LESSON 14: How common are other trait variations?

PREVIOUS LESSON *We jigsawed several data readings looking at different traits to see if our gene-to-trait story with MSTN was the same. After constructing simple models and comparing them, we shared out with the class the patterns we observed, and discussed whether these traits are harmful or beneficial.*

THIS LESSON

INVESTIGATION

1 day

In this lesson, we collect data from our own class's arm spans, and create a graph to represent them. We also measure the lengths of many sunflower seeds and use digital tools to graph these because there are many more lengths. We generate histograms and adjust the "bin" size to see how that changes the shape of the graph. We consider where heavily muscled cattle would be represented if we were able to show the variety of musculature for cattle on a graph like these.

NEXT LESSON *We will check on our planaria and share our observations about their development. We will revise our classroom consensus model to reflect how different factors influence musculature in cattle. We will read about other examples of trait variations and develop models to communicate how genes and environmental factors impact that trait.*

BUILDING TOWARD NGSS

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

WHAT STUDENTS WILL DO

Use mathematics and computational thinking with a digital tool to find patterns in a large set of trait variation data.

WHAT STUDENTS WILL FIGURE OUT

- Graphing the variation we can see in a population of living things results in a bell-shaped curve.
- Most phenotypes are in the middle of the graph, so "typical" isn't just one phenotype or another - it's a range.
- A few phenotypes are in the extremes of the graphs.

Lesson 14 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Discuss a way to investigate variation of traits in a quantitative way.	A	
2	10 min	**COLLECT, GRAPH, DISCUSS ARM SPAN DATA (OPTIONAL)** Collect arm span data from the class, graph it, and analyze it.	B	tape measures or meter sticks (possibly taped to the wall), chart or sticky notes for collecting arm spans
3	10 min	**COLLECT AND GRAPH SUNFLOWER SEED LENGTH DATA** Students work in partnerships to measure sunflower seeds, then combine and graph the whole class's data using an online tool.	D-F	10 sunflower seeds, ruler, internet-connected computer, blank spreadsheet for sunflower seed data
4	5 min	**DISCUSS SUNFLOWER SEED DATA** Students discuss the histogram of sunflower seed data,the digital tool they used, and define population.	G	half-piece of paper to add "population" to our word wall
5	10 min	**EXPLORE OTHER LOCALLY COLLECTED DATA SETS** Students collect and graph data from other examples of trait variations found around their school or homes.	H	locally collected materials to measure for variation data, ruler, scale (optional), internet-connected computer
6	10 min	**SHARE AND DISCUSS OTHER EXAMPLES OF VARIATION DATA** Students share other histograms, then discuss how the bell-shaped curve pattern could apply to musculature of cattle.	I	internet-connected computer
7	5 min	**PROGRESS TRACKER** Students summarize today's learning by adding an entry to their Progress Trackers.	J	

End of day 1

Lesson 14 • Materials List

	per student	per group	per class
Lesson materials	• 10 sunflower seeds • science notebook	• tape measures or meter sticks (possibly taped to the wall) • ruler • internet-connected computer • locally collected materials to measure for variation data • scale (optional)	• chart or sticky notes for collecting arm spans • blank spreadsheet for sunflower seed data • half-piece of paper to add "population" to our word wall

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.

If you're doing the optional arm span measurements, consider taping flexible rulers or meter sticks horizontally along the walls to make gathering that data a bit faster.

Set up a Google sheets spreadsheet for collecting sunflower seed length data and share with the class so students can all enter their data as they're measuring.

You may wish to share the link to http://www.shodor.org/interactivate/activities/Histogram/ with students to facilitate their getting to the site more efficiently.

Consider what other examples of measurable variation you'd like your class to gather during this lesson, and plan how students will collect them (go outside to find leaves, borrow produce from the cafeteria to weigh, find online insect collections to sift through, etc.).

