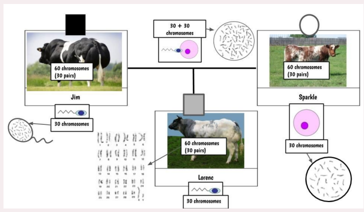
LESSON 5: Where do the babies with big muscles come from?

PREVIOUS LESSON *We updated our class consensus model to include our findings about the role diet and exercise play in making muscles. We then attempted to apply our class model to explain how the extra-muscled cattle would have developed their muscles, but we were not convinced of our model's implications. So, we asked a farmer more about these cattle and found out that they have calves that are heavily muscled. We discussed how this information impacted our model.*

THIS LESSON

INVESTIGATION

1 day



We observe cow 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 then reassemble their cattle family trees 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 a summary of a genetic study to find evidence of causal relationships among allele, protein, and phenotype.*

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 the patterns that emerge between the number and types of chromosomes in the sex cells of parents and the body cells of offspring, and how the chromosomes in a muscle cell of the offspring consist of a subset of chromosomes from each parent. Use the patterns in the model to predict that each parent must randomly contribute half of their chromosomes to sex cells.

WHAT STUDENTS WILL FIGURE OUT

- If an individual is heavily muscled, they must have at least one parent who is also heavily muscled.
- Even if an individual has a parent that is heavily muscled, it doesn't necessarily mean they will also have super-big 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 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	3 min	**NAVIGATION** Observe photos of baby cows with typical muscles and really big muscles.	A	
2	5 min	**DEVELOP CONVENTIONS FOR FAMILY TREES** Discuss the best way to represent characteristics of individuals that are part of our cow families and agree to share common symbols to do so.	B-E	
3	15 min	**BUILD FAMILY TREES USING COW FAMILY PHOTOS** Work in small groups to organize the family trees 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*, tape, one family set (7 individuals) from *Family Cards* or *Duplicate Family Cards*
4	10 min	**BUILDING UNDERSTANDING DISCUSSION ABOUT PHENOTYPES IN FAMILIES** Discuss patterns the students uncovered while working with their graphic organizers. Using the patterns, make predictions about potential offspring given a set of parents. Develop a more robust model as a class to represent how parents and offspring are related - building from the graphic organizers..	J-Q	
5	12 min	**INVESTIGATE WHAT IS FOUND INSIDE EGG AND SPERM CELLS** Examine the components and types of structures in egg and sperm cells to discover that muscle cells (and parts of muscle cells) are not passed from parents to offspring, but instead chromosomes are passed on from parent to offspring when sperm fertilizes an egg.	R-S	tape, *Chromosomes in Sex Cells*
				End of day 1
6	15 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.	T-X	tape, *Chromosomes in Sex Cells*, *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 ideas learned so far.	Y-AA	
8	8 min	**NAVIGATION** Reflect on new ideas about how phenotypes and inheritance as well as chromosomes are related to the patterns regarding the number of types of chromosomes in different cells. Set up to build on this learning by thinking about what information is needed to dig deeper into understanding chromosomes..	AB	
				End of day 2

Lesson 5 • Materials List

	per student	per group	per class
Lesson materials	• *Family Phenotype Graphic Organizer* • science notebook • tape • *Chromosomes in Sex Cells* • *Karyotype of Lorenc's Muscle Cell*	• one family set (7 individuals) from *Family Cards* or *Duplicate Family Cards*	

Materials preparation (25 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.

- Use color copies of the following materials from your kit *Family Cards* and *Duplicate Family Cards* (or color-print them) and slip each sheet into a page protector. There should be 2 copies of each of the 4 families (with seven individuals in each family). Use binder clips to keep each family separate. You will have 8 family sets (enough for 8 groups).
- Cut an 8.5" x 11" piece of paper in half for words on the Word Wall. You may want to laminate these to keep for next year's class.
    - Phenotype
    - Chromosome
- Have tape available for students to attach handouts to their science notebooks.

Lesson 5 • Where We Are Going and NOT Going

Where We Are Going

Before this lesson, students were still wondering if it was possible that baby cows could be getting their big muscles from their parents. We are developing models to show that at least one parent has to have the heavily muscled phenotype in order for an offspring to also be 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 consists of 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).

Where We Are NOT Going

Students examine a muscle cell karyotype to determine that the offspring's muscle cells have two sets of chromosomes, but we are not extending this to other types of cells in the organism's body as this idea is part of the high school grade band.

