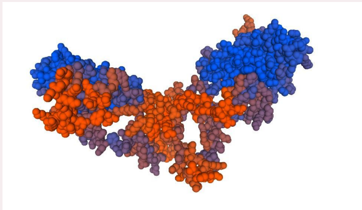
LESSON 6: What is the connection between chromosomes and the heavily muscled phenotype?

PREVIOUS LESSON *We observed cow 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 offspring; the fertilized egg as well as individual muscle cells have twice the chromosome number as sex cells.*

THIS LESSON

INVESTIGATION

2 days



In this lesson, students view a video and images to support discussion of the super-small yet hugely complex scale of chromosomes. As such, the data students use about chromosomes in this lesson is in the form of colored geometric shapes that symbolize different alleles. Students reassemble their cattle family trees with added information about each individual's chromosomes and which versions of the myostatin protein each has. Each group constructs an initial model to explain the connections it found, and then the class works to build a consensus model showing correlation. Finally, students read and discuss a summary of a genetic study to find evidence of causal relationships among allele, protein, and phenotype.

NEXT LESSON *Students will evaluate and critically read an article about the function of the myostatin protein. Students will obtain information and communicate during class discussion using evidence from the text about how the structure of typical myostatin limits muscle growth, and the different shape of nonfunctional myostatin leads to greater muscle growth in some organisms.*

BUILDING TOWARD NGSS

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

WHAT STUDENTS WILL DO

Develop and use a model to describe correlational relationships among chromosome pairs containing two variants, specific proteins, and the trait of musculature.

Obtain, evaluate, and communicate information by critically reading a scientific text adapted for classroom use 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

- Specific regions of the chromosomes are called genes, and the possible alternate forms of the genes are called alleles.
- The heavily muscled phenotype is correlated to a specific form of protein called myostatin.
- Animals that are heavily muscled have two copies of the allele for the different-looking myostatin protein.
- If an animal has just one allele that makes that different-looking myostatin protein, that animal might be sort of heavily muscled (it might be hard to tell).
- Scientists have used genetic modification to figure out that the allele causes the different-looking protein, which is related to the heavily muscled phenotype.

Lesson 6 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**WATCH A VIDEO TO HELP UNDERSTAND SCALE** View and discuss a video to help grasp the super-small scale of chromosomes.	A-B	https://www.teachersopensciedfieldtest.org/muscles
2	10 min	**USE SYMBOLS TO SUPPORT WORK AT THIS SCALE** Discuss the scale of chromosomes and consider how we might be able to investigate something so small, yet so complex.	C-F	
3	15 min	**REASSEMBLE FAMILY TREES WITH NEW INFORMATION** Students work in the same groups as in the previous lesson, and reassemble the same cattle family tree, this time looking for patterns in new information that's been added.	G-I	*Guiding Questions for Chromosome /Protein Data*, the same sets of cattle family photos (*Family Cards* and *Duplicate Family Cards*) each group used in Lesson 5 with added half-sheets from *Protein and Chromosome Data* and *Duplicate Protein and Chromosome Data* inserted into the correct animal's page protector
4	15 min	**DEVELOP INITIAL MODELS IN A SMALL GROUP** Groups work to construct an initial model explaining the connections they found on their cattle family tree now that it also includes chromosome and protein data.	J	chart paper
				End of day 1
5	5 min	**GALLERY WALK THROUGH INITIAL MODELS** Students circulate among the groups' different initial models to look for similarities and differences.	K	initial models from Day 1
6	10 min	**DEVELOP A CONSENSUS MODEL FOR CORRELATIONS** Students co-construct a consensus model summarizing correlations among the heavily muscled phenotype, chromosome information, and myostatin protein.	L	initial models from Day 1, classroom consensus model
7	10 min	**READ EVIDENCE SUPPORTING CAUSATION** Students read a summary of the study that identified the myostatin protein as the cause of a heavily muscled phenotype in mice.	M-O	*Unknown material with identifier: ge.l6.rdg*
8	15 min	**CONSENSUS DISCUSSION ABOUT CAUSES** Students come to consensus about the terms gene, allele, and genotype, and that scientists were able to prove causation of the heavily muscled phenotype.	P-R	*Unknown material with identifier: ge.l6.rdg*
9	5 min	**PROGRESS TRACKER** Students record in the Progress Tracker section of their science notebooks what they've figured out about the relationship between the heavily muscled phenotype, chromosomes, and the myostatin protein.	S	
				End of day 2

