideas or that the student may be struggling to bring those ideas together in a written explanation or model. Additional probing of their thinking can provide insight about whether the student is struggling with a science practice or science idea or both.
- If all or almost all of the ideas marked with a + are present in a student's response, this may indicate the student is able to use these science ideas in an explanatory model or written explanation.

Refer to *Rubric for the "Revise Your Model" Assessment* for specific connections to elements of this lesson's three-dimensional performance expectation and for guidance about providing feedback to students.

Directions: Choose one of the following ways to explain how an animal's genotype can influence its phenotype of musculature.

Since students were able to choose to develop their model in drawing or writing, you should expect responses in only one area from each student.

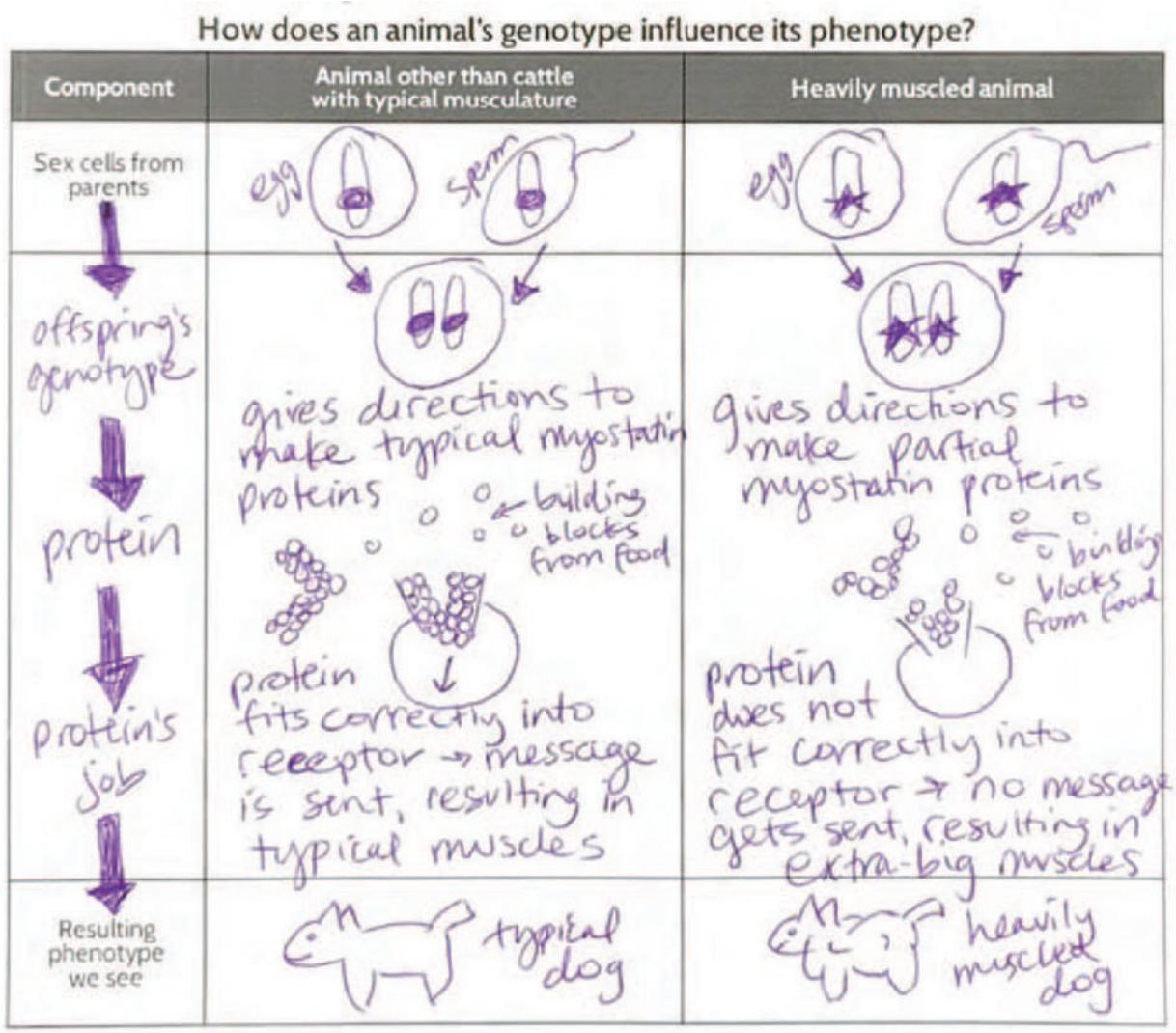
Choice 1: Develop a model in the space below to explain how an animal's genotype can influence its phenotype of musculature.

- Choose an animal other than cattle that we have seen with extra-big muscles, such as sheep, dogs, pigs, or fish.
- Label the components of your model in the column on the left. Be sure to indicate cause-and-effect relationships.
- Show how these components influence the phenotype we see for both a typically muscled animal and a heavily muscled animal.
- You may choose to use words from the following list to make your ideas clear, but you may not need to use all of them: genotype, phenotype, sperm, egg, allele, protein, myostatin, receptor, gene, food, chromosomes, offspring.

How does an animal's genotype influence its phenotype?

Component	Animal other than cattle with typical musculature	Heavily muscled animal
sex cells from parents ↓	+ Sperm and egg both show an allele related to typical myostatin (each has a circle symbol).	+ Sperm and egg both show an allele related to partial myostatin (each has a star symbol).
	+ The egg and sperm join to form the offspring's cell.	+ The egg and sperm join to form the offspring's cell.
+ offspring's genotype ↓	+ Offspring's cell shows both alleles for typical myostatin (two circle symbols).	+ Offspring's cell shows both alleles for partial myostatin (two star symbols).
	+ Model indicates in words or symbols that this genotype causes production of typical myostatin proteins.	+ Model indicates in words or symbols that this genotype causes production of partial myostatin proteins.
+ protein ↓	+ assembled from "building blocks" from food	+ assembled from "building blocks" from food
	+ Model shows typical myostatin proteins with complete shapes constructed of smaller bits.	+ Model shows partial myostatin proteins as incomplete shapes constructed of smaller bits.
+ protein's job ↓	+ Model shows how the typical myostatin protein fits into a cell's receptor correctly.	+ Model shows how the partial myostatin protein does not fit correctly into a cell's receptor.
	+ Proper function is indicated: message is sent inside cell.	+ Lack of function is indicated: message is not sent inside cell.
	+ The protein's function leads to developing typical muscles.	+ The protein's lack of function leads to developing extra-big muscles.
Resulting phenotype we see	+ Animal has typical muscles.	+ Animal is heavily muscled.

A sample model is also shown here.



Choice 2: Explain in writing how an animal's genotype can influence its musculature.

- Include explanations for both a typically muscled animal and heavily muscled animal.
- Be sure to describe cause-and-effect relationships.
- You may choose to use words from the following list to make your ideas clear, but you may not need to use all of them: genotype, phenotype, sperm, egg, sex cells, allele, protein, gene, food, chromosomes, parents, offspring, myostatin, receptor.

Look for the following ideas in a student's written explanation:

- Typically muscled and heavily muscled animals are explained.
- Sperm and egg for each individual have alleles related to typical or partial myostatin.
- The egg and sperm join to form the offspring's cell.
- Offspring has two copies of alleles related to typical or partial myostatin.
- The typical genotype causes production of typical myostatin proteins.
- The genotype related to extra-big muscles causes production of partial myostatin proteins.
- Proteins are assembled from "building blocks" from food.
- Typical myostatin protein fits into cells' receptors correctly.
- Partial myostatin protein does not fit into cells' receptors correctly.
- Protein's function is indicated: message is sent inside cell or not.
- Typical protein leads to typical muscles.
- Partial protein leads to extra-big muscles.

Example student response for written explanation

In my model, it shows that the two dogs' phenotypes have been influenced by their genotype. First, these two dogs got different chromosomes from their parents. For each dog, one allele came from a sperm cell, and one allele came from an egg cell. Together, those alleles make the genotype that dog has for the gene related to myostatin. Then in each dog's body, the alleles they have give directions for rearranging the building blocks from the dog's food into myostatin proteins. But, the alleles are differently shaped versions of the gene, so they cause differently shaped myostatin proteins to be produced. The dog with typical muscles has the genotype with alleles that cause the typical myostatin protein to be produced. That typical protein has the shape it needs to fit into cells' receptors, so a message is sent which leads to typical muscles. The heavily muscled dog has the genotype which causes a partial myostatin protein. The partial myostatin does not fit into the cells' receptors correctly, so no message is sent, and the result we see is extra-big muscles.

LESSON 8: ANSWER KEY 1

Using Pedigrees to Make Predictions

Ranchers noticed that certain bulls and cows reliably had offspring with traits they were interested in (like extra-big muscles or fast growth). This led to the practice of keeping herd books. This is a place where ranchers keep track of which cows are mated to which bulls and all the resulting offspring. When a bull/cow combination gives an exceptional offspring with desirable trait variations, ranchers might pair the same parents multiple times. Both desirable and undesirable variations are recorded. If undesirable trait variations (such as weak legs or feet) result from a match between a cow and bull, they will not continue to cross them. Over time, ranchers are able to create detailed pedigrees documenting family lineages. The most successful ranchers are those that are best at predicting which cow and bull crosses will result in the best combination of desirable characteristics while minimizing the undesirable characteristics. The following are examples of some of these cow/bull offspring records that were organized into pedigrees tracing individual cattle phenotypes with regard to musculature.

Work with your group to count up the total number of offspring for each of the different types of parental crosses and count how many offspring have each of the three different types of musculature phenotypes.

A. Both parents were homozygous for the allele for myostatin that results in big muscles:

Cross: EE x EE Breeding pair(s): _____#1_____

Phenotype of offspring	Genotype of offspring	Keep track of how many offspring by making hash marks or writing numbers for each family	Total number (Proportion)
Heavily muscled	EE		6 (6/6 = 100%)
Medium-muscled	Ee		0 (0%)
Typically muscled	ee		0 (0%)
		TOTAL of all offspring:	6

B. Both parents were homozygous for the allele for myostatin that results in typical muscles:

Cross: ee × ee Breeding pair(s): _____#2_____

Phenotype of offspring	Genotype of offspring	Keep track of how many offspring by making hash marks or writing numbers for each family	Total number (Proportion)
Heavily muscled	EE		0 (0%)
Medium-muscled	Ee		0 (0%)
Typically muscled	ee		6 (6/6 = 100%)
		TOTAL of all offspring:	6

C. One parent was homozygous for the allele for myostatin that results in big muscles, and the other was homozygous for the allele that results in typical muscles:

Cross: EE × ee Breeding pair(s): _____#5 and #11_____

Phenotype of offspring	Genotype of offspring	Keep track of how many offspring by making hash marks or writing numbers for each family	Total number (Proportion)
Heavily muscled	EE		0 (0%)
Medium-muscled	Ee		12 (12/12 = 100%)
Typically muscled	ee		0 (0%)
		TOTAL of all offspring:	12

D. One parent was homozygous for the allele for myostatin that results in big muscles, and the other parent was heterozygous:

Cross: EE × Ee Breeding pair(s): _____#4, #7 and #9_____

Phenotype of offspring	Genotype of offspring	Keep track of how many offspring by making hash marks or writing numbers for each family	Total number (Proportion)
Heavily muscled	EE		12 (12/26 = 46%)
Medium-muscled	Ee		14 (14/26 = 54%)
Typically muscled	ee		0
		TOTAL of all offspring:	26

E. One parent was homozygous for the allele for myostatin that results in typical muscles, and the other parent was heterozygous:

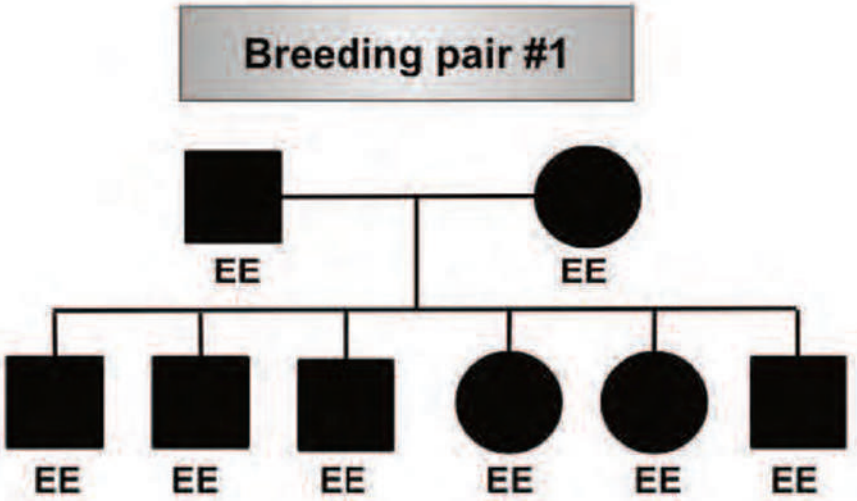
Cross: ee × Ee Breeding pair(s): _____#3 and #10_____