In future lessons, students will uncover the idea that there are genes on chromosomes and that different versions of genes for a trait 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. 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

3 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, the cattle 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 cows and they are* born *with these big muscles. That led us to start brainstorming some possible explanations for these two questions.*

Suggested prompt	Sample student response
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? *Where do the babies with big muscles come from?*	*One or both parents were heavily muscled too.* *This musculature is something they inherited.* *They got their muscles from their parents.*

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, etc.

Avoid confirming or denying if 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.

Suggested prompt	Sample student response
How could the pictures help answer our question about where babies with big muscles come from? *What would we need pictures of?*	*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 their grandparents..*

Say, *OK, Let's start by looking at a few individuals together as a class so we can determine some common conventions for what we call heavily muscled or typically muscled.*

2 · DEVELOP CONVENTIONS FOR FAMILY TREES

5 min

MATERIALS: None

Discuss as a class how to represent individuals. Display **slide B**. Say, *Looking at these two cows, we see that they are obviously different.*

Suggested prompt	Sample student response
If we wanted to keep track of the differences and some similarities, what traits would we keep track of and record on our graphic organizer?	*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 a boy or a girl.*
How would you describe these two different animals in terms of the variation they have for muscles?	*Falco has really big muscles.* *Zena has typical muscles.*

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

Show **slide C.** Say *OK, when looking at family relationships sometimes scientists sometimes 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 could shade in the shape to represent whether they show they heavy muscle variation or the typical variation.*✱

Display **slide D.**

Suggested prompt	Sample student response
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, *We have been talking about these traits and characteristics for each trait that our individuals have. Some parts of what our cows look like could be from the environment and how they have grown up (for example food and exercise), and some of what the cows look like seems to be inherited or passed down from their parents. We are claiming that the combination of all these factors makes the individual look the way it does. And we are trying to figure out how those factors work together. We call **the way an individual looks for a specific trait or characteristic**, their **phenotype**. From now on in class, when we are referring to what a cow looks like with regard to a trait, such as how many muscles it has, we are going to use this word, so we'll also post it here on the word wall.*✱

✱ ATTENDING TO EQUITY

It is important for you 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 female or male. There are more gender identities than just male or female. Gender definitions, expectations, and roles vary in different cultures, with some cultures embracing multiple gender definitions. In this unit, you should refer to biological sex, rather than gender.

✱ ATTENDING TO EQUITY

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.

ADDITIONAL GUIDANCE Definitions on the word wall can be modified over time. If in the course of this unit we see that docile behavior and short gestation times are also part of a cow'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 Falco and Zena, it was pretty easy to describe their phenotype for musculture and pretty straightforward in how to assign them a symbol for it. Let's consider another possible phenotype and figure out what to do for that individual.*

Display **slide E** and collect some ideas about how to represent them.

Suggested prompt	Sample student response
How would you describe Fantasie's phenotype for musculature?	*I think she is heavily muscled.* *I think she has typical muscles.* *I think she is somewhere in between*
What evidence would you use to support the category in which you placed her? ✱	*If you look at the muscles by her back legs, they are more defined, and they "stick out" past her tail.* *The front and main part of her body doesn't seem to have extra muscle definition.* *Some parts of her body have extra muscles like near her back legs, but the rest of her body looks like it has typical muscles.*
What ideas do you have to represent the individuals that we aren't really sure about?	*We could use a question mark.* *We could use the same shape, but either shade it in or use stripes to indicate it is an in-between phenotype.*

✱ SUPPORTING STUDENTS IN ENGAGING IN ARGUMENT FROM EVIDENCE

The point of this discussion is not to decide whether she is definitely heavily muscled or not. Or even that she is an "in-between" phenotype. The discussion's purpose is to surface the need for a way to represent an individual we are not sure about, or how to represent individuals that could be "in between" our two phenotypes.

If students disagree on how to categorize Fantasie, 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.