Lesson 6 • Materials List

	per student	per group	per class
Lesson materials	• *Guiding Questions for Chromosome /Protein Data* • science notebook • *Unknown material with identifier: ge.l6.rdg*	• the same sets of cattle family photos (*Family Cards* and *Duplicate Family Cards*) each group used in Lesson 5 with added half-sheets from *Protein and Chromosome Data* and *Duplicate Protein and Chromosome Data* inserted into the correct animal's page protector • chart paper • initial models from Day 1	• https://www.teachersopensciedfieldtest.org/muscles • initial models from Day 1 • classroom consensus model

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.

Be sure https://www.teachersopensciedfieldtest.org/muscles plays correctly.

Use color copies of the following materials from your kit *Protein and Chromosome Data* and *Duplicate Protein and Chromosome Data* (or color print them) and cut the pages so each animal's protein card is a half-sheet. Slide the protein information into the corresponding photo's page protector from Lesson 5.

Lesson 6 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students figure out that the myostatin protein is related to the heavily muscled phenotype (they see correlation first and then read evidence of causation later). However, they do not discover how myostatin works to influence musculature until Lesson 7. So, refrain in this lesson from pointing out the derivation of the name “myostatin” - students will read about it in the next lesson. This lesson does name “gene,” “allele,” and “genotype” to help students discuss the patterns they’re seeing using scientific terms.

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 we refer to it only as myostatin in this unit, to avoid confusion. The summary simplifies the gene targeting process the scientists used. Also, 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 this unit, so when students discover that a specific allele is the cause of a differently shaped protein, they connect to differently shaped genetic material, but not the details of how the protein is produced.

LEARNING PLAN for LESSON 6

1 · WATCH A VIDEO TO HELP UNDERSTAND SCALE

5 min

MATERIALS: https://www.teachersopensciedfieldtest.org/muscles

Navigate to today's work from 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 prompt	Sample student response
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?	*Well we saw patterns in the parents and babies who had extra-big muscles. Every baby that had big muscles also had at least one parent with big muscles too. 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!*

Introduce the video showing the scale of chromosomes. Display **slide B**.

Say, *I have a video to show you that I think will help us kind of frame our thinking around chromosomes today. When we are working with chromosomes, we are working in a realm that is too small for our eyes to see, and even smaller than our classroom microscopes to see. So I want to show you this video to help us get a sense of the scale we're thinking about now. While you're watching the video, ask yourself, "How could you describe the size of chromosomes to a friend? Are chromosomes bigger or smaller than a cell?"*✱

Play the video. Show https://www.teachersopensciedfieldtest.org/muscles , and pause as needed to point out to students that 400x is about as detailed as we can see with our classroom microscopes. Continue the video and then pause to point out the chromosomes - what we want to investigate more today. Play the video until the end to see that there are atoms making up the 3D molecule.

ADDITIONAL GUIDANCE After watching the video clip with pauses to talk about what they're seeing, it may be helpful to have your students watch the same clip a second (or even third) time without pausing, to see the "zoom in" happen smoothly.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING SCALE, PROPORTION, AND QUANTITY

Students need a sense of how very small chromosomes are, but also that they are huge molecules composed of atoms arranged in complex patterns. Setting up this understanding of scale frames the need for using symbols to represent differences in the chromosomes students want to compare when they work with the cattle family trees.