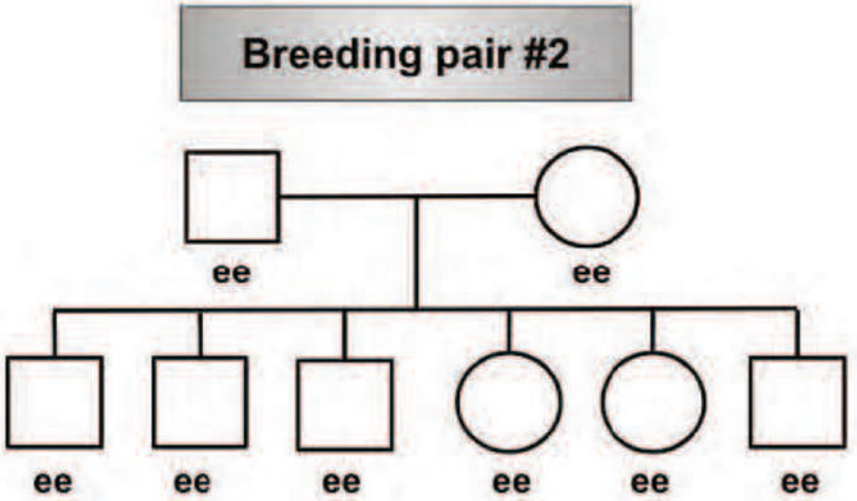
Phenotype of offspring	Genotype of offspring	Keep track of how many offspring by making hash marks or writing numbers for each family	Total number (Proportion)
Heavily muscled	EE		0
Medium-muscled	Ee		8 (8/15 = 53%)
Typically muscled	ee		7 (7/15 = 47%)
		TOTAL of all offspring:	15

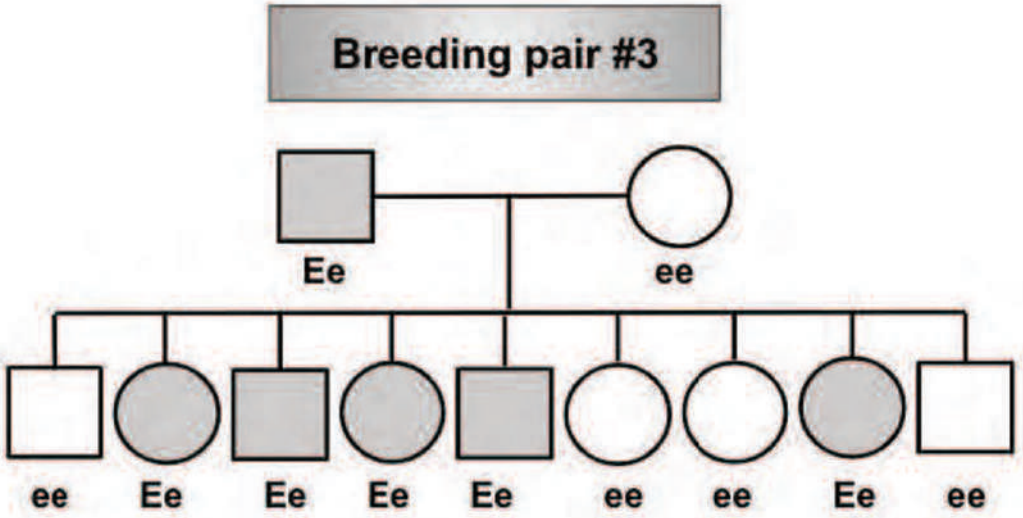
F. Both parents were heterozygous:

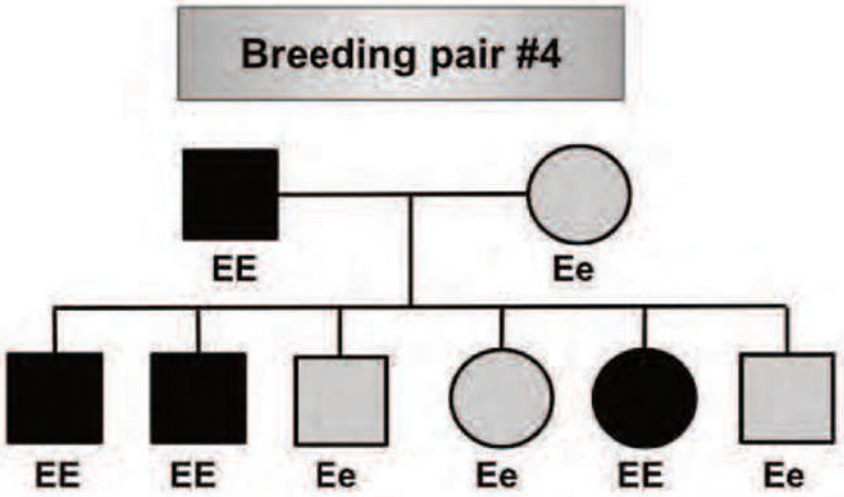
Cross: Ee × Ee Breeding pair(s): _____#6 and #8_____

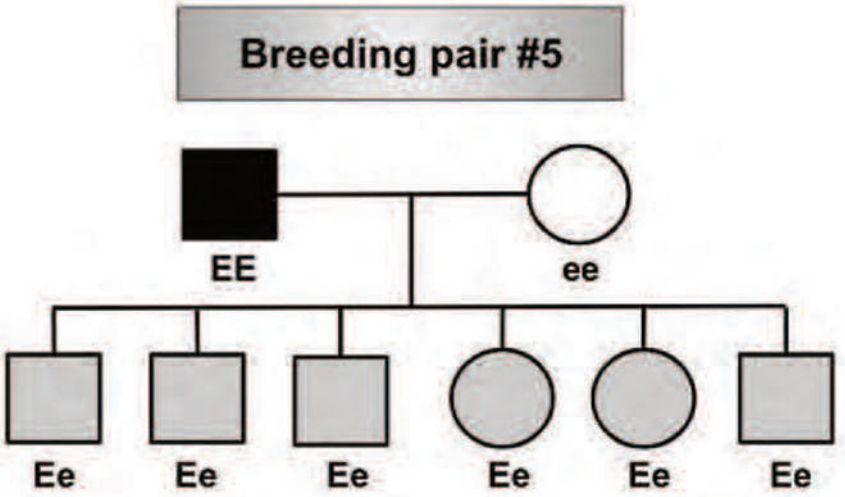
Phenotype of offspring	Genotype of offspring	Keep track of how many offspring by making hash marks or writing numbers for each family	Total number (Proportion)
Heavily muscled	EE		4 (4/20 = 20%)
Medium-muscled	Ee		11 (11/20 = 55%)
Typically muscled	ee		5 (5/20 = 25%)
		TOTAL of all offspring:	20