3 · BUILD FAMILY TREES USING COW FAMILY PHOTOS

15 min

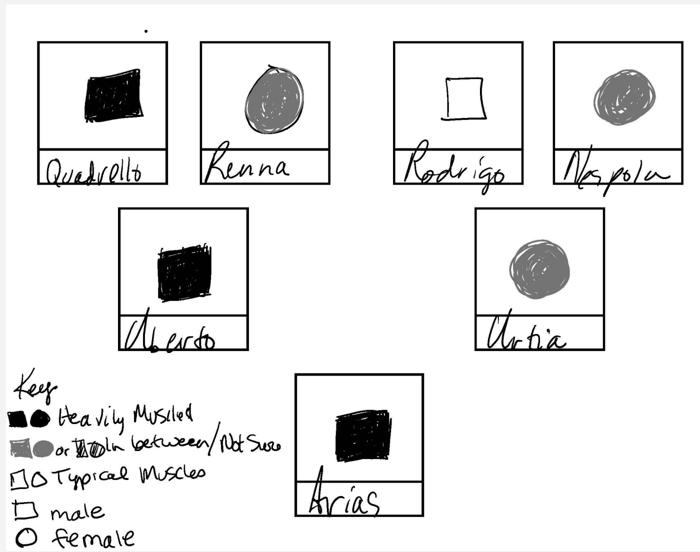
MATERIALS: *Family Phenotype Graphic Organizer*, science notebook, tape, one family set (7 individuals) from *Family Cards* or *Duplicate Family Cards*

Organize groups and materials for family tree activity. Give all students a copy of *Family Phenotype Graphic Organizer* and ask them to also open their notebooks to the next available page. Show **slide F** and Say, *Fold the graphic organizer in half and attach one half to the page so you will be able to open the page (like a book) to work on the full size organizer, yet save notebook space.*

Divide students into groups of 3 or 4 (depending on the number of students). There are 8 sets of families (two copies of each family). Give each group a family set (consisting of 7 individuals sheets placed in sheet protectors and held together with binder clips.

Say, *To find out which family you have, look in your packet to find one of the following names: Eva, Jacki, Arias or Elkie. Use this name to title your organizer. You may also write the name of this individual in the box at the bottom of the organizer as shown on the slide.* Show **slide G.** Say, *Create a key on the side of this graphic organizer so those looking at this will know what is meant by the different squares.* Show **slide H** to show the addition of the key.

Work in small groups to build the family trees. Show **slide I** and say, *Clear space for your group so each person can easily see all of the cows in the family. Work as a group to discuss what symbols should be entered for your first individual and begin recording your observations in your science notebook using the symbols we agreed on in the key. When you finish the first individual, find its parents, decide where it makes sense to add those parents on the organizer and continue to decide which symbols to enter for each individual in your science notebook. Do not put your first individual away, but continue to build your family tree as you go so you will be able to look at your graphic organizer and the family together when you are finished. If you finish both sets of grandparents, begin to record patterns you see on the next page of your notebook.*✱



✱ SUPPORTING STUDENTS IN DEVELOPING AND USING PATTERNS

Circulate to listen for students using patterns to make their decisions as they work in small groups. If they are not explicitly using evidence to discuss patterns that are surfacing as a reason for assigning symbols, try using some of the following prompts:.

What are you noticing about a cow that determines if you are calling it black or grey? Is it always easy to decide if it should be black or gray? Did you decide as a group on any specific characteristics that would give the cows either black, grey or white shapes? How are these characteristics similar to or different from the cows in your family?

4 · BUILDING UNDERSTANDING DISCUSSION ABOUT PHENOTYPES IN FAMILIES

10 min

MATERIALS: science notebook

Discuss what we learned and decide next steps. Show **slide J**.

Say, *So let's look at these hypothetical families. Do we all agree that this could happen, according to the patterns we saw? First, let's discuss the patterns we saw.*

Suggested prompt	Sample student response
What were some of the patterns for the different musculature phenotypes in the families you studied?	*Most of the families we looked at were pretty heavily muscled.* *Some of the cows had way bigger muscles than others, but didn't have the biggest muscles.* *Some cows were big, but you couldn't really see muscle definition, they were smooth.*
What were some of the characteristics you used to determine if you said the individual definitely had big muscles or not?	*You could see the lines that separated the muscle.* *The cows looked "cut."* *The muscles by their back legs (butt muscles) stuck out way past their legs.* *The pictures were even taken sometimes to show their big butts.* *If the cows had typical muscles, their legs and butts were in line with each other and the tail would hang straight down.*

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. Start with the sex. What symbol did you give Jim? Ballerina? Lorenc? Cubby, Ballerina, Jalon?* Once the class has determined the sex of all of the individuals, show **slide K,** and the symbols for sex will appear for all individuals.

Now Say, *OK, how about their phenotype symbols? What would you consider Jim - heavily muscled, typically muscled or somewhere in between? Sparkle? Lorenc? Cubby, Ballerina, Jalon?* Show **slide L** to reveal symbols for phenotype.

Use patterns to make predictions about relatedness of example families. Encourage students to cite specific evidence when discussing their claim about which individual was raised with its birth family.