ADDITIONAL GUIDANCE	The video labels DNA. Up to this point in the unit, we have avoided the term "DNA" because the details about it are beyond the middle school band. However, if you haven't already acknowledged it with your class, now might be the time to point out that the chromosomes are made of DNA, and leave it at that. Students have likely heard the term DNA before and may naturally make connections to DNA and chromosomes. Do not say the DNA carries "instructions" because that will undermine the figuring out that students need to do themselves in subsequent lessons to reach a solid understanding of the key ideas in this unit.

2 · USE SYMBOLS TO SUPPORT WORK AT THIS SCALE

10 min

MATERIALS: None

Look at the molecular structure of chromosomes. Show **slide C**. 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 pink and teal images of chromosomes in the video might lead students to think that chromosomes are made up of something they've never seen before. The purpose of this discussion is for students to see that 1) chromosomes have 3D structure and 2) demystify that chromosomes/DNA 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 3D structure.
- The chromosomes in the video kind of look like rope candy, but they are actually made up of the same atoms we've seen before in living things in the OpenSciEd 7th grade units: 7.3 *How do things inside our bodies work together to make us feel the way we do*? and 7.4 *Where does food come from, and where does it go next?*
- The scale of chromosomes and DNA is *really* small. It might be really hard to compare these structures.

Suggested prompt	Sample student response
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 sub-parts.* *They look like a twisted rope.* *They are made up of atoms.*
We've seen chromosomes represented in the karyotypes inside cells, but these molecular models are a different type of representation. Do chromosomes look flat (2D) or three-dimensional? What makes you think that?	*I think chromosomes looked flat in the karyotypes, but here they look 3D. I think that because the structure of atoms looks like they are organized in a rope-like structure and the molecules look overlapping, which makes me think they have depth - like 3D structure.*

Suggested prompt	Sample student response
Which atoms make up chromosomes? *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?*	*They are made up of hydrogen, oxygen, nitrogen, carbon, and phosphorus.* *These are the same atoms in food molecules from the Inside Our Bodies and Maple Syrup units.*

Problematize needing to use symbols to work at a scale too small to see. Display **slide D.**

Suggested prompt	Sample student response
So now we have some different possible 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 compare the atoms that make them up. *In either case, what kind of challenges will we face when trying to make comparison of structures at these really small scales?*	*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.* *Even those karyotypes didn't show us as zoomed in as the video got - like, we couldn't see the atoms that make them.*

Say, *You are right, I think... in either case these chromosomes and 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. Such simplified models can help us more quickly keep track of what we notice and make comparisons, rather relying on having to always work with the more complex photographs of the entire chromosome or a model of all the atoms that make up the entire molecular structure. Let's try and establish a series of 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 E1**.

Suggested prompt	Sample student response
This is an image of chromosome pair 2. Colors have been added to show where three pairs of corresponding dark bands that are found on each chromosome in this pair. *What additional patterns does this visualization help see in these chromosomes?*	*It's easier to see what's the same and what's different with the shapes and colors rather than just the darker and lighter bands (stripes) on the chromosomes themselves.* *It helps us see that one of the bands (the blue one) has a different length in one chromosome vs. the other.*

Display **slide E2**.

Suggested prompt	Sample student response
Shapes were now added to help keep track of these patterns. *What do the colors of the shapes represent?*	*The color helps us identify which band is the corresponding section on each chromosome.*
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 one.*

Display **slide F**. Say, *Since we want to compare chromosomes from quite a few cattle in a family, let's plan on using colors and symbols to represent these sorts of patterns, rather than the photographs of the chromosomes themselves.*

Point to the representation on the right and ask students to explain what it represents.