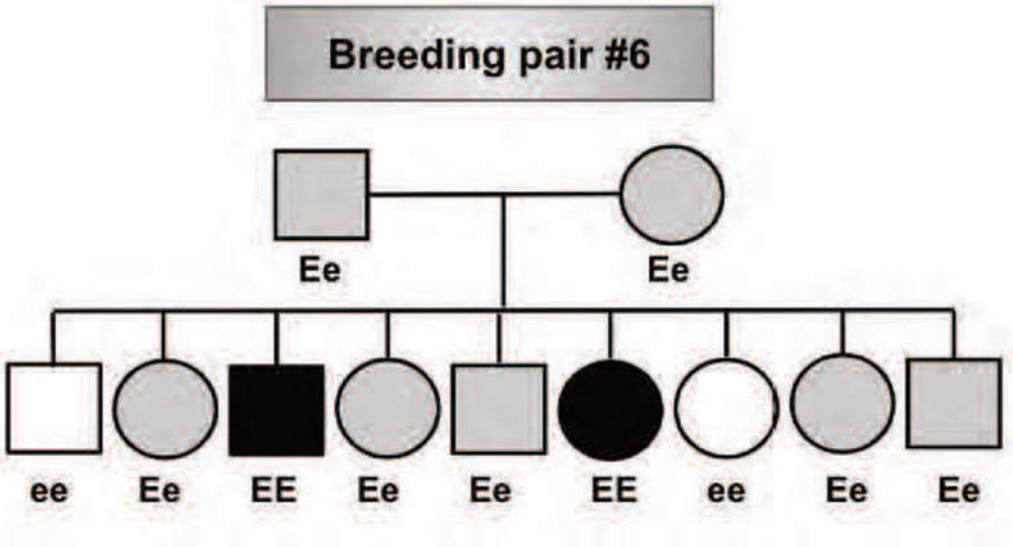

Breeding pair #1
EE
EE
EE
EE
EE
EE
EE
EE

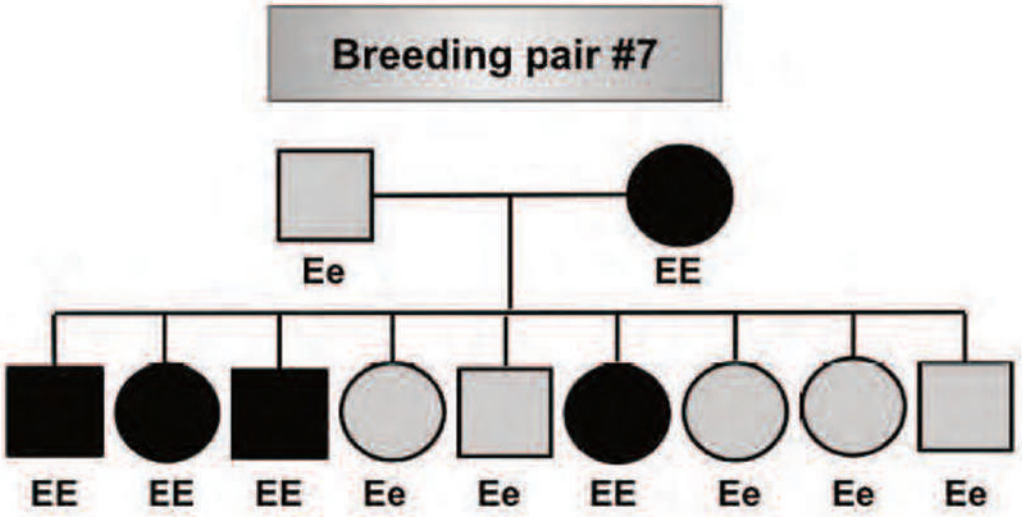

Breeding pair #2
ee
ee
ee
ee
ee
ee
ee
ee

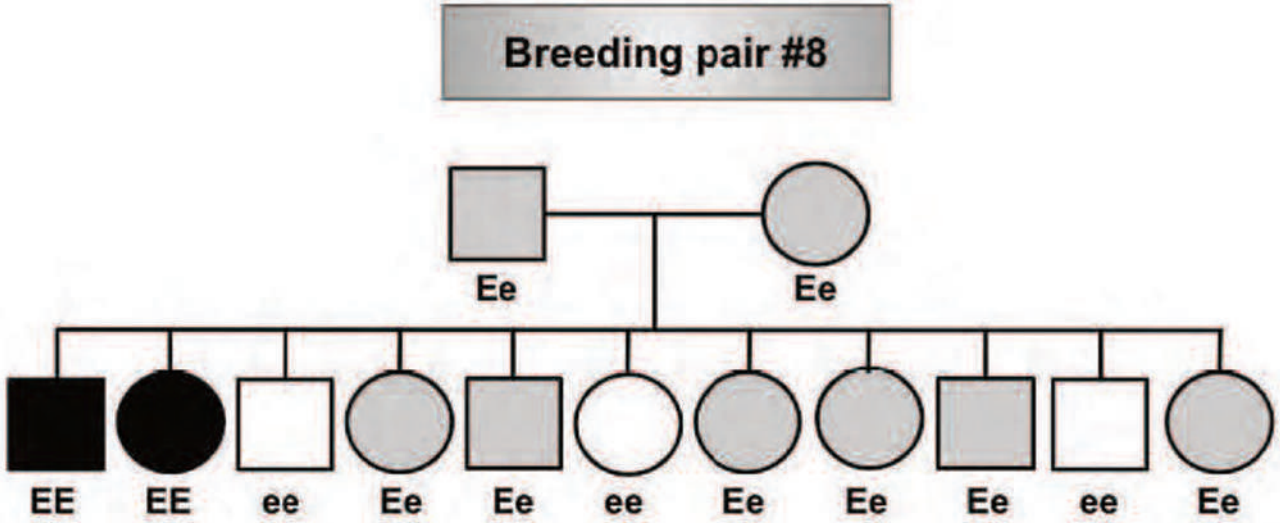

Breeding pair #3
Ee
ee
ee
Ee
Ee
Ee
Ee
ee
ee
Ee
ee

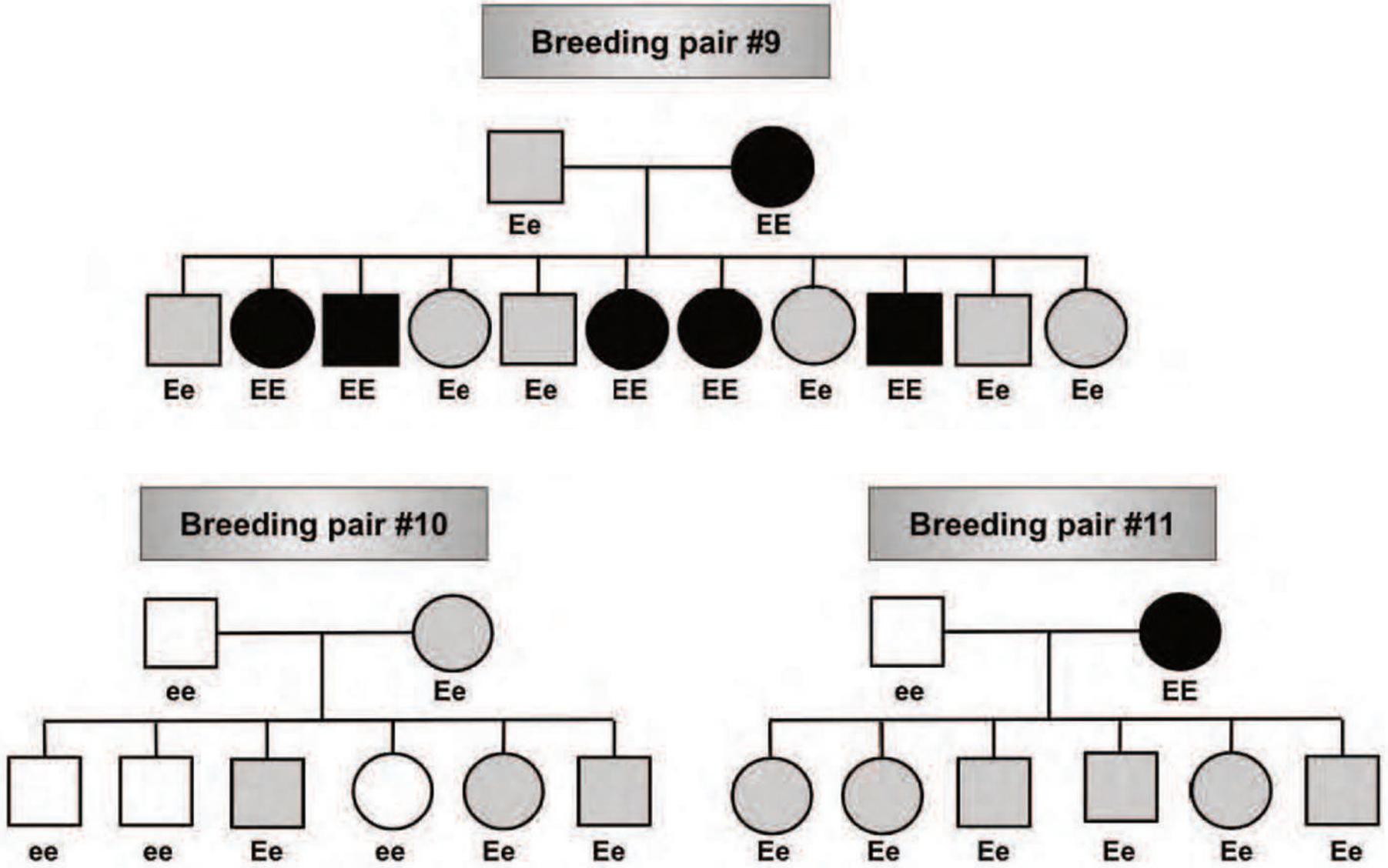

Breeding pair #4
EE
Ee
EE
EE
Ee
Ee
EE
Ee


Breeding pair #5
EE
ee
Ee
Ee
Ee
Ee
Ee
Ee


Breeding pair #6
Ee
Ee
ee
Ee
EE
Ee
Ee
EE
ee
Ee
Ee


Breeding pair #7
Ee
EE
EE EE EE Ee Ee EE Ee Ee Ee


Breeding pair #8
Ee
Ee
EE EE ee Ee Ee ee Ee Ee Ee ee Ee


Breeding pair #9
Ee
EE
Ee EE EE Ee Ee EE EE Ee EE Ee Ee
Breeding pair #10
ee
Ee
ee ee Ee ee Ee Ee
Breeding pair #11
ee
EE
Ee Ee Ee Ee Ee Ee

LESSON 10: RUBRIC 1

Rubric for Goldfish Assessment

Directions: The alignment table shown here indicates how student work on G*oldfish Assessment* and *Checklist for Obtaining and Evaluating Information from Scientific Text* supports each element of this three-dimensional, lesson-level performance expectation. The descriptors listed with the elements describe possible evidence that the element is used effectively in the student's explanation.

The rubric that follows offers the same descriptors as the alignment table, but in a format that may allow you to more easily record student progress and/or communicate feedback to students. This rubric does not attempt to predict all the possible ways students may still show that they are developing their understandings and use of practices, nor does it attempt to forecast all the possible ways students may show they have advanced understanding and/or especially deep use of practices. Instead, you may mark examples of evidence you see and jot notes about where specifically a student has room for improvement or has shown above-and-beyond understanding. You can then share this feedback with students (in writing or in a conversation).

10. A Critically read scientific texts and construct an explanation using models and math to describe how sexual reproduction results in offspring with genetic variation in the context of goldfish coloration.

SEP Elements	DCI Elements	CCC Elements
8.1 Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s). 6.2 Construct an explanation using models or representations. 5.4 Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems. Student demonstrates comprehension of the goldfish study article by • determining the central idea of the article and/or the question the author was asking about the predictable patterns of variation in the trait of goldfish scales between parents and offspring and • identifying the evidence that Dr. Chen collected about these patterns using an appropriate research method. Student models the patterns of goldfish matings and offspring proportions as described in the text, including representation of the genotypes and phenotypes in each pedigree. Student uses a model to explain the cause-effect relationships leading to the phenotypes of transparent- and brown-scaled fish. Student uses probability calculations and/or Punnett squares to predict the chances of different matings resulting in specific phenotypes.	LS3.A: 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. (Mutations are not specifically addressed in this assessment.) LS3.A: Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. LS3.B: 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. LS4.B In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring. Student uses models to explain the patterns of inherited trait variations from parents to offspring, representing that individuals have two of each chromosome and, hence, two alleles of a gene related to scale color, one acquired from each parent. Student uses a model to explain the cause-effect relationships which lead to the phenotypes of transparent- and brown-scaled fish: • Each individual has two alleles of a gene related to scales, and one allele was acquired from each parent. • The genotypes are homozygous but with different alleles for brown and transparent scales. • The two genotypes cause different-shaped proteins to be produced. • Student indicates that the protein leads to the phenotype, including a description and/or drawing of the phenotype for each fish. Student uses information from a scientific text and probability calculations and/or Punnet squares to predict the chances of different matings resulting in specific phenotypes, such as these: • A brown × transparent mating has a 100% chance of producing a speckled fish. • A specked × speckled mating has a 50% chance of producing a speckled fish.	1.3 Patterns can be used to identify cause and effect relationships. 2.2 Cause and effect relationships may be used to predict phenomena in natural or designed systems. Student obtains information about inheritance patterns described in the goldfish article to identify cause-and-effect relationships that result in different phenotypes of offspring. Student uses models to explain the cause-and-effect relationships which lead to certain phenotypes of goldfish. Student uses mathematical concepts to predict the probabilities of offspring phenotypes that will result from certain goldfish matings.

This rubric is intended for teacher use, not for students to use as a checklist while developing their responses.

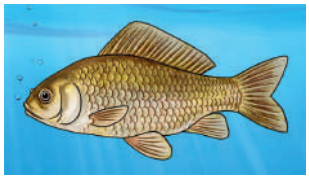
Element of CCC, SEP, and DCI being assessed	Evidence that element is used effectively	Evidence of development or extension
8.1 Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).	Student demonstrates comprehension of the goldfish study article by • determining the central idea of the article and/or the question the author was asking about the predictable patterns of variation in the trait of goldfish scales between parents and offspring and • identifying the evidence that Dr. Chen collected about these patterns using an appropriate research method. Student models the patterns of goldfish matings and offspring proportions as described in the text including representation of the genotypes and phenotypes in each pedigree.	
6.2 Construct an explanation using models or representations.	Student uses a model to explain the chain of cause-effect relationships leading to the phenotypes of transparent- and brown-scaled fish.	
5.4 Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.	Student uses probability calculations and/or Punnett squares to predict the chances of different matings resulting in specific phenotypes.	

Element of CCC, SEP, and DCI being assessed	Evidence that element is used effectively	Evidence of development or extension
LS3.A: 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. (Mutations are not specifically addressed in this assessment.) LS3.A: Variations of inherited traits between parent and offspring arise from genetic differences that result from the sub-set of chromosomes (and therefore genes) inherited. LS3.B: 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. LS4.B In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.	Student uses models to explain the patterns of inherited trait variations from parents to offspring, representing that individuals have two of each chromosome and hence two alleles of a gene related to scale color, one acquired from each parent. Student uses a model to explain the cause-effect relationships that lead to the phenotypes of transparent and brown-scaled fish: • Each individual has two alleles of a gene related to scales, and one allele was acquired from each parent. • The genotypes are homozygous but with different alleles for brown and transparent scales. • The two genotypes cause different-shaped proteins to be produced. • Student indicates that the protein leads to the phenotype, including a description and/or drawing of the phenotype for each fish. Student uses information from a scientific text and probability calculations and/or Punnett squares to predict the chances of different matings resulting in specific phenotypes, such as: A brown × transparent mating has a 100% chance of producing a speckled fish. A specked × speckled mating has a 50% chance of producing a speckled fish.	
1.3 Patterns can be used to identify cause and effect relationships.	Student obtains information about inheritance patterns described in the goldfish article to identify cause-and-effect relationships that result in different phenotypes of offspring.	
2.2 Cause and effect relationships may be used to predict phenomena in natural or designed systems.	Student uses models to explain the cause-and-effect relationships which lead to certain phenotypes of goldfish. Student uses mathematical concepts to predict the probabilities of offspring phenotypes that will result from certain goldfish matings.	

Name: _____ Date: _____

Goldfish Assessment

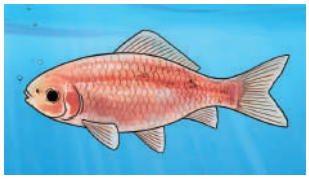
A. Brown goldfish



B. Speckled goldfish



C. Transparent goldfish



Goldfish are an important symbol in Chinese culture. Chinese people have been breeding goldfish for over 2,000 years. The type of fish they were bred from, the Asian carp, is normally gray, brown, or silver. But relatively rare mutations that produce red, orange, yellow, or no coloration in goldfish have been observed and recorded in China for at least 1,600 years. Research on goldfish breeding and genetics began over 100 years ago. Shisan C. Chen (1894–1957) was a Chinese geneticist who made some of the first discoveries of patterns in goldfish genetics.

Dr. Chen wrote a paper in 1928 titled "Transparency and Mottling, a Case of Mendelian Inheritance in the Goldfish *Carassius Auratus*" that described his experiments and results.* In his experiments, he had three different-looking goldfish (see drawings above), which he figured out were a result of whether their scales were transparent or reflective. In brown goldfish (A) the scales are reflective (you cannot see through them). Speckled goldfish (B) have some reflective and some transparent scales, and transparent goldfish (C) have all transparent scales.

Dr. Chen found that these variations in the trait of goldfish scales are passed from parents to offspring in predictable patterns. Here is a summary of the main results from Dr. Chen's paper:

Brown goldfish. I made matings between females and males of the brown goldfish. The offspring of these matings consisted of only brown goldfish (drawing A).

Transparent fish. I made nine matings between female and male transparent fish. These nine matings produced many thousands of offspring, and all of them were transparent fish (drawing C).

Breeding transparent fish with brown fish. I made ten matings between transparent females and brown males and ten matings between brown females and transparent males. All these matings produced only fish with a speckled pattern (drawing B).

Breeding speckled fish with speckled fish. I made seven matings between female and male speckled fish. The results of these matings show that among the offspring there were always about ¼ transparent fish, ½ speckled fish, and ¼ brown fish.

1a. Synthesize the data using the *Checklist for Obtaining and Evaluating Information from Scientific Text* to make sense of and evaluate the information in the reading.

1b. Using the information you obtained from the reading, visually represent each mating in Dr. Chen's scientific paper by creating 4 pedigrees, one of each mating he did in his experiment. Make four offspring for each mating. Be sure to include a key for phenotype and genotype in your pedigree.

1c. In 1928, when Dr. Chen did research on goldfish, scientists did not yet know about genetic material, proteins, and phenotypes. Write or draw a model that explains how the transparent fish's phenotype is influenced by its genotype, starting with how that fish got its genotype and including a protein. Also include an example of the brown fish for comparison. Be sure to indicate cause-effect relationships in your model and/or explanation.

2a. Speckled goldfish are popular fish because of their beautiful colors. If a goldfish breeder wanted to **breed speckled fish**, should the breeder mate a speckled female with a speckled male *or* a brown female with a transparent male? Which breeding combination would you recommend and why? Use Punnett squares or probability calculations showing the potential outcomes of each mating to support your answer.

2b. Use words and/or drawings to show how the offspring's genotype results from the parents' chromosomes. (You may or may not explain this cause-effect relationship using your Punnett square or your math work.)

3. (This item will not be scored.) The goldfish breeder kept two speckled siblings (both from the same parents) in two different environments. The breeder noticed that the fishes' scale colors stayed the same in these different environments, but their size was different: one was significantly larger than the other. Predict three possible environmental factors that could be influencing the size variation between these two goldfish.

_____

_____

_____

_____

_____

Source

*Chen, S. C. (1928). Transparency and Mottling, a Case of Mendelian Inheritance in the Goldfish *Carassius Auratus*. *Genetics*, 13 (5), p. 434–52. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1200991/pdf/434.pdf

LESSON 10: ANSWER KEY 1

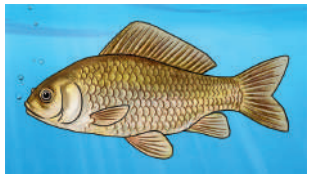
Key for Goldfish Assessment

Scoring Guidance: The sample student responses provided below use a + notation that can help you identify different ideas that students should or could include in their responses.

- If several of the ideas marked with a + are missing from a student's response, this may indicate the student has not mastered the science ideas or may be struggling to bring those ideas together in a written explanation or model. Additional probing of their thinking can provide insight about whether they are struggling with a science practice, science idea, or both.
- If all or almost all of the ideas marked with a + are present in a student's response, this may indicate that the student has mastered the science ideas and is able to use them in a written explanation or explanatory model.

Refer to *Rubric for Goldfish Assessment* for specific connections to elements of this lesson's three-dimensional performance expectation and for guidance about providing feedback to students.

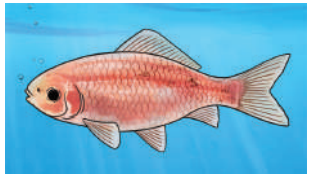
A. Brown goldfish



B. Speckled goldfish



C. Transparent goldfish



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Dr. Chen found that these variations in the trait of goldfish scales are passed from parents to offspring in predictable patterns. Here is a summary of the main results from Dr. Chen's paper:

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Breeding transparent fish with brown fish. I made ten matings between transparent females and brown males and ten matings between brown females and transparent males. All these matings produced only fish with a speckled pattern (drawing B).