✱ ATTENDING TO EQUITY

Some students may say genes/DNA/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 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 interest for all students whether they have heard these terms or not. Try saying something like, "Hmm interesting, I wonder if anyone else has heard these terms before? Should we zoom into these cells to see what we can figure out?" to move the investigation forward while keeping students with all levels of background knowledge involved.

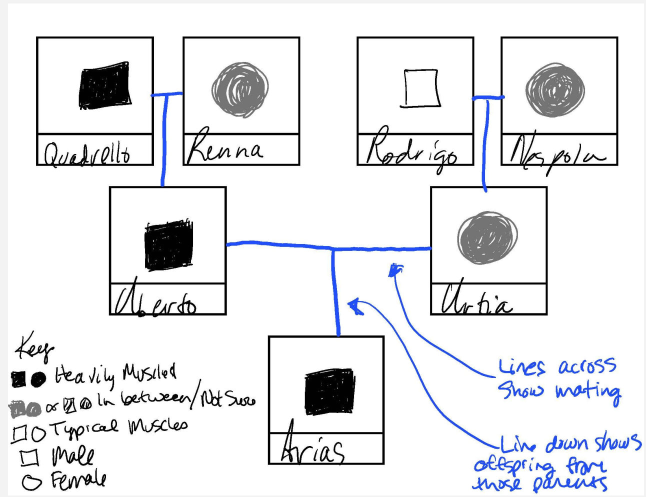
Suggested prompt	Sample student response
According to the patterns you saw in the families you studied, do both of these families show what you expect to see?	*We saw in our families that for the offspring to have extra-big muscles, at least one of the parents also had to have extra-big muscles.* *Jalon's parents both have typical muscles, we don't think this fits with our pattern.*
What if I told you that a farmer purchased a calf from a neighbor when it was a baby and picked a cow that already had another baby so this calf could be fed - could you pick which family this calf was a birth child of?	*I bet it is Jalon's family because neither of the parents have super big muscles, but Jalon's muscles are huge.*
If I told you I had a photo of the sibling that Jalon was raised with and Ballerina gave birth to, could you predict what it would look like? What symbol would you probably assign it?	*We think the calf Ballerina gave birth to looks more like them, with typical muscles.* *I bet the symbol will be white/non-shaded.*

Test predictions about relatedness. Display s**lide M** to reveal Jalon's brother, Jesse, who was the biological offspring to Cubby and Ballerina, to confirm student predictions.

Develop model to show relationships between individuals. Show **slide N.**

Suggested prompt	Sample student response
So we know Jim and Sparkle must have mated for Lorenc to exist. Is there an easy way we can show this on our graphic organizers?	*We could put a heart between them.* *We could connect them with a line - we've seen some examples of family trees that have done that before.*
I really like these ideas. Let's focus on showing the connections between them by using lines. How can we show how Lorenc is connected to Jim and Sparkle?	*We could use another line drawn straight down.*

Update your models to show relationships between individuals. Say, *Go ahead and mark up your own graphic organizers to show the relationships within the family you studied.* Display **slide O** to show the line between Jim and Sparkle and then move to **slide P** to show their relationship to Lorenc. *If you need to, you can add a note to remind yourself why you drew those lines.* Give students time to make the connections on their own organizers. At this point the graphic organizers should look something like the example shown here.



Say, *OK, this is great, it seems like there is definitely something to the idea that having big muscles is passed on from the parents, but how does this actually happen?*

Suggested prompt	Sample student response
Did the the parents each give some muscle cells to their offspring and these grew? What are the physical things parents ACTUALLY pass to their offspring?	*The parents are contributing egg and sperm.*
What actually has to happen with that egg and sperm for there to be a baby cow?	*The egg needs to be fertilized by the sperm.*
Great, so we have this sperm, which is one cell, and it merges with the egg, which is also one cell. How do these single cells get to be a baby cow? What does this line connecting down physically represent? Is the baby cow one giant cell?	*When the egg is fertilized by the sperm, that cell will eventually divide into many cells and develop into the offspring.*
OK, so what was in the egg and sperm that eventually made it so the baby had big muscles? Were there little pieces of muscle cells that were transferred? ✱	*We're not sure... maybe we need to look inside the egg and sperm to see.*
What about this fertilized cell, does this have muscles?	*Well it can't have muscles, because it is a single cell, and we saw muscles are made of many cells.* *When cells have food they can use the proteins and other parts of food to make new cells, so this cell needs to get from here to the baby cow by doing that.*

Display **slide Q** to uncover the ideas about eggs and sperm and fertilization students have figured out.