Suggested prompt	Sample student response
Someone please remind us: What do these lines, colors and symbols represent?	*The line represents an entire chromosome.* *There are two lines with two stacks of symbols on each for the two halves of the chromosomes, because that bull had one of this pair in chromosome 2 from one parent and one from the other parent. So each side (each stack) shows us that part that came from each parent.* *The colored shapes represent a different area/location of the chromosome.* *The color helps us identify the corresponding section in each chromosome.*

Say, *One important difference we can see in these chromosomes already is that in the blue coded section of the chromosome shows difference in length between the two chromosomes in this pair, which means the underlying atomic structure must be different there. Though we know that one of these chromosomes came from the female parent and one came from the male parent, we don't know why this section is different, and the other sections aren't, and what that means for this individual or their traits.*

3 · REASSEMBLE FAMILY TREES WITH NEW INFORMATION

15 min

MATERIALS: *Guiding Questions for Chromosome /Protein Data*, the same sets of cattle family photos (*Family Cards* and *Duplicate Family Cards*) each group used in Lesson 5 with added half-sheets from *Protein and Chromosome Data* and *Duplicate Protein and Chromosome Data* inserted into the correct animal's page protector

Set a purpose for working with family tree photos again, including chromosome and protein data.

Say, *Okay, since we are working at this new, very microscopic scale, let's merge in some of the chromosome level information into the cattle families we were keeping track of before. I have chromosome information or the same cattle families you worked with last time. So your group will get the photos in the page protectors again for the same family, but this time you'll also have those symbol stacks showing you the information about chromosome 2 for each animal, like we saw on the slide. You will also now see molecular representations for another protein found in the muscles cells of all these cattle. Before we look at these molecular representations for this new protein though, let's review what we know about the two other proteins that we investigated in our earlier lessons.*

Display **slide G**.

Suggested prompt	Sample student response
These two other proteins were called myosin and actin. Remind us: what do myosin and actin do?	*They are inside muscles - they make the muscles move, stretch, or contract.* *The myosin grabs onto the actin and pulls along to make the muscle move.*
Remind us: What are these proteins made out of?	*We eat food and our bodies rearrange those building blocks to make proteins like this.* *Those little spheres are atoms - these are big molecules made of lots of atoms.*
How does their structure help them do their job?	*The myosin has to be shaped so it can grab the actin.* *They're each bundled together like strings so they can pull and stretch.*

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. Next you'll see a new type of protein on these cards with your cattle... not myosin and actin - this will be a different protein found in muscles. And this different proteins will have a different structure. Let's see if we can find any patterns between this new protein and the individuals it is found in that can help us figure out what's going on with the heavily muscled cattle.*

Clarify where myostatin proteins are found. Display **slide H**. Invite students to respond to the question, "The name of the new type of protein we will be looking at is called myostatin. Based on the information shown in this table, is myostatin found in sperm or egg cells?" with a thumb up or thumb down.

Say, *In Lesson 5 we looked at some of the components inside sex cells. Only a* ***very*** *few number of proteins exist inside sperm and eggs. The proteins we are about to analyze, called myostatin, are* ***not*** *found in the sperm and eggs. You will see two versions of it on your data, but they're both called myostatin. They can be found inside and outside the body cells of baby and adult cattle. Your job is to lay out the family tree again and find patterns with this new information.*

Suggested prompt	Sample student response
What are you going to be looking for while you're sorting through these cattle families?	*We wanted to see how their chromosomes are related to whether they have extra-big muscles.* *We are going to look for patterns in these chromosome symbols to see if there's a connection to whether the cattle are heavily muscled.* *And we're going to look at the new different proteins and see if we find patterns with these, too.*
How will you keep track of the patterns you see?	*We'll want to go back to the family tree handout we have in our science notebooks from last time, and make some new notes and markings.*

Distribute the materials and direct students to begin working. Display **slide I**. Be sure students are working in the same groups as last time, and have the photos and data for the same cattle family. Students will also need *Guiding Questions for Chromosome /Protein Data* to help them make sense of the patterns they're finding. Give students about 10 minutes to work on this task.