Breeding speckled fish with speckled fish. I made seven matings between female and male speckled fish. The results of these matings show that among the offspring there were always about ¼ transparent fish, ½ speckled fish, and ¼ brown fish.

1a. Synthesize the data using *Checklist for Obtaining and Evaluating Information from Scientific Text* to make sense of and evaluate the information in the reading.

See *Key for Checklist for Obtaining and Evaluating Information from Scientific Text for* sample student responses to this part of the task.

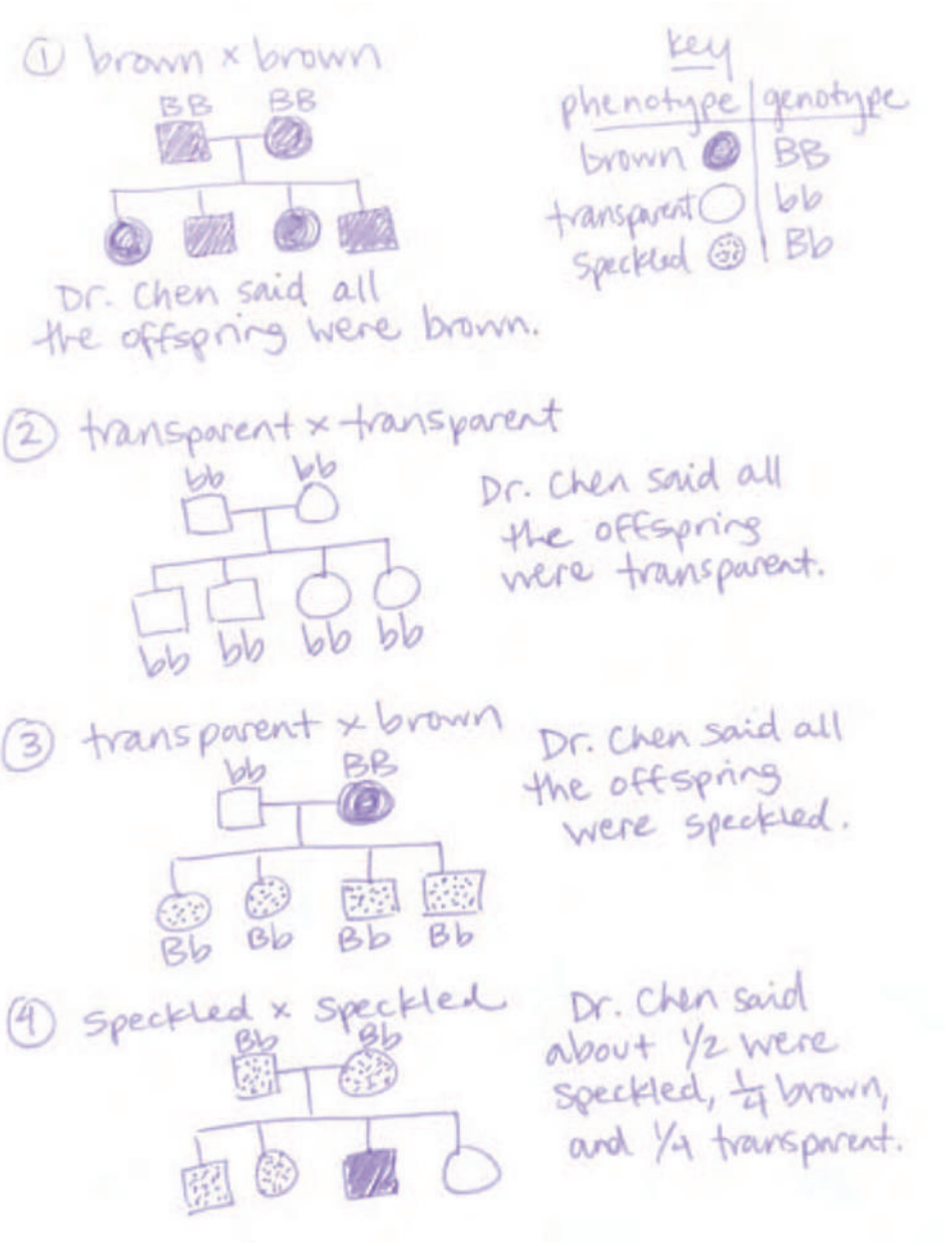
1b. Using the information you obtained from the reading, visually represent each mating in Dr. Chen's scientific paper by creating 4 pedigrees, one of each mating he did in his experiment. Make four offspring for each mating. Be sure to include a key for phenotype and genotype in your pedigree.

+ Student represents each of the four matings as described in the text (such as are shown in the sample student response below).

+ Pedigrees represent the correct proportion of offspring as described in the text (such as are shown in the sample student response below).

+ Student includes a key or some way to note the genotypes and phenotypes in each pedigree.

Sample student response (considered complete) to the right.



1c. In 1928, when Dr. Chen did research on goldfish, scientists did not yet know about genetic material, proteins, and phenotypes. Write or draw a model that explains how the transparent fish's phenotype is influenced by its genotype, starting with how that fish got its genotype and including a protein. Also include an example of the brown fish for comparison. Be sure to indicate cause-effect relationships in your model and/or explanation.

+ Student shows that each individual has two alleles of a gene related to scales, and one allele was acquired from each parent.

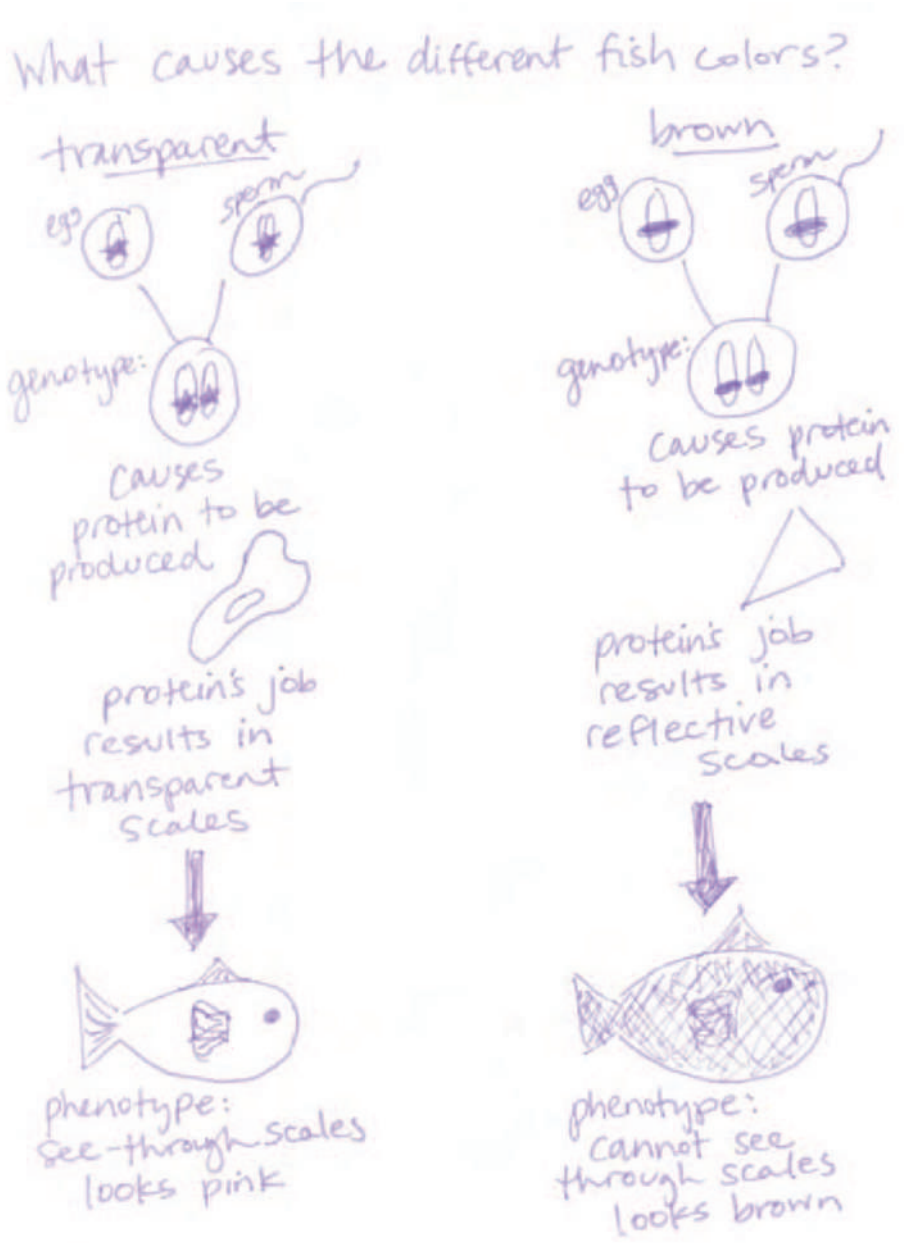
+ Student shows and/or describes the genotypes as homozygous but with different alleles for brown and transparent.

+ Student shows or describes the genotypes affecting the protein that is produced in each case.

+ Proteins for brown fish and for transparent fish are differently shaped.

+ Student indicates that the protein leads to the phenotype, including a description and/or drawing of the phenotype for each fish.

Sample student response (considered complete) to the right.



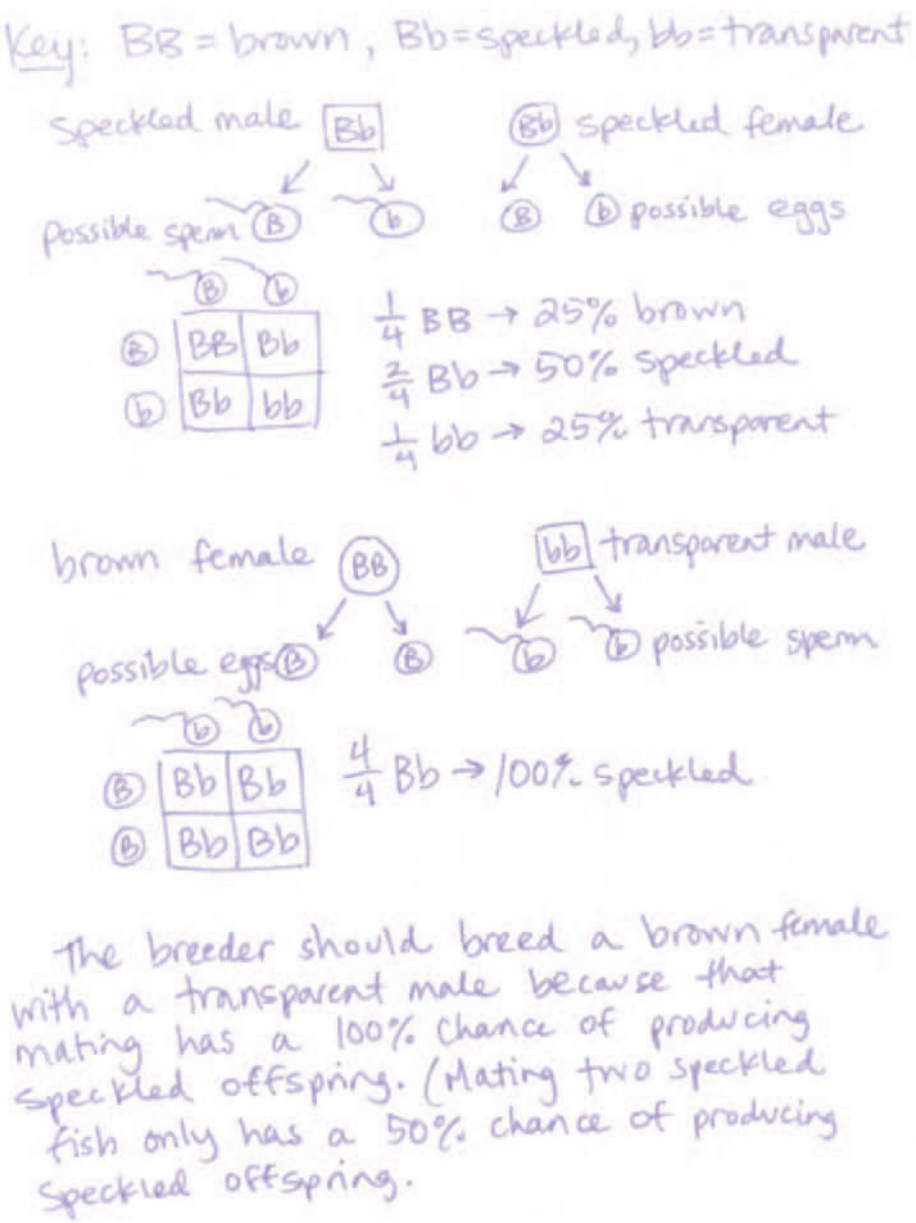
2a. Speckled goldfish are popular fish because of their beautiful colors. If a goldfish breeder wanted to **breed speckled fish**, should the breeder mate a speckled female with a speckled male *or* a brown female with a transparent male? Which breeding combination would you recommend and why? Use Punnett squares or probability calculations showing the potential outcomes of each mating to support your answer.

+ The breeder should breed a brown female with a transparent male because that combination has a 100% chance of producing a speckled fish.

+ Breeding a speckled male with a speckled female has only a 50% chance of resulting in speckled fish.

+ Punnett squares or probability calculations use representations or numbers to show alleles in the parents and offspring.

Sample student response (considered complete) to the right.