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.

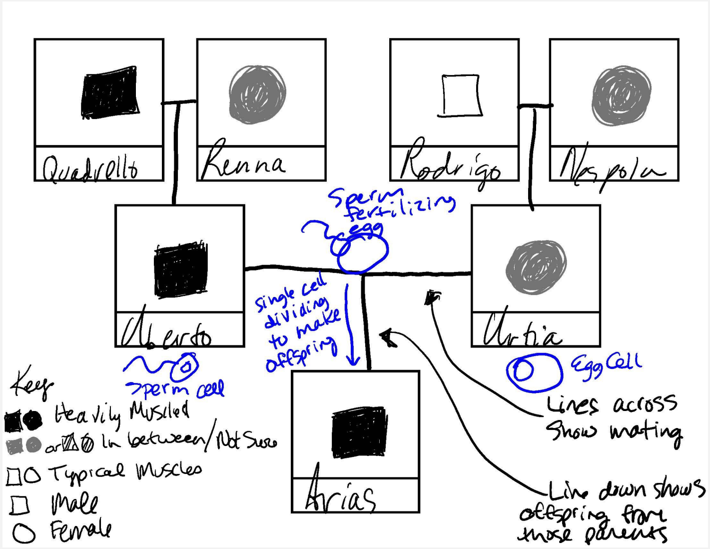
KEY IDEAS

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:

- If an individual is heavily muscled, they must have at least one parent who is also heavily muscled.
- Even if an individual has a parent that is heavily muscled, it doesn't necessarily mean the individual will also have super-big muscles.
- We're wondering HOW the super-big muscles physically get from parents to their offspring.

Update the graphic organizer to show egg, sperm and fertilization. Say, *Let's record what we now know in our science notebooks. Show the types of sex cells produced by the parents, and show them meeting for fertilization. Add any additional notes that will help you understand what is happening in along the lines you added. For the sake of space and neatness, make these additions only to the parents and main offspring (not the grandparents).*



5 · INVESTIGATE WHAT IS FOUND INSIDE EGG AND SPERM CELLS

12 min

MATERIALS: science notebook, tape, *Chromosomes in Sex Cells*

Observe patterns in egg, sperm, and muscle cells and make some observations. Display **slide R.** Ask students to turn their science notebooks to the next open page and create a Notice/Wonder chart for this activity.

Suggested prompt	Sample student response
What do you notice about what is in the egg cell and the sperm cells compared to the muscle cells?	*There are some things they all have in common like tubulin, 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.*

Show **slide S**. Explain that the images on the slide were taken from photographs showing what you would see inside the nuclei of egg and sperm cells if you used a microscope to zoom way in. Point out that egg and sperm are not to scale - eggs are MUCH larger than sperm!). Ask students to take a moment to record what they notice and wonder about what is inside the egg and sperm cells.

Suggested prompt	Sample student response
What similarities and differences do we notice between the egg and sperm?	*Both cells have squiggly structures that are all different sizes.* *Some of the squiggly things are straight and some bent.* *It looks like they are striped or have bands that are dark and light.*
Did anyone try to count how many were in each cell?	*It looks like they might have the same number.* *They are too hard to count though because they are on the screen.*

Examine chromosomes in egg and sperm cells. Give all students a copy of *Chromosomes in Sex Cells* and 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 write anything they want on their handout to help them make sense of what they are observing. Come back together as a class to share ideas.

Suggested prompt	Sample student response
What other patterns did you notice now that you could look at these cells up close?	*The sperm and the egg each had 30 structures.* *All of 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.*
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.* *There will be a total of 60 structures in the new cell.*
Do you remember what happens to this new cell?	*It will divide to make 2 new cells - as long as it has been fertilized and has enough food to be able to make new cells.* *It will keep dividing until it becomes an embryo, then eventually a baby. As long as it has enough food to make the new cells and proteins to do so.*

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

Suggested prompt	Sample student response
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 egg and sperm cells and in body cells.*

Add "chromosome" to the word wall. Chromosomes - physical structures that are passed from parents to offspring in egg and sperm cells, and they are also found in an individual's body cells.

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 final activity).

ADDITIONAL GUIDANCE	Students may say that all body cells will have these chromosomes in the same number and type, however we're only looking at muscle cells. Yes, the genetic material would be found in most other body cells, too, but we don't learn how that works until high school (so we don't want to go there now).