4 · DEVELOP INITIAL MODELS IN A SMALL GROUP

15 min

MATERIALS: chart paper

Small groups develop initial models for relationships they've found. As groups finish their work arranging the cattle family trees, call everyone's attention back for the next direction. Display **slide J**.

Say, *We have seen some pretty strong patterns in these family trees! We should capture the correlations - the association or relationship we think we've found here. I will give your group a piece of chart paper and your task is to work together with your group to create an initial model that shows the relationships you found among the chromosome symbols, the proteins, and whether the cattle show the heavily muscled phenotype or not.*✱

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 indication 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.

✱ 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).

End of day 1

5 · GALLERY WALK THROUGH INITIAL MODELS

5 min

MATERIALS: science notebook, initial models from Day 1

Students silently consider similarities and differences among initial models. Display **slide K**. As they come into the classroom, direct students to have their group's initial model out on their desk/table for others to see (or have students hang them on the walls around the room). Then, students should silently and independently walk around to view the initial models created by the other groups. Students create a T-chart in their science notebooks titled "Initial Models of Phenotypes, Chromosomes, and Proteins: Similarities/Differences" and record their thinking as they compare and contrast the models around the room.

6 · DEVELOP A CONSENSUS MODEL FOR CORRELATIONS

10 min

MATERIALS: science notebook, initial models from Day 1, classroom consensus model

Meet in a Scientists Circle to develop a consensus model. Display **slide L**. 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 group's thinking on a classroom consensus model.

KEY IDEAS

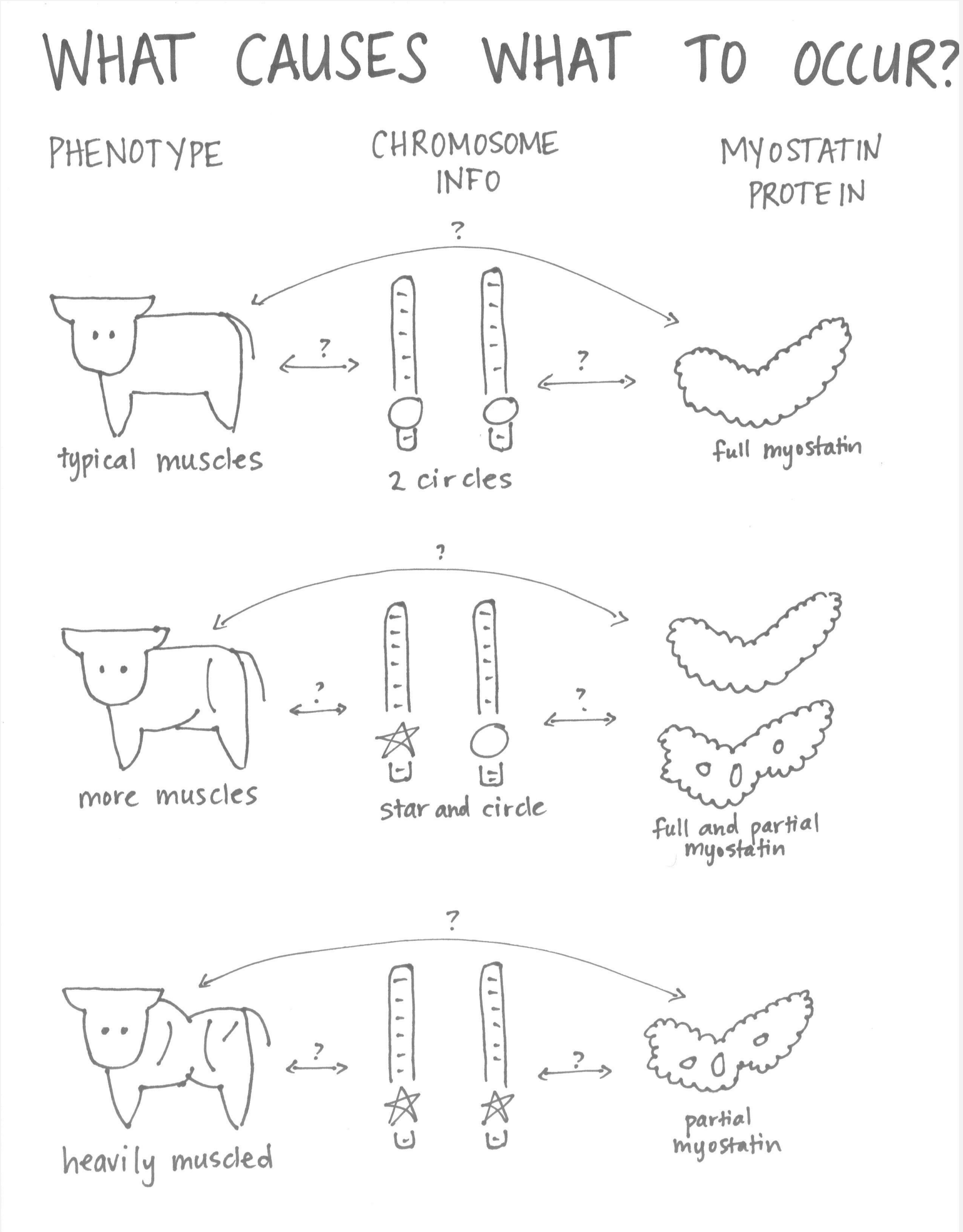
Purpose of this discussion: Come to consensus about the patterns we saw in the cattle family trees, and represent these ideas in a consensus model of the correlations between the chromosome information, the myostatin proteins, and phenotypes.