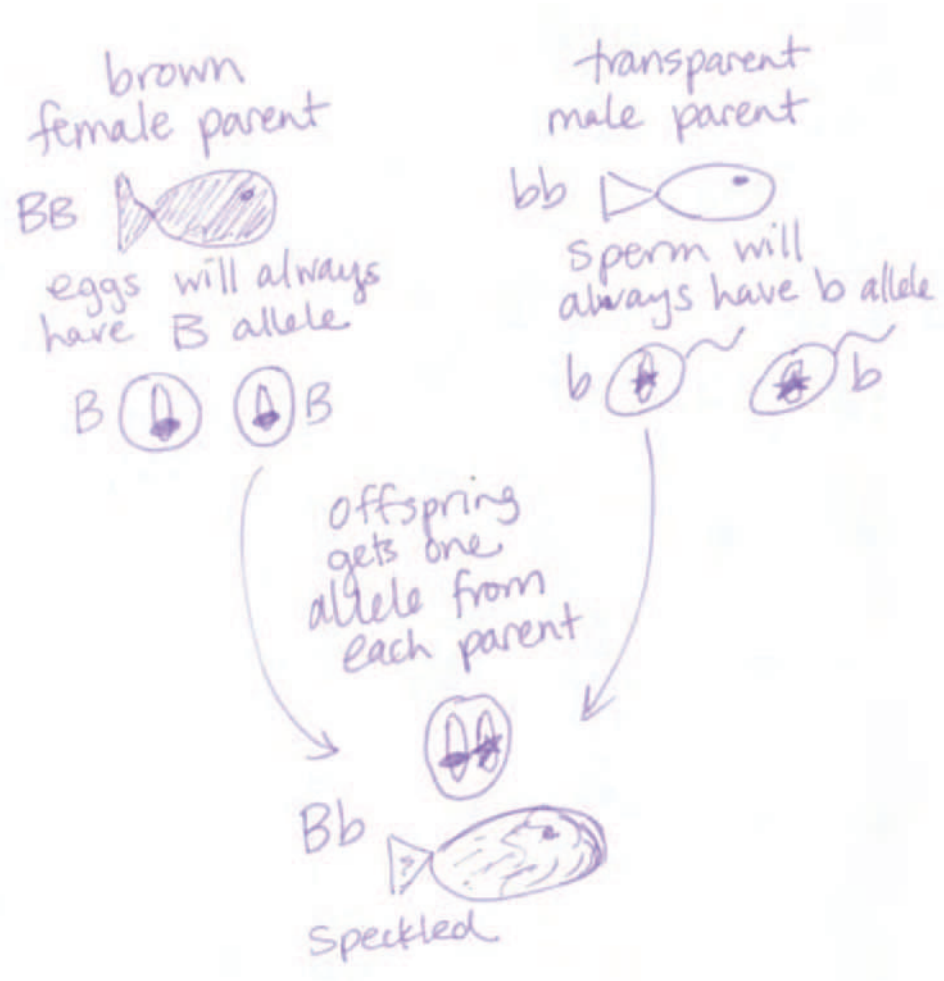
2b. Use words and/or drawings to show how the offspring's genotype results from the parents' chromosomes.

+ Student shows one chromosome being inherited from each parent.

+ Student shows that each allele is associated with a chromosome from each parent.

+ Words and/or symbols (such as arrows) indicate that the parents' chromosomes are the cause and the offspring's genotype is the result.

Sample student response (considered complete) to the right.



3. (This item will not be scored.) The goldfish breeder kept two speckled siblings (both from the same parents) in two different environments. The breeder noticed that the fishes' scale colors stayed the same in these different environments, but their size was different: one was significantly larger than the other. Predict three possible environmental factors that could be influencing the size variation between these two goldfish.

Do not include this response in your evaluation of the student's work in the unit at this point. Instead, consider this item a formative assessment moment to see student thinking about environmental as well as genetic influences on trait variation and use these ideas to inform future class discussions.

Sample student responses may include the following:

- diet, what they are eating
- amount of exercise
- amount of oxygen in the water
- temperature of the water
- size of the tank and living space
- whether there are other fish sharing the tank or space

Source

*Chen, S. C. (1928). Transparency and Mottling, a Case of Mendelian Inheritance in the Goldfish *Carassius Auratus*. *Genetics*, 13(5), p. 434-52. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1200991/pdf/434.pdf

Name: _____ Date: _____

Lesson 10 Checklist for Obtaining and Evaluating Information from Scientific Text

Obtaining information from scientific text

• Read for the gist—skim the title, headings, images.	What is the central idea or claim? _____ _____
• Mark up the text.	Select methods for marking the text. • Keep track of questions you have in the margins. • Circle key words. • Put question marks by words you want to learn more about. • Underline main ideas. • _____(another method of your own)
• If the text is about research, ask yourself these questions about the text.	What question was the author asking? _____ What evidence did they collect? _____ _____

Evaluating information from scientific text

• Identify the goal of the text.	What is the goal of the text—to share information, to convince someone of something, to distract people from a larger issue, something else? _____ _____
• If it is a research study, identify how the study was done.	Are the research methods used appropriate for the purpose of the study? Why or why not? _____ _____

LESSON 10: ANSWER KEY 2

Key for Checklist for Obtaining and Evaluating Information from Scientific Text

Scoring Guidance: The sample student responses provided below use a + notation that can help you identify different ideas that students should or could include in their responses.

- If several of the ideas marked with a + are missing from a student's response, this may indicate the student is still developing in this practice.
- If all or almost all of the ideas marked with a + are present in a student's response, this may indicate that the student is approaching mastery with this practice and is ready to carry out this practice in the future without using this checklist.

Refer to *Rubric for Goldfish Assessment* for specific connections to elements of this lesson's three-dimensional performance expectation and for guidance about providing feedback to students.

Obtaining information from scientific text	
• Read for the gist—skim the title, headings, images.	What is the central idea or claim? + Variation in the trait of goldfish scales is passed from parents to offspring in predictable patterns.
• Mark up the text.	Select methods for marking the text. • Keep track of questions you have in the margins. • Circle key words. • Put question marks by words you want to learn more about. • Underline main ideas. • _____(another method of your own) + Student has selected and used at least one method to mark up the text.
• If the text is about research, ask yourself these questions about the text.	What question was the author asking? + Look for a version of a question about passing trait variations from parent to offspring, for example: Can we see predictable patterns in the way goldfish parents pass the trait of reflective scales to their offspring? What evidence did they collect? + Dr. Chen mated goldfish and collected the numbers (or proportion) of brown, transparent, and speckled goldfish produced from each mating.

Evaluating information from scientific text	
• Identify the goal of the text.	What is the goal of the text—to share information, to convince someone of something, to distract people from a larger issue, something else? + The goal of the text is to share information about a set of experiments.
• If it is a research study, identify how the study was done.	Are the research methods used appropriate for the purpose of the study? Why or why not? + The scientist mated goldfish and kept track of which fish he mated and what the resulting offspring looked like. These methods are appropriate for the purpose of the research because if you do not know if or how a trait variation is inherited, the only way to find out is to breed offspring.

Negative Control Demonstration

To ensure the protocol is not resulting in the substance seen in the video where the scientists extracted genetic material from animal cells, students should ask to see this protocol applied to a substance they know does not have any genetic material. They should also want to make sure we are not extracting some other molecule all of these samples would have in common, like protein.

Safety Precautions

- Wear indirectly vented chemical-splash goggles, a nonlatex apron, and vinyl or nitrile gloves during the setup, investigation, and cleanup of the lab.
- Immediately wipe up any spilled water on the floor—this is a slip and fall hazard.
- Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
- Never taste or eat any substance or chemical in the lab.
- Use caution when working with heated liquids—this can burn skin!
- Make sure there is appropriate ventilation to remove alcohol vapors, which are flammable. Otherwise, this activity should be done under a fume hood.
- To prevent a fire hazard, make sure there are no active flames when using alcohol in this activity.
- Wash your hands with soap and water immediately after completing this activity.

Testing Water

1. Place 30 mL of plain tap water in the 1 QT heavy-duty ziplock bag.
2. Add 20 mL of warm salt water into the bag with the plain tap water. Make sure the salt water is not too hot so it does not melt the bag. Remove the air and seal the bag.
3. Gently mix the salt water with the plain tap water in the sealed bag.
4. Add 1 spoonful of dish soap to the bag. Remove the air and seal the bag.
5. Gently but thoroughly mix the soap with the solution. Be careful not to make too many suds!
6. Put a piece of cheesecloth over the top of a 100-mL beaker (or similar container) and secure it with a rubber band. Then gently push down on the top, making a little pocket. You will use this to strain your sample.
7. Slowly pour the mixture through the cheesecloth. Be careful not to overfill. You may have to wait while some liquid flows through to pour the entire sample.
8. After the sample has completely flowed through the cheesecloth, remove the rubber band and cheesecloth from the container and discard the cheesecloth into the trash.
9. Add a pinch of meat tenderizer to the filtered sample and stir gently to mix.



10. Slowly pour 20 mL of ice-cold alcohol into the beaker with the sample. Tilt the beaker slightly and pour down the side of the glass, being careful *not* to mix the layers.
11. If genetic material is present in the sample, you will see little white strands forming in between the layers of the sample and the alcohol (you will not see any solid form as a result of this protocol).
12. Use a wooden skewer to show there is nothing to collect and no strands to pull up and spool.
13. Give students time to observe and record what they see.

Testing Protein Mixture

1. Follow the directions on the protein drink package to mix one serving of protein drink.
2. Place 30 mL of protein drink in the 1 QT heavy-duty ziplock bag.
3. Add 20 mL of warm salt water into the bag with the protein drink sample. Make sure the salt water is not too hot so it does not melt the bag. Remove the air and seal the bag.
4. Gently mix the salt water with the protein drink in the sealed bag.
5. Add 1 spoonful of dish soap to the bag. Remove the air and seal the bag.
6. Gently but thoroughly mix the soap with the solution. Be careful not to make too many suds!
7. Put a piece of cheesecloth over the top of a 100-mL beaker (or similar container) and secure it with a rubber band. Then gently push down on the top, making a little pocket. You will use this to strain your sample.
8. Slowly pour your sample through the cheesecloth. Be careful not to overfill. You may have to wait while some liquid flows through to pour the entire sample.
9. After the sample has completely flowed through the cheesecloth, remove the rubber band and cheesecloth from the container and discard the cheesecloth into the trash.
10. Slowly pour 20 mL of ice-cold alcohol into the beaker with the sample. Tilt the beaker slightly and pour down the side of the glass, being careful not to mix the layers.
11. If genetic material is present in the sample, you will see little white strands forming in between the layers of the sample and the alcohol (there will be a white precipitate, but it will not be the stringy substance seen in the video that extracted genetic material from egg and muscle tissue and you will not be able to spool it).
12. Use a wooden skewer to show there are no strands to pull up and spool.
13. Give students time to observe and record what they see.

Guidance for Flower Dissection

Summary: The flower dissection is an opportunity for students to investigate the connection between structure and function in a particular biological system—that of a sexual reproductive system of plants, a flower. Most flowers have both male and female reproductive structures in the same bloom, though there is a wide variety of arrangements of these structures in different types of flowers. Students should be able to find at least most of the parts that are labeled on the *Flower Diagram* handout.

General guidance

- Students will need to take apart most of the parts of the flower in order to find all the structures.
- Students should proceed *slowly* and look carefully before removing any parts of the flower.
- Most parts of the flower will come apart fairly easily if pulled on. Students should use tweezers and scissors only when necessary.
- Have students work from the outside of the flower to the inside, removing the outer parts first and examining the shapes and relationships of the parts that are left before removing additional parts.
- Different types of flowers may have structures that are somewhat different in shape or presentation than what is shown in the diagram. Have students look for similarities, not the identical appearance of structures from the diagram.

Specific guidance

- Pollen may come off on students' fingers as they work with the stamens. It is usually a yellowish powder. Pollen grains are usually very interesting viewed under magnification, if that is available in your classroom.
- The top of the pistil is called the *stigma*. It is often, though not always, sticky. Students may be able to feel this stickiness. A small amount of sticky liquid may come off on their fingers.
- Students should be able to see that the style is attached to the ovary and the ovary is in the center of the flower.
- If the ovary is carefully cut in half, it is often possible to see ovules. They may be the same color as the ovary tissue and will look like small, round objects.

Safety guidance

- Use safety glasses with side shields or safety goggles, vinyl or nitrile gloves, and a nonlatex apron during the setup, investigation, and cleanup of this activity.
- Use caution when using sharp tools and materials (e.g., tweezers, scissors) because they can cut or puncture skin.
- Avoid touching your face (so substances do not get near your nose or mouth). Never taste or eat any substance in the lab.
- Immediately pick up any items on the floor (e.g., leaves or flowers) in the work zone so they do not become a slip and fall hazard.

- Use caution when working with material that may be wet (e.g., flowers) as water on the floor may create a slip and fall hazard.
- Wash your hands with soap and water immediately after completing this activity.