End of day 1

6 · DISCOVER PATTERNS USING KARYOTYPES

15 min

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

Examine chromosomes in egg, sperm and muscle cells. Show **slide T**. Say, *Check in with your elbow partner - What do we expect to see if we were to zoom into the nucleus of one of Lorenc's muscle cells at the same level we did for the egg and sperm cells?*

Show **slide T1**. *Say, Scientists have also found chromosomes in the muscle cells of cattle. And not just muscle cells. They also find them in skin cells, bone cells, brain cells, lung cells, liver cells. Chromosomes can be found in the nucleus of the cells that make up the rest of the body structures too.*

Show **slide U** and say, *Can you tell if your predictions are correct? I heard some of you say you expected to see 60 chromosomes. Did anyone confirm that there are 60 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 need to organize the chromosomes like this so they are able to see patterns. This shows 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 also have 60 chromosomes, except egg and sperm cells, of course.*

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. However, an important equity concern to keep in mind is that in humans we have two distinct characteristics, biological sex and gender. This unit does not address gender, which is a social construct that refers to how individuals position themselves and are positioned by others in relation to roles as female or male. Therefore, students should refer to biological sex during the unit, rather than gender. 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 causes the development of a male reproductive system. Without a Y chromosome and functional SRY, an XX embryos develop into a female. While SRY is central, there are many other genes involved in influencing maleness. When SRY is mutated and produces a non-functional protein, the individual presents externally as female (and is usually raised as a female, that is, has a female gender identity), 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.

Observe patterns in chromosomes. Display **slide V** and direct students to lay each of their handouts (*Chromosomes in Sex Cells* and *Karyotype of Lorenc's Muscle Cell*) side-by-side in portrait orientation on their desks. Students should flip both pages over and tape them together along the seam on the back (explain that we will be writing on the front side and we don't want to write over the tape). After we're done with this activity, we will fold and tape these pages into our notebook to keep this record of our work.

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 x / y) come from the other parent or any other version of dividing the chromosomes in half. This activity should help students sort out that each parent contributes one copy of each of the chromosomes.

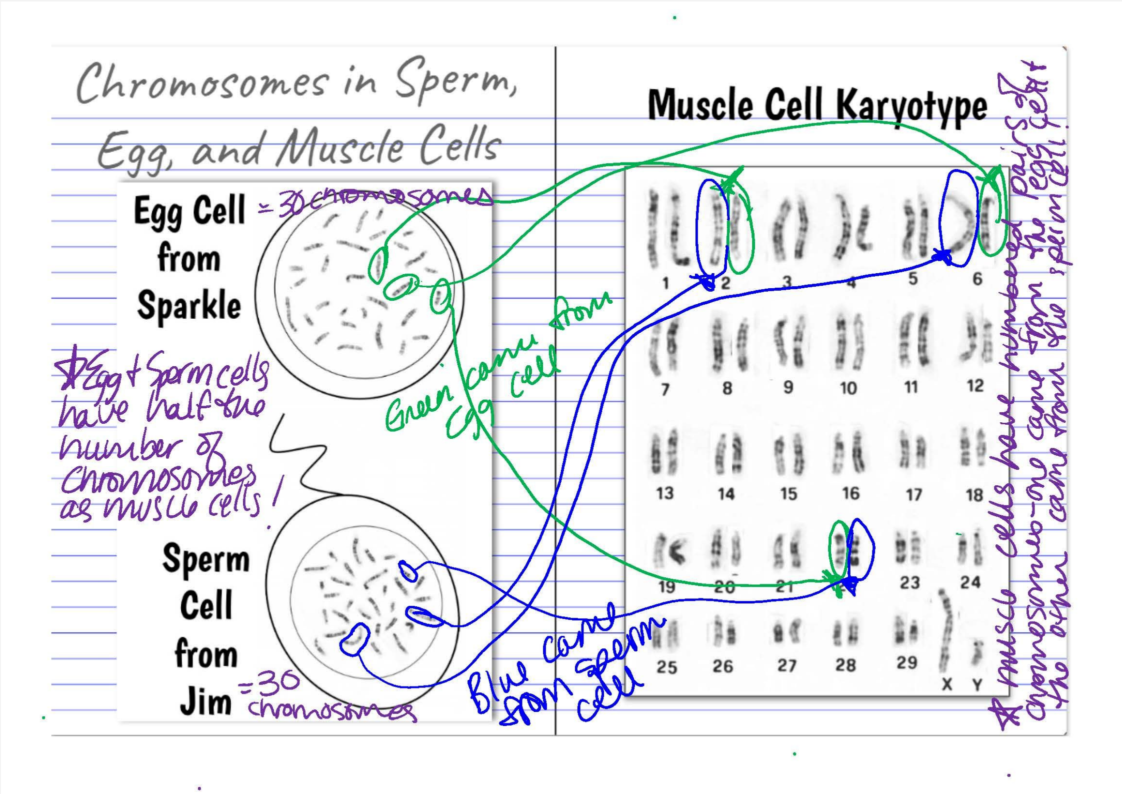
Say, *Even with the chromosomes organized this way, there are still a lot of things to pay attention to. Maybe if we just focus on a few of these chromosomes at a time, it will be easier for us to make sense of how they are organized. Let's try to figure out where these chromosomes come from, but let's just look at 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 arrows, lines, circles, or use labels to show how the chromosomes in Sparkle's egg and/or Jim's sperm are also in the individual karyotype of Lorenc's muscle cell. When you find both parts of chromosome 6, do the same with chromosome 22, and finally do the same with chromosome 2.*