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 shape is related to the partial myostatin protein, and the blue circle shape is related to the fully-formed myostatin.
- The heavily muscled phenotype and the partial myostatin are correlated.
- If an animal has two blue stars we notice that animal is also heavily muscled.
- When an animal has just one blue star, that animal might look heavily muscled, but it's harder to tell.

Suggested prompt	Sample student response
What patterns did you find with the family trees when we added the chromosome and protein information?	*The heavily muscled cattle all had the myostatin protein with holes in it… the one that looked incomplete, like it's not all there.* *The cattle who were harder to tell if we wanted to call them heavily muscled or not (we colored them gray on our family trees last time)… they had both shapes of the protein.* *It was just blue shapes that were connected to the myostatin proteins.* *The other colors, the orange and the green, they didn't matter with which myostatin proteins the animal had.*
Was there a specific blue shape connected to each of those myostatin proteins?	*Yes, the specific blue shapes were related to proteins.* *If the cattle had the blue star and circle, they had both kinds of protein.* *Two copies of the blue star meant they only had the partial myostatin protein.* *Two circles meant they only had the full protein.*
What similarities did you find in how groups modeled the same ideas?	*Many groups used arrows between the parts of the model to show how they are connected or related.* *But since we don't know which one(s) caused the other(s), we have arrows on both ends of the lines and/or question marks along those lines to show that we don't know what is causing the other, just that they're related.*

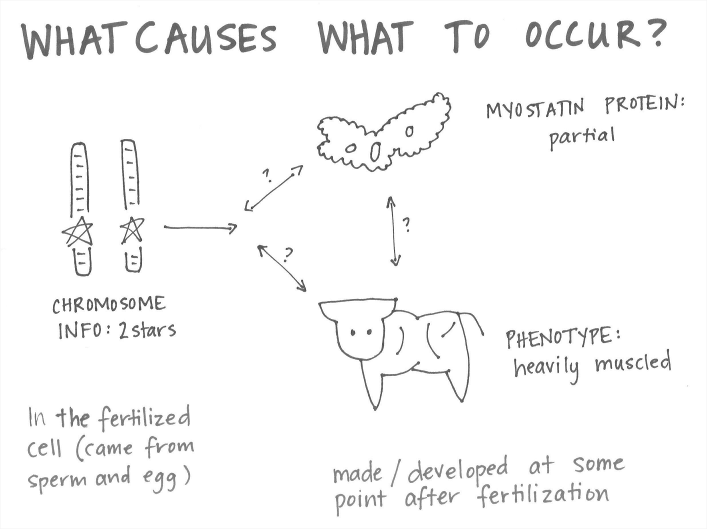
See example classroom consensus model for correlation here:



Establish that chromosomes are the first step. Refer back to the classroom consensus model and discuss what part of the model we do know for sure, based on evidence from the previous lesson.