Arranging the dissection on the paper

Students can arrange the separated parts of the flower on the paper in whatever way they like. They should be spread out enough to allow for labeling and attached carefully. Glue sticks work well for this purpose but take some extra time to dry before it is no longer sticky. Tape will also work but is not as neat. One example is shown here:

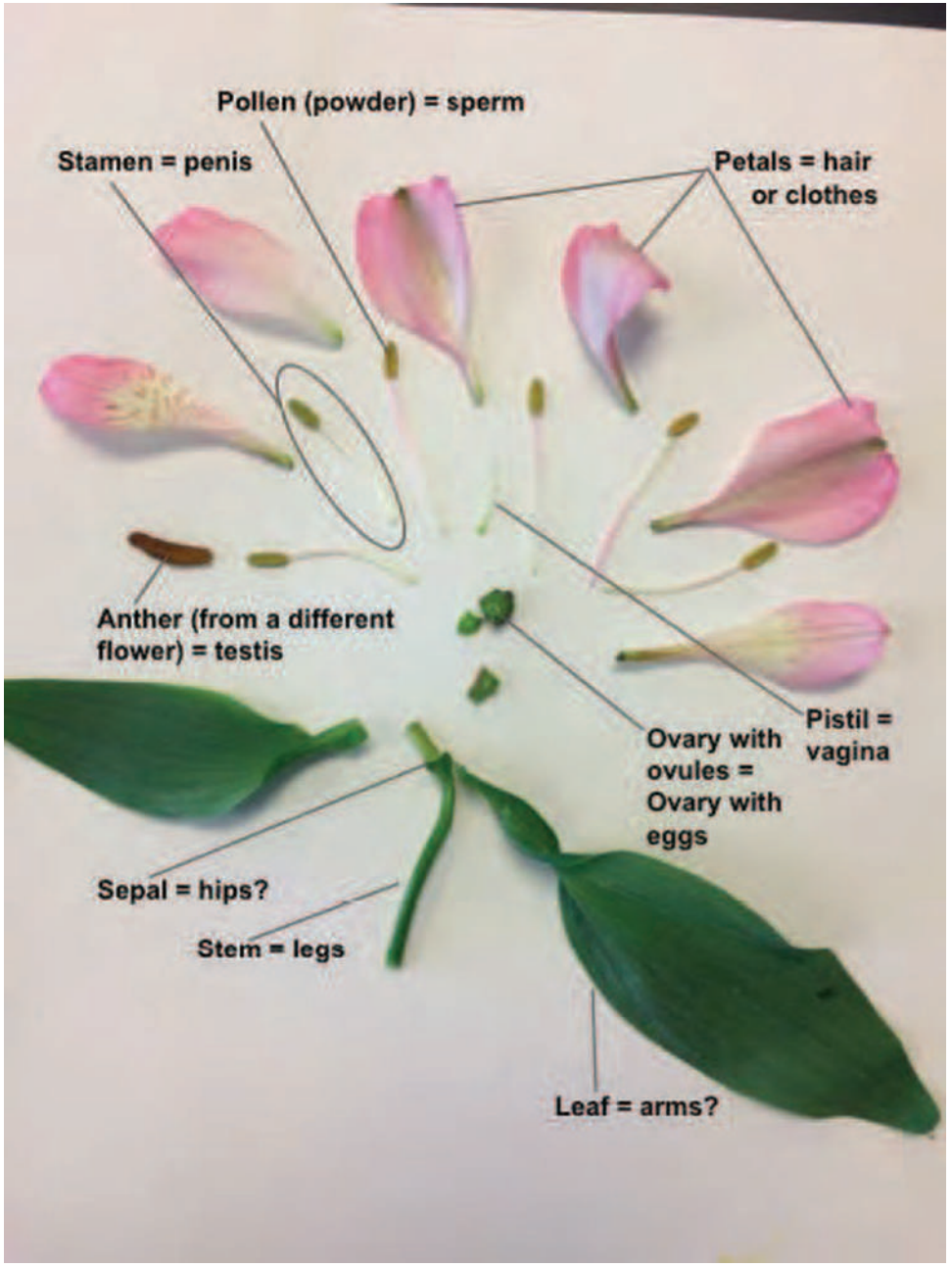


Labeling the dissection

An example of how students might choose to label their dissection is shown here. Students should be given a great deal of flexibility in assigning human equivalents to the flower structures. It is not critical that they identify every single flower structure or that they identify any particular human equivalents, except that they should identify and equate the functions of

- pollen with sperm and
- ovules with eggs.

In fact, pollen is a more-complicated structure than sperm, but it does contain the male sex cell of the flower, and it moves to get to the ovule, so it is most similar to the sperm in function. Similarly, the ovule is not the exact structural equivalent of the egg, but it is most similar to the egg in function.



Name: _____ Date: _____

LESSON 13: ANSWER KEY

Key for Exit Ticket

On the left is a photo of a lily flower. On the right is a drawing of the whole lily plant and some of its parts. Lillies are pollinated by moths.



Jim Evans, CC BY-SA 4.0



Walter Hood Fitch, PD-US

Sample student responses are shown below.

1. Using labels you add to the pictures, drawings of your own, and/or writing, explain how the lily plant is likely to reproduce and make seeds. Be sure you include:

- the most important structures

Look for students to include:

+ the pollen or sperm, indicated by text description or by labeling its location on the anther, and

+ the ovule or egg, indicated by text description or by labeling its location at the base of the flower.

(While pollen and ovules are structurally different than sperm and eggs, students are considering them as functional equivalents, so either response is acceptable. Other male or female structures may be indicated but are not expected.)

- the functions of those structures

+ The function of the pollen is to fertilize the ovule or to contribute the genetic information from the male parent to the offspring.

+ The function of the ovule is to combine with the pollen in fertilization or to contribute the genetic information from the female parent to the offspring.

- an explanation of the process of how sexual reproduction happens in the lily plant

+ The pollen is carried to the female parts of the flower by a moth.

+ It reaches the ovule in the ovary of the flower and fertilizes the ovule.

+ The ovule then becomes a seed.

1. If a gardener liked a particular lily flower that grew in their garden, and wanted to make more plants with the same kind of flower, how would you recommend that they do that? Explain why you recommend that way of doing it.

- Students should cite either asexual reproduction or a breeding strategy that will yield a very similar flower, as described below.
  - Asexual reproduction of lilies would rely on splitting the bulbs of the plant. However, if students suggest that a cutting or runner could be used, that is OK. This way of doing it is recommended because it will produce plants that are the same as the flower they liked.
  - Breeding of lilies would rely on manually transferring pollen from the male parts of the flower to the female parts of the same flower (or a different bloom that is on the same plant or even a different flower that looks the same) and then collecting and growing the seeds. This way of doing it is recommended because combining genetic information from flowers that are the same will result in offspring that are the same.

An example of a potential student response is shown below.



On the left is a picture of a lily flower. On the right is a picture of the whole lily plant and some of its parts. Lillies are pollinated by moths.

1. Using labels you add to the pictures, drawings of your own, and/or writing, explain how the lily plant is likely to reproduce and make seeds. Be sure you include:

- the most important structures
- the functions of those structures
- an explanation of the process of how sexual reproduction happens in the lily plant

The pollen is carried from the male parts of the flower to the female parts by a moth.

The pollen combines with the ovule to make a seed. It's probably inside some kind of fruit.

Name: _____ Date: _____

Lesson 14 Self-assessment for Obtaining, Evaluating, and Communicating Information

Place a check in each row to reflect on how you used this practice while researching your organism.		Did not do 	Sometimes did 	Always did 
Obtaining information	We identified the gist or central idea for each information source.			
	We identified the details from the information source that supported the central idea.			
	We made sense of information from any relevant images or diagrams that were included in the information source.			
	I contributed to the work of obtaining information.			
Evaluating information	We identified why each source was written or created.			
	We identified evidence supporting the author's/ creator's central ideas.			
	We checked that the information is reliable by using any or or all of these steps: • We found multiple resources cited by the author/ creator. • The ideas in this source align with ideas we have already figured out. • This author used appropriate study methods. • We have reasons to trust that this source is credible.			
	I contributed to the work of evaluating information.			
Communicating information	Our presentation met the purpose of communicating information: to share about the organism and how it reproduces asexually.			
	Our presentation was communicated in a way that could be easily understood by those who were hearing it and seeing it.			
	Our presentation fit the constraints of the activity (1-2 min in length).			
	I contributed to the work of communicating information.			

Looking at your responses in the "Obtaining information" section on the chart, how would you rate yourself on a scale of 1 (much improvement needed) to 5 (excellent)? _____

In what ways could you improve next time how you are obtaining information?

_____

_____

Looking at your responses in the "Evaluating information" section on the chart, how would you rate yourself on a scale of 1 (much improvement needed) to 5 (excellent)? _____

In what ways could you improve next time how you are evaluating information?

_____

_____

Looking at your responses in the "Communicating information" section on the chart, how would you rate yourself on a scale of 1 (much improvement needed) to 5 (excellent)? _____

In what ways could you improve next time how you are communicating information?

_____

_____

LESSON 14: ANSWER KEY

Asexual Reproduction Notes Key

Organism	How does it reproduce asexually?	How does the offspring's genetic information compare to the parent's?
spider plants	Baby plants grow off stems called *stolons** or *runners*. The babies are exact copies of the parent plant (no sex cells are needed to make them).	Baby plants are genetically identical to the parent.
potatoes	Potatoes are thickened parts of underground stems called *tubers*. They are part of the parent plant—no sex cells are needed to make them. The tubers (potatoes) have "eyes" that will sprout new plants the following season.	Plants that grow from tubers are genetically identical to the plant that formed the tubers.
aphids	The females' egg cells develop into clones of themselves—no males, no sperm, no fertilization. That is called *parthenogenesis*.*	Daughters are genetically identical to the females.
hydra	Hydra develop babies by "budding"—new individuals form on the outside of the parent and, when developed enough, detach. No sex cells are needed to make buds.	The baby hydra are genetically identical to the original parent.
marbled crayfish	The females' egg cells develop into clones of themselves—no males, no sperm, no fertilization. That is called *parthenogenesis*.*	Daughters are genetically identical to the females.
bacteria	A single-celled bacterium just splits into two cells (after it makes a copy of its genetic information so each half gets it). That is called *binary fission*.*	Each of the two new bacteria cells is genetically identical to the original one that split.
coral	Corals form "buds" that pop off and form a new colony. No sex cells are needed to make buds. Or, if a piece of a coral breaks off, it can form a new colony, too (called *fragmentation**).	The new corals are genetically identical to the original parent.
planaria	A planarian can break into pieces, and each piece will regenerate into a new planarian that is a clone of the original. That is called *fragmentation*.*	Planaria that regenerate from pieces of the original are genetically identical to the original.
echeveria	Echeveria reproduce by sprouting small offshoots from the mother plant. These baby plants can be separated and replanted in their own space.	These baby plants are clones of the original plant, meaning that they are genetically identical to the original plant.

*Teacher discretion if you want students to learn, use, or know these terms.

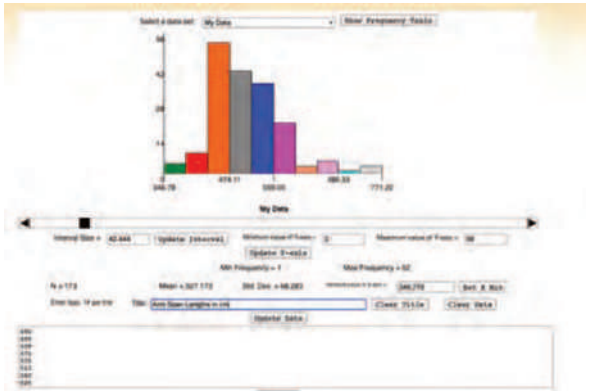
Alternate Histogram Tool Instructions

1. On the "Activity" tab, select "My Data" from the "Select a data set" dropdown menu.



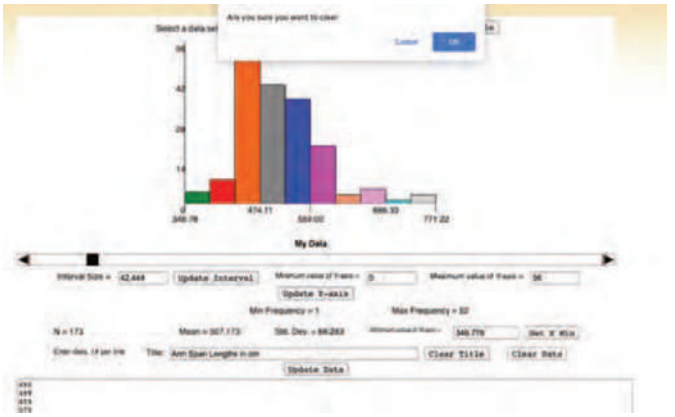
Shodor Foundation, CC BY-NC 3.0

2. Click the "Clear Title" button and type a title that is appropriate for your data.



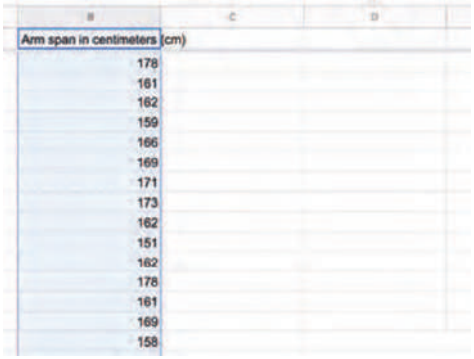
Shodor Foundation, CC BY-NC 3.0

3. Click the "Clear Data" button and then "OK" in the pop-up box that appears.



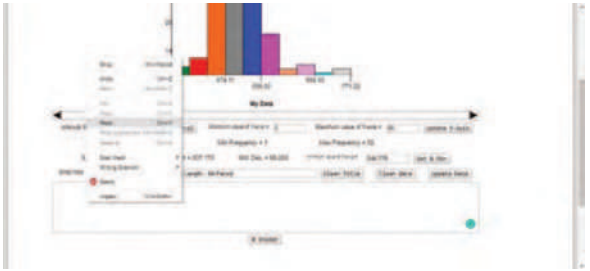
Shodor Foundation, CC BY-NC 3.0

4. Copy data from a spreadsheet file.



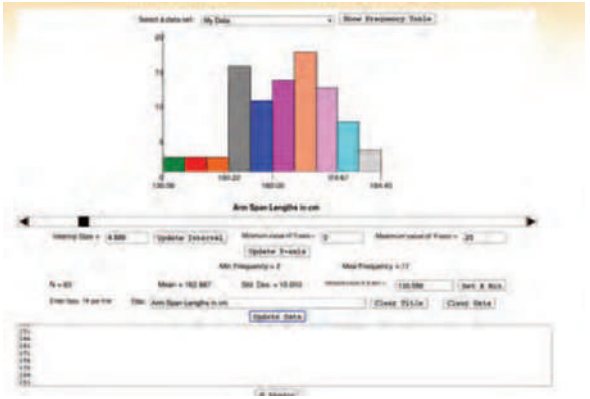
	Arm span in centimeters (cm)
	178
	161
	162
	159
	166
	169
	171
	173
	162
	151
	162
	178
	161
	169
	158

5. Paste the data into the data window.



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6. Click the "Update Data" button.