After explaining the directions, show **slide W** to highlight the chromosomes students are being asked to work with.

Discuss what students discovered about these chromosomes. Display **slide X.**

Suggested prompt	Sample student response
So, what patterns do you see? How are these chromosomes organized?	*There are 60 total, but they are organized into 30 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?	*Maybe each pair is organized so one came from the sperm cell and one came from the egg cell.*
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 chromosome 22 and chromosome 2 as well.*

Suggested prompt	Sample student response
Do you have any new questions about these chromosomes?	*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?*



KEY IDEAS

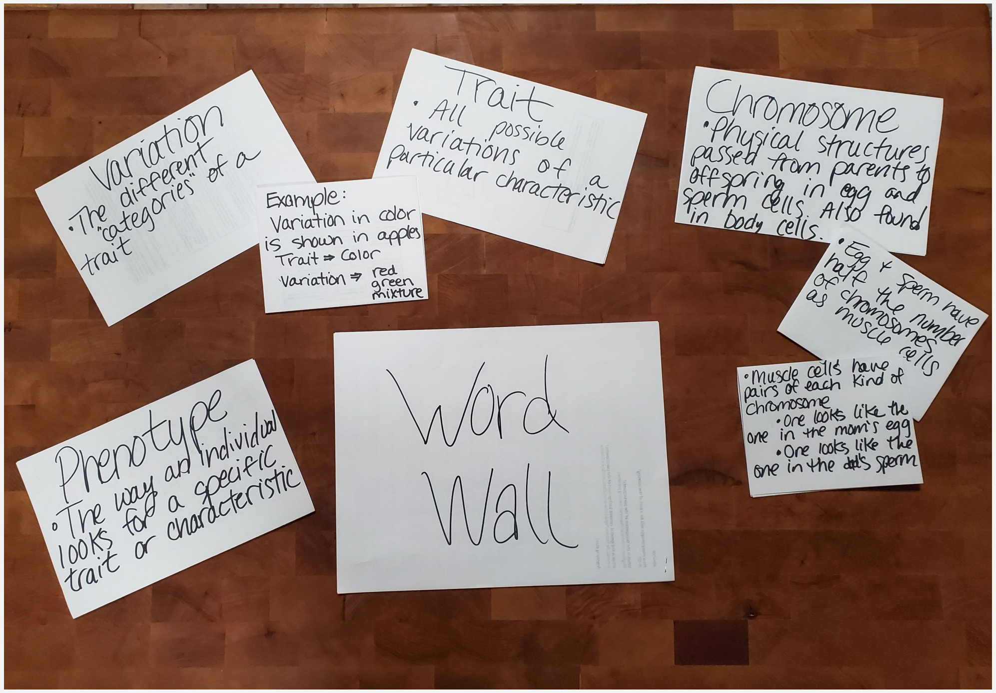
Purpose of this discussion: To help students make their reasoning with evidence public so that other students can connect with the ideas about the inheritance of chromosomes. We will also build on these ideas by motivating the need to zoom in even closer to see what is going on with these chromosomes.

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 cows' phenotype.

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 not sure we are even close to knowing everything. I think we should add to our definition of chromosome, but maybe to make sure it doesn't get too messy we can keep adding cards to our word as we figure out more things?*

Use sticky notes, index cards, or quartered paper to add "Egg and sperm have half the number of chromosomes as muscle cells" and "Muscle cells have pairs of each kind of chromosome, one looks like the one originally in the egg and one looks like the one originally in the sperm".