Suggested prompt	Sample student response
So we've seen that 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 start figuring out causes (rather than just correlations), can we at least decide which comes first? Which of these pieces would be a beginning point?	*Well the offspring are only getting the chromosomes from their parents... there weren't myostatin proteins in the egg and sperm cells. So it has to start with the chromosomes, because that's what they get from the parents.*
Okay, how should we update our consensus model to show this?	*Let's draw the chromosome first, and then an arrow to the other two pieces.* *But we still don't know which of those comes next in the chain of cause-effect.* *So we still need double arrows and/or question marks between those.*

See example of updated classroom consensus model here:



7 · READ EVIDENCE SUPPORTING CAUSATION

10 min

MATERIALS: *Unknown material with identifier: ge.l6.rdg*

Turn and talk about how scientists could prove a cause-effect relationship.

Say, *Okay, we've established that this relationship starts with the chromosome. And though we know these proteins and the entire multi-cellular organism don't appear until well after fertilization, we still don't know if that chromosome causes the different protein or the phenotype. Let's think like scientists here. If we had all the lab equipment and technology we needed, what could we do to figure out if that chromosome region is what causes the appearance of this type of protein? Turn and talk to a partner for a minute about that.*

Display **slide M**. After about 1 minute, bring the discussion back to the whole group.

Suggested prompt	Sample student response
What could we (or scientists in a totally well-equipped lab) do to see if the gene that the organism inherits really is what causes the appearance of a particular protein?	*We would want to do an experiment to test it.*
How could we do that?	*We would want to get to the chromosomes... can we (or the scientists) work with them inside cells?*

Say something like, *Large mammals are sometimes tricky to work with for these types of experiments, both because of their size and how long it takes for a baby to develop. Cattle take 283 days to carry a baby to birth, which is almost the same 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.*

Read about a study of mice and myostatin. Say, *When scientists want to test a cause, they do a controlled experiment. I have a summary of a study for you to look at, and the scientists did work with mice. While you read, think to yourself, "What did the scientists predict? What did they do to find evidence to confirm their predictions?"*

Display **slide N**. Say, *You will want to mark up the text to help you stay focused and so you can find your ideas again. Consider using some of the following methods, or others that work well for you: Circle key words, underline main ideas, keep track of your questions in the margins, and put question marks by words or ideas you want to learn more about.*

Distribute *Unknown material with identifier: ge.l6.rdg* and direct students to begin reading.

ADDITIONAL GUIDANCE

Unknown material with identifier: ge.l6.rdg summarizes a very complicated scientific study, and as such even this summary is at the high end of the grades 6-8 text complexity band. If you anticipate that your students will struggle to understand the text when reading independently, it is perfectly acceptable for you to read it aloud to the class. After one read-through together, you could direct students to reread individually and mark up the text, or they could work with a partner to complete that task.

Partner talk about the terms in the study summary. Display **slide O** and prompt students to turn and talk with a neighbor about which new words they saw in this article. Have them underline the context clues in the summary that can help them determine the meaning of these new words. After a minute of partner talk, bring the class back together to talk through what they read.