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7. Use the slider or change the "Interval Size" field and then click the "Update Interval" button to change the width and number of the bars.



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LESSON 17: RUBRIC

Rubric for Redwoods Assessment

Directions: The alignment table shown here indicates how student work on *Redwoods Assessment* supports each element of this three-dimensional, lesson-level performance expectation. The descriptors listed with the elements describe possible evidence that the element is used effectively in the student's explanation. The rubric that follows offers the same descriptors as the alignment table but in a format that may allow you to more-easily record student progress and/or communicate feedback to students. This rubric does not attempt to predict all the possible ways students may still show that they are developing their understandings and use of practices, nor does it attempt to forecast all the possible ways students may show they have advanced understanding and/or especially deep use of practices. Instead, you may mark examples of evidence you see and jot notes about where specifically a student has room for improvement or has shown above-and-beyond understanding. This feedback can then be shared with students (in writing or in a conversation) to support their learning.

This rubric is intended for teacher use, not for students to use as a checklist while developing their responses. If you would like your students to refer to a rubric during the assessment, the Lesson 17 *Teacher Guide* suggests how to develop one with them.

17.B Construct an explanation about how environmental and genetic factors influence the growth of organisms and how organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring.

SEP Elements	DCI Elements	CCC Elements
6.4 Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events. Student has constructed an explanation for the varying heights of redwood trees which shows an understanding of a key science idea: that genetic factors as well as environmental factors affect the growth of organisms.	LS1.B Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. LS1.B Genetic factors as well as local conditions affect the growth of the adult plant. Student explanation includes specific examples of environmental factors influencing redwood tree growth in Humboldt State Park, such as temperature, access to water, amount of light, soil conditions, and/or human interactions. Student explanation includes examples of genetic factors influencing redwood tree growth, such as their genetic information has instructions for proteins that help make them so tall and/or there could be a gene (or more than one) related to supertallness, and the supertall trees have a different allele for that gene than the average-height trees have. Student explains in the context of redwood tree growth how asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.	2.3 Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. Student explains the multiple influences (genetic and environmental) on the heights of redwood trees. Student explains the patterns of redwood tree growth by using their knowledge of the cause-effect relationships involved with passing on genetic information via sexual or asexual reproduction.

Element of CCC, SEP, and DCI being assessed	Evidence that element is used effectively	Evidence of development or extension
6.4 Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events.	Student has constructed an explanation for the varying heights of redwood trees which shows an understanding of a key science idea: that genetic factors as well as environmental factors affect the growth of organisms.	
LS1.B Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring.	Student explains in the context of redwood tree growth how asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.	
LS1.B Genetic factors as well as local conditions affect the growth of the adult plant.	Student explanation includes specific examples of environmental factors influencing redwood tree growth in Humboldt State Park, such as temperature, access to water, amount of light, soil conditions, and/or human interactions. Student explanation includes examples of genetic factors influencing redwood tree growth, such as their genetic information has instructions for proteins that help make them so tall and/or there could be a gene (or more than one) related to supertallness, and the supertall trees have a different allele for that gene than the average-height trees have.	
2.2 Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.	Student explains the multiple influences (genetic and environmental) on the heights of redwood trees. Student explains the patterns of redwood tree growth by using their knowledge of the cause-effect relationships involved with passing on genetic information via sexual or asexual reproduction.	

Name: _____ Date: _____

Redwoods Assessment

Part 1

Your class will discuss the information about coast redwoods that is summarized on the following pages. You might choose to jot some notes while you participate in the discussion. Consider these questions.

- What factors might affect how tall a coast redwood tree can grow?
- What do you notice about the height of the trees in the two specific areas on the maps?

Coast redwood trees are the tallest trees in the world. They grow only along the coast in California and Oregon. These redwood trees thrive there because of the very specific environmental conditions that support their survival, including moderate temperatures, abundant rain, and summer fog.





Characteristic	Information about coast redwood trees
Range	Along the Pacific coast from the middle of California to the southwest corner of Oregon
Average height	200 to 240 feet (60-70 m) tall, some around 350 feet tall (100 m)
Lifespan	800 to 1,500 years, some live up to 2,000 years
Genetic information	Almost the largest set of genetic information cataloged by scientists, coast redwoods contain 9 times the genetic information a human has.

Coast redwoods: reproduction

Sexual reproduction

- Many seeds are produced in cones and drop from the tree.
- Up to 75% of the seeds cannot actually produce seedlings.
- Even if a seed might be able to produce a seedling, ground conditions often prevent growth (e.g., not enough light, too difficult to get roots into the soil).
- Trees with the most successful seeds are between 250 and 1,200 years old.



Asexual reproduction

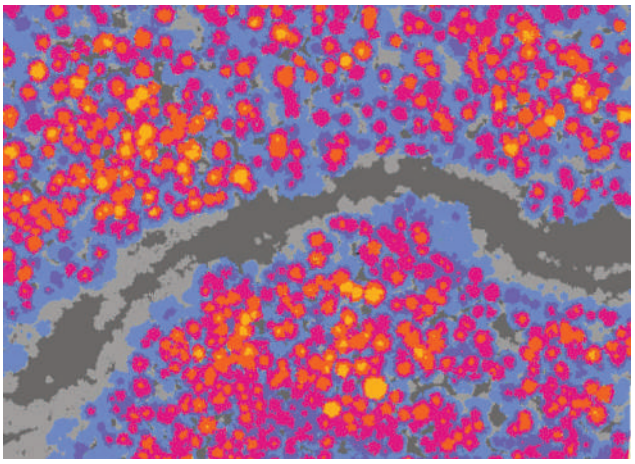
- The parent tree sprouts new trees from its roots near the trunk.
- This allows offspring trees to use resources from the parent's roots.
- This next generation of offspring trees forms a circle around the parent tree.
- Asexual reproduction is usually more successful than sexual reproduction.



How redwoods grow so tall is something scientists are still trying to figure out. In the Humboldt Redwoods State Park in California, scientists examined how tall the coast redwood trees are in different areas of the park to try to understand why some trees were taller in some areas of the park than in other areas of the park. They used a technology called LiDAR that allowed them to use laser sensors from the sky to measure the height of the trees off the ground. When they used this technology in the park, they created maps showing the heights of the trees.

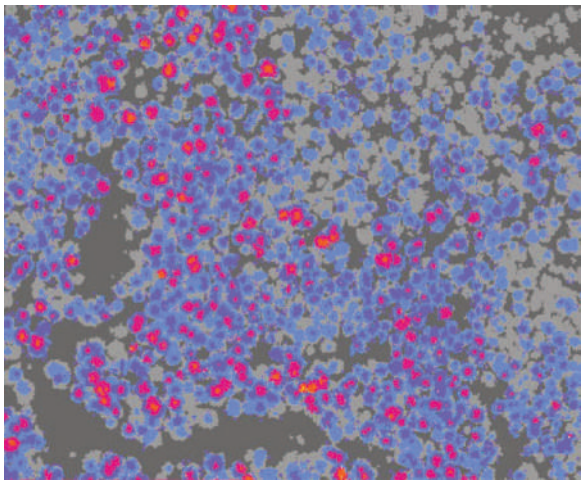
The maps below show the heights of the redwood trees in two different areas of about 62 acres each. Both maps show old-growth areas where the trees are more than 100 years old and do not get much taller each year.

Map 1: Along Bull Creek



Mark Graham

Map 2: In a creek valley

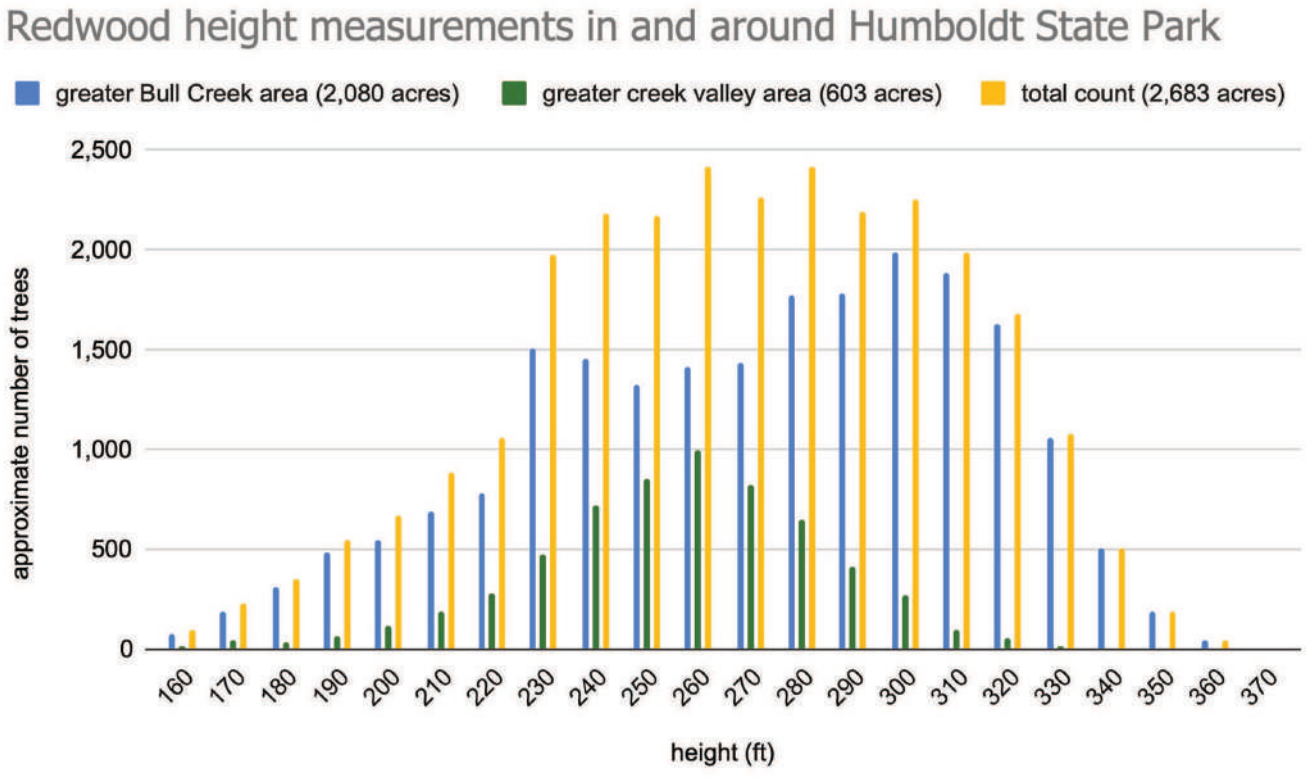


Mark Graham

map key

yellow	orange	pink	purple	Blue
over 328 ft (100 m) tall	over 295 ft (90 m) tall	over 262 ft (80 m) tall	less than 262 ft (80 m) tall	

This graph shows the tree heights measured in these mapped areas plus additional surrounding areas, for a total of 2,683 acres of redwood forest in and around the state park:



Data Source: Canopy height distribution in old growth redwood forests from www.verylargeandtallredwoods.com

Part 2

Use the data from this study and what you have figured out in the unit about how genetic and environmental traits affect organisms to explain: How does this study mapping the heights of coast redwood trees help us understand what factors might affect how they grow so tall? Respond to the prompts below to construct your explanation.

a. Explain how environmental factors could influence the height of the redwood trees. In your explanation, include rationale for why you think environmental factors do or do not influence height of the trees.

b. Explain how genetic factors could also influence the height of the redwood trees. In your explanation, include rationale for why you think genetic factors do or do not influence height of the trees.

c. Consider the histogram that shows tree height data from the two areas plus the combined, total area of the redwood forest. Develop a model in the space below to explain how both genetic and environmental factors in differing amounts could cause the range of height variation among all the redwoods in these areas.

d. In the Bull Creek area, the tallest redwood trees are clustered together. Also, the histogram shows there are more supertall trees there than in the creek valley area. Explain how the ways that coast redwood trees reproduce could cause these patterns in the data.

Key for Redwoods Assessment

The scoring guidance provided here uses a + notation that can help you identify different ideas that students should include in their responses.

- If several of the ideas marked with a + are missing from a student's response, this may indicate the student has not yet mastered the science ideas or that the student may be struggling to bring those ideas together in a written explanation or other communication. Additional probing of their thinking can provide insight about whether the student is struggling with a science practice or science idea or both.
- If all or almost all the ideas marked with a + are present in a student's response, this may indicate the student is able to use these science ideas in a written explanation or other communication.
- If ideas marked with a ++ are present in a student's response, this indicates that the student is bringing a deeper understanding of the science ideas or a deeper engagement with the practice to their response. Students should not be marked off if ideas marked with a ++ are not present in their response.

Refer to *Rubric for Redwoods Assessment* for specific connections to elements of this lesson's three-dimensional performance expectation and for guidance about providing feedback to students.

Part 1

Your class will discuss the information about coast redwoods that is summarized on the following pages. You might choose to jot some notes while you participate in the discussion. Consider these questions.

- What factors might affect how tall a coast redwood tree can grow?
- What do you notice about the height of the trees in the two specific areas on the maps?

Students may or may not have recorded ideas here, and you may or may not have noted who participated in this class discussion and how. Nonetheless, if such recorded ideas and/or noted discussion participation occurred, student ideas from part 1 could provide you with evidence of student understanding and use of DCIs and CCCs. However, the intent of this assessment is that part 1 supports access for all students to background knowledge about the context of redwood tree growth, and then part 2 gives students an opportunity to show what they know while engaging in a specific practice. As such, you can expect student responses to part 2 to provide clearer evidence of their progress in three-dimensional learning than their notes or participation in part 1.