7 · MAKE PREDICTIONS ABOUT THE NUMBER OF CHROMOSOMES

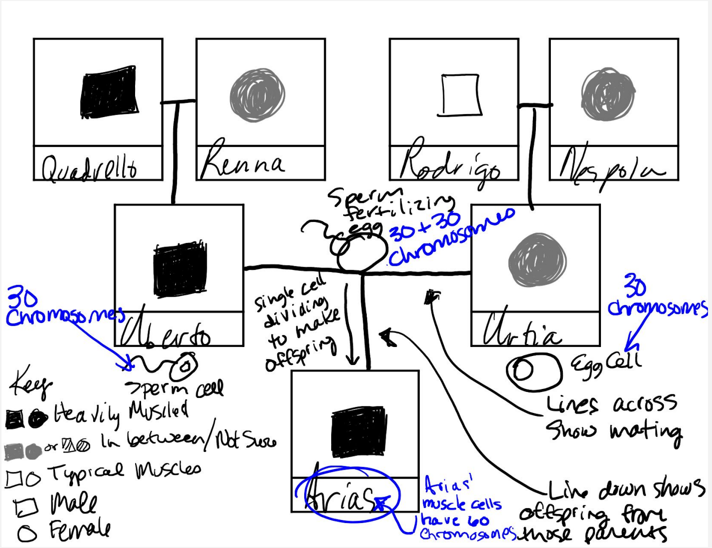
5 min

MATERIALS: None

Update the Family Phenotype Graphic Organizer. Show **slide Y.**

Say, *Let's go back to the page in our science notebook with our cow family trees 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.*

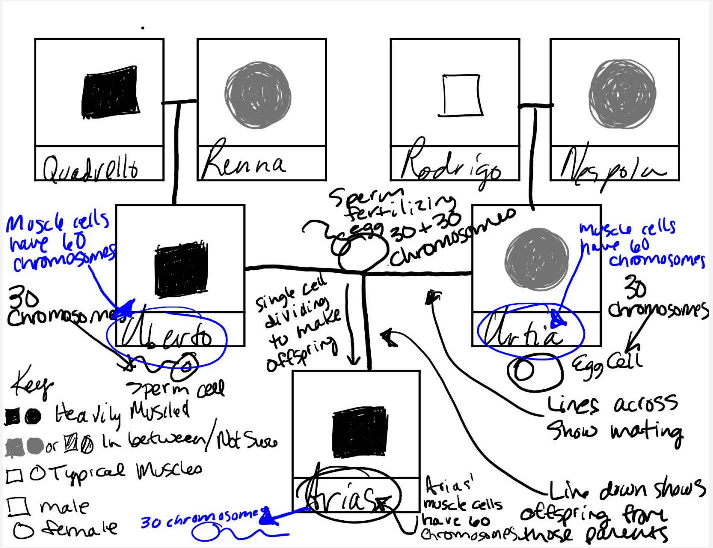
Make predictions about the number of chromosomes in the rest of the cells. Say, *We figured out that there are 30 chromosomes in Jim's sperm cell and the same amount in Sparkle's egg cell. Then we wondered if, when these two met, the offspring would have 60 chromosomes in their muscle cells and other body cells, and we saw this was true, right?* Show **slide Z.**



Suggested prompt	Sample student response
Let's start with Lorenc, we saw his muscle cells have 30 pairs of chromosomes to give him 60 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 60 chromosomes in their muscle cells, and made sex cells with only 30 chromosomes, many chromosomes do you predict will be in the sperm cells that Lorenc will make?	*Lorenc will have 30 chromosomes in the sex cells he produces.*
Do you think his sperm cells will just have a randomly chosen set of 30?	*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 46 chromosomes (23 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 23 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 family tree to include the number of chromosomes in the other cells. Say, *OK use this new information to update the family trees in your science notebook one more time.* Display **slide AA** to confirm student predictions while they add the chromosome numbers to their science notebooks.



8 · NAVIGATION

8 min

MATERIALS: None

Reflect on what we know and what we still need to figure out. Advance to **slide AB** and say, *OK we made a lot of progress today. What do we know now, and what do we need to figure out next?*

Suggested prompt	Sample student response
What were the most important things we figured out today?	*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 sexual reproduction - that it 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.*
What do we still have to figure out? What are you now wondering?	*If we see patterns of the phenotype in the family trees and we know that the chromosomes are the thing that's being passed from parents to offspring, then what's the connection between the chromosomes and the phenotype. What are the chromosomes doing to "give" the cattle big muscles?*