8 · CONSENSUS DISCUSSION ABOUT CAUSES

15 min

MATERIALS: *Unknown material with identifier: ge.l6.rdg*

Hold a Consensus Discussion about what we figured out from the article. Students bring their copies of *Unknown material with identifier: ge.l6.rdg* and gather in a Scientists Circle. Display **slide P.**

KEY IDEAS

Purpose of this discussion: Establish the causal relationship between gene (allele), the different-looking myostatin protein, and the heavily muscled phenotype.

Listen for these ideas:

- Specific regions of the chromosomes are called genes, and the possible versions of the gene are called alleles.
- Scientists changed the shape of a gene to figure out that a different allele causes the different-looking protein, which causes the heavily muscled phenotype.
- The heavily muscled phenotype is caused by a specific form of a protein called myostatin.
- Animals that are heavily muscled have two copies of the allele for the different-looking myostatin protein.
- An animal's genotype is the combination of alleles that it has.

Suggested prompt	Sample student response
What new terms do we need to add to our word wall now? What do they mean?	*"Gene" is a certain region of the chromosome.* *The gene is the part of the chromosome that's responsible for a certain protein... like does it make it? In the study, the scientists changed the shape of the gene and that resulted in a differently shaped protein.*
Let's remind ourselves what scale we're at. Remember the video we saw last time? The chromosomes are huge complicated molecules, and the genes are specific regions of those molecules, like the shading we saw on the chromosome photos. The proteins are molecules at that same level of scale. And the shape of the genetic information is related to the shape of the protein. Why weren't we looking at the actual shapes of the genes when we did our cattle family tree sort, then?	*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. Not really star shapes on chromosomes.*

Suggested prompt	Sample student response
When we say "shape change" about a gene, what's actually changing shape?	*The actual shape changes are happening in the molecules we saw in the video, those atoms of hydrogen and nitrogen and such that we saw on that slide.*
So what is that called, when there are different shapes of genes?	*Different forms of genes are called alleles.*
Or, what other new words did you see in this article?	*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 this called?	*The combination of alleles that an animal has is its genotype.*
What's the difference between genotype and phenotype, then?	*The genotype is the genes... which alleles an animal has.* *The phenotype is how the animal looks (because of those alleles).*
What did the scientists predict, and how did they test it?	*They thought the myostatin protein was causing the extra-big muscles. So they changed the chromosomes at the place (the gene) they thought made the myostatin protein.* *If the mice with that changed gene (new allele) had extra-big muscles, that would prove their prediction correct.*
So let's summarize: What did we figure out from the work these scientists did?	*The cells with the changed gene (different allele) made a different version of the myostatin protein.* *The mice with the changed chromosomes/genes (different alleles) had extra-big muscles, so they proved it!* *The heavily muscled phenotype is caused by having a differently shaped gene (allele), which makes a differently shaped protein, which leads to the heavily muscled phenotype.*

ADDITIONAL GUIDANCE

If/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 an organism's genetic information, that's genetic modification.*

Display **slide Q** and **slide R** 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.*

9 · PROGRESS TRACKER

5 min

MATERIALS: science notebook

Update Progress Trackers in science notebooks. Using **slide S**, direct students to add to their Progress Tracker in their science notebooks.

Say, *We need to 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 consensus model and determine what we need to figure out next.*

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
What is the connection between chromosomes and the heavily muscled phenotype?	• Specific regions of the chromosomes are called genes, and the possible alternate forms of the genes are called alleles. • The heavily muscled phenotype is caused by a specific form of a protein called myostatin. • Animals that are heavily muscled have two copies of the allele for the different-looking myostatin protein. • If an animal has just one allele that makes that different-looking myostatin protein, that animal might be sort of heavily muscled (it might be hard to tell). • Scientists changed the shape of a gene to figure out that a different allele causes the different-looking protein, which causes the heavily muscled phenotype.

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 an article 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 a heavily muscled phenotype in animals. Students are also introduced to several specific new science words when they read the article. 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 modeling. If desired, the teacher may choose to discuss with the class how the scientific vocabulary present in this text impacts the tone of the writing, in addition to its meaning.