Coast redwood trees are the tallest trees in the world. They grow only along the coast in California and Oregon. These redwood trees thrive there because of the very specific environmental conditions that support their survival, including moderate temperatures, abundant rain, and summer fog.





Characteristic	Information about coast redwood trees
Range	Along the Pacific coast from the middle of California to the southwest corner of Oregon
Average height	200 to 240 feet (60-70 m) tall, some around 350 feet tall (100 m)
Lifespan	800 to 1,500 years, some live up to 2,000 years
Genetic information	Almost the largest set of genetic information cataloged by scientists, coast redwoods contain 9 times the genetic information a human has.

Coast redwoods: reproduction

Sexual reproduction

- Many seeds are produced in cones and drop from the tree.
- Up to 75% of the seeds cannot actually produce seedlings.
- Even if a seed might be able to produce a seedling, ground conditions often prevent growth (e.g., not enough light, too difficult to get roots into the soil).
- Trees with the most successful seeds are between 250 and 1,200 years old.



Asexual reproduction

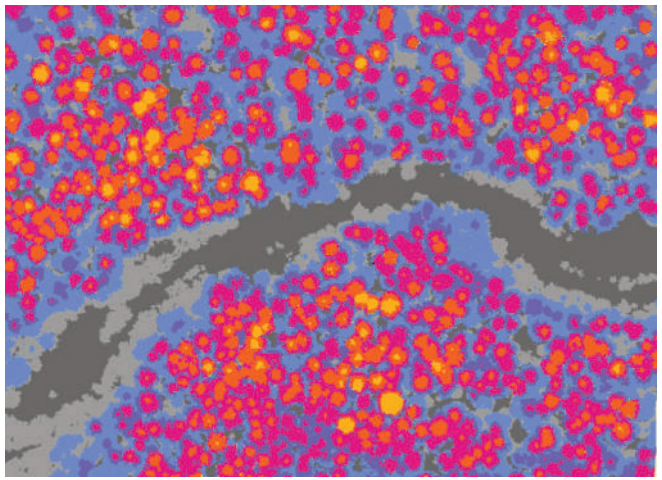
- The parent tree sprouts new trees from its roots near the trunk.
- This allows offspring trees to use resources from the parent's roots.
- This next generation of offspring trees forms a circle around the parent tree.
- Asexual reproduction is usually more successful than sexual reproduction.



How redwoods grow so tall is something scientists are still trying to figure out. In the Humboldt Redwoods State Park in California, scientists examined how tall the coast redwood trees are in different areas of the park to try to understand why some trees were taller in some areas of the park than in other areas of the park. They used a technology called LiDAR that allowed them to use laser sensors from the sky to measure the height of the trees off the ground. When they used this technology in the park, they created maps showing the heights of the trees.

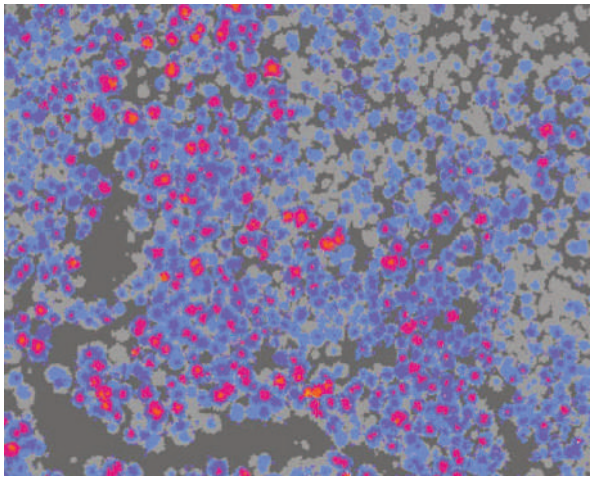
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Mark Graham

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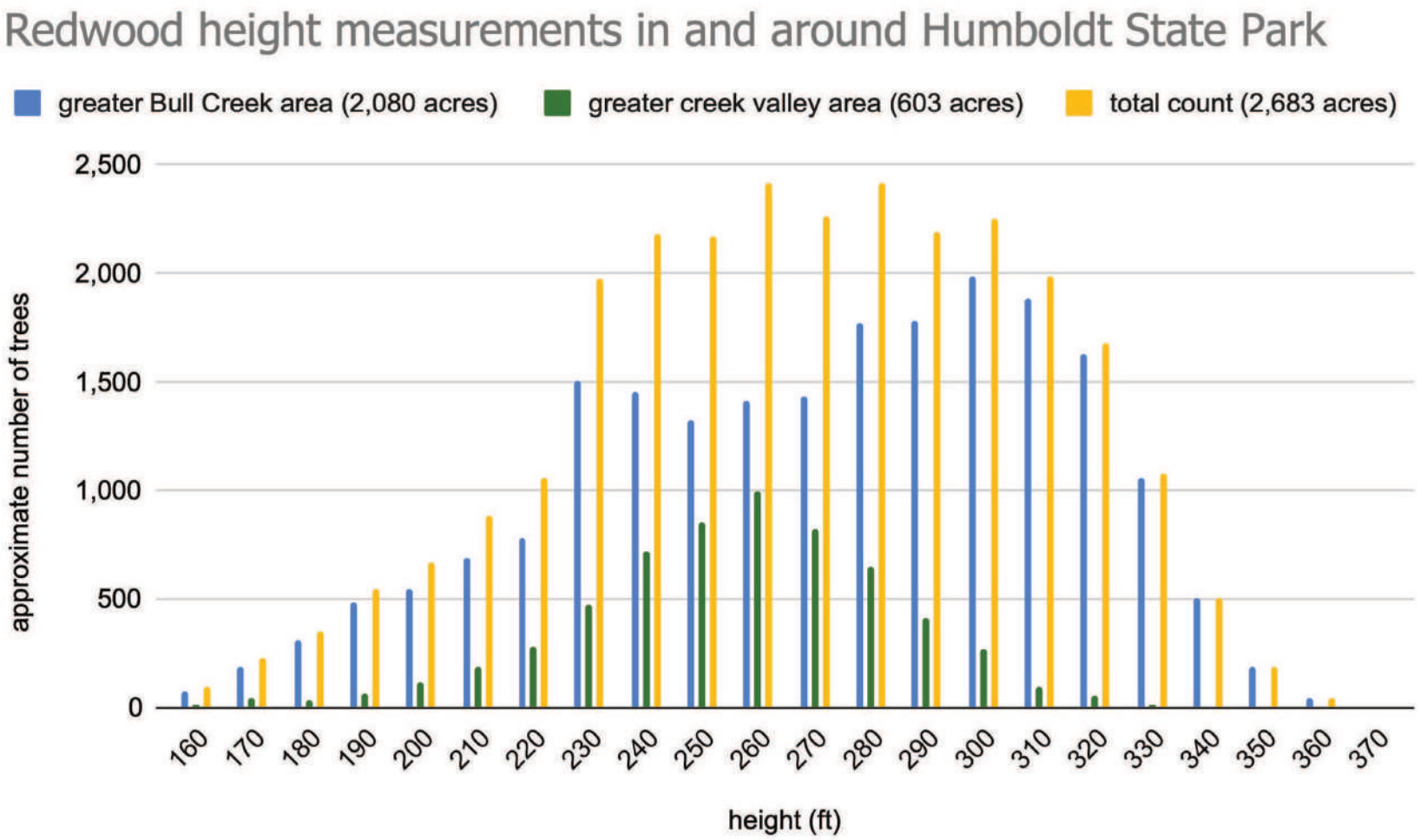


Mark Graham

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This graph shows the tree heights measured in these mapped areas plus additional surrounding areas, for a total of 2,683 acres of redwood forest in and around the state park:



Data Source: Canopy height distribution in old growth redwood forests from www.verylargeandtallredwoods.com

Part 2

Use the data from this study and what you have figured out in the unit about how genetic and environmental traits affect organisms to explain: How does this study mapping the heights of coast redwood trees help us understand what factors might affect how they grow so tall? Respond to the prompts below to construct your explanation.

a. Explain how environmental factors could influence the height of the redwood trees. In your explanation, include rationale for why you think environmental factors do or do not influence height of the trees.

+ Since there is so much variation in the heights of trees in these different areas, environmental factors must play a role.

+ Students should list more than one of the following environmental factors as causing redwoods to grow taller (or not):

- enough water (accessible by roots and/or humidity in the air)
- enough light
- the right soil conditions
- the right temperature
- human interactions (positive or negative)

++ Students provide rationale for why any of the above factors would influence the height variation.

++ Based on the maps that show taller trees around Bull Creek, we can infer that environmental factors are better at supporting their growth in that area.

b. Explain how genetic factors could also influence the height of the redwood trees. In your explanation, include rationale for why you think genetic factors do or do not influence height of the trees.

+ Genetic information helps explain why living things are different, so the trait of height is at least partially influenced by genetic factors—their genetic information has instructions for proteins that help make them so tall (compared to other types of trees and/or compared to other coast redwoods).

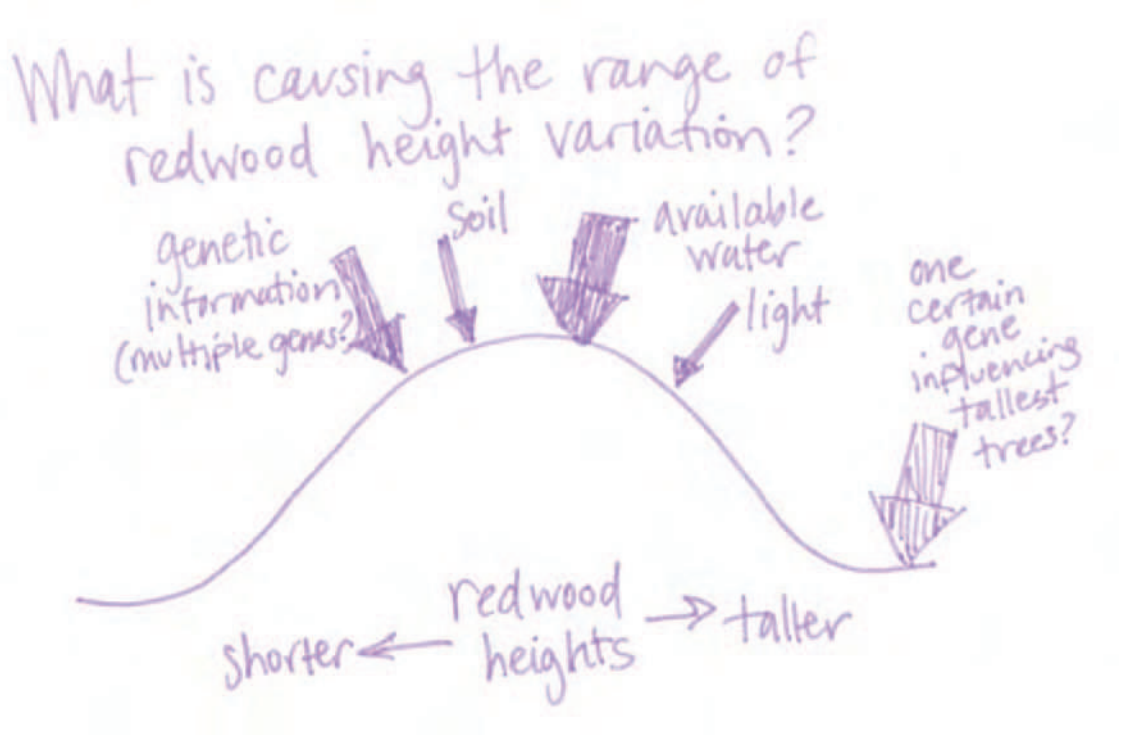
+ There could be a gene (or more than one) related to supertallness in coast redwoods, and the supertall trees have a different allele for that gene than the average-height coast redwoods have.

++ The supertall trees seem to be clustered together, and redwoods are more likely to reproduce asexually (with offspring clustered around the parent), so the offspring in those clusters would have the same genetic information (genotype, gene(s), allele(s)) that influences supertallness as their parent. (This idea is specifically assessed in prompt d.)

++ Students might infer that if the trees have so much genetic information, it must play a role in their growth. This is OK even though we do not know whether this has an impact on their height.

c. Consider the histogram that shows tree height data from the two areas plus the combined, total area of the redwood forest. Develop a model in the space below to explain how both genetic and environmental factors in differing amounts could cause the range of height variation among all the redwoods in these areas.

Sample student model:



+ Model shows range of heights from short to tall.

+ Model indicates differing impacts of genetic and environmental factors (such as with different-sized arrows and/or words).

+ Model shows a few specific environmental factors.

+ Model includes mention of genetic information and/or multiple genes.

+ If a single-gene influence is mentioned, it is on the extreme ends of the range.

++ Environmental factors and/or multiple genes likely have more of an influence than a single gene (since there is a continuous range of tree heights, not a few specific categories or types).

d. In the Bull Creek area, the tallest redwood trees are clustered together. Also, the histogram shows there are more supertall trees there than in the creek valley area. Explain how the ways that coast redwood trees reproduce could cause these patterns in the data.

+ Redwoods are more successful at reproducing asexually, which means offspring trees will be growing near their parent.

+ Asexual reproduction results in offspring with identical genetic information as their parent.

+ Since their height is at least partly influenced by genetic factors, supertall trees are likely clustered together, and more of them are found in that area because the parent trees are passing on to their offspring through asexual reproduction the genetic information that leads to supertallness.

+ Sexual reproduction does not explain those patterns in the data because that would result in more variety—if the trees were reproducing sexually the parent trees would not necessarily pass on their supertall gene alleles and we would not see those clusters of supertall trees.



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Daniel H. Franck

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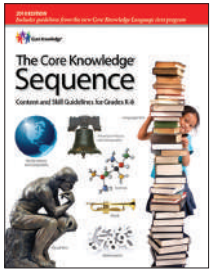
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