Lesson 14 • Where We Are Going and NOT Going

Where We Are Going

This lesson provides a bridge between the genetics-heavy figuring out of Lesson 13 and the influence of environmental factors and genetics in Lesson 15. Students use measurable data in today's lesson to see the range of variation within a trait so they can generalize the idea of a "range of typical" to traits that are not so easily measured. Seeing outliers in such a small part of the bell-curve of population data helps illustrate how rare those significantly different phenotypes (such as heavily muscled cattle) are. That said, this lesson provides opportunity for flexibility about locally sourced data. If you anticipate that measuring student arm spans is not a good fit for your classroom, there are other options for collecting measurable examples of trait variation.

Where We Are NOT Going

The histogram tool includes other data sets pre-populated (before students clear them to input their own). We do not recommend including those histograms in your discussion of trait variation, as most are not heritable traits and we do not know the sources of the data.

LEARNING PLAN for LESSON 14

1 · NAVIGATION

5 min

MATERIALS: None

Navigate into today's work. Display **slide A.** Ask, *What were we planning to investigate today? Who can remind us what question we wondered about last time?*

Elicit responses such as: How common are the variations within a trait? How could we measure the variation within a trait? We know the heavily muscled cattle are very uncommon compared to other cattle - do other traits have such a range of variation and extreme differences?

Say, *Cool. If we want to investigate how common (or uncommon) trait variations are, we will need to do some measuring or counting or categorizing, yes? So let's start there.*

Suggested prompt	Sample student response
What kinds of "categories" have you looked at for traits so far? When you've been describing the variation in a group, what are some examples of how you "sort" the individuals?	*The pigeons had crests on their heads or not.* *Cattle and other animals can have typical muscles, more muscles, or be heavily muscled.* *Sunflower seed length could be long or short or medium.*
OK, so some trait variations lend themselves to easily formed categories such as "crest" or "no crest." But have all of them been that easy to create categories for?	*No!* *With the cattle, it was difficult to tell if one was heavily muscled or more muscled. Sometimes it was also hard to tell if it had typical muscles or more muscles. And not all of them in the same group looked the same.*
Got it. Sorting things is easier if we have categories, right? And these categories can help us see patterns in our data. But if we have really complex data (like these trait variations) it's hard to decide if more categories would help us see patterns or not. So sometimes if we want to see patterns in complex data, we try to get a quantitative value... something we can measure. The musculature of cattle would be difficult to measure, right? So, I'm thinking we should gather quantitative data from a source we can measure instead, like the lengths of things... arm spans and/or sunflower seeds. But will they have categories, like the pigeons had crest or no crest?	*Not really categories, unless we decide which lengths count as "short" and which count as "long."* *I think there will still be a range of sizes, like we had a range of muscles.*
Okay, so we'll do some measuring first, and then we can see if we have a range of lengths, or decide on categories, once we have our data.	*Okay.*

2 · COLLECT, GRAPH, DISCUSS ARM SPAN DATA (OPTIONAL)

10 min

MATERIALS: tape measures or meter sticks (possibly taped to the wall), chart or sticky notes for collecting arm spans

ALTERNATE ACTIVITY	Body size and stature can be a sensitive topic for people of any age, but especially for middle schoolers. If you have concerns about collecting arm span data from your class, skip this activity and go straight to measuring sunflower seeds.

Measure arm spans and collect data. Display **slide B**. Have volunteers help you demonstrate how to work as a group to measure arm span. Either have the person being measured stand back against the wall where you have taped meter sticks and/or other measuring tools, fingertips at zero, and read the measurement at the other fingertips. Or, away from a wall, have one helper hold a tape measure at the back of the arm being measured (starting at the fingertips) and have another helper stretch it across the person's back to their other fingertips.

Distribute tape measures, meter sticks, rulers, etc. to groups, or point out the area(s) you have set up for measuring arm spans (measuring tools taped horizontally on the wall). Direct students to efficiently collect their data and record it on a chart or shared class spreadsheet (one measurement per row down a single column) projected for everyone to see. Do not record names, just arm span lengths.

Graph class arm span data.

Say, *As you know, it's really hard to make much sense of our data when they're a disorganized list of numbers. So we're going to organize them into a histogram. You might recall from math class that histograms help us see the "shape" of our data, and I'm hoping that using histograms today will help us answer our question about how common some trait variations are. To make a histogram, we are going to group our data into "bins" - in this case, those will be groups of lengths. I've got a grid started here (on **slide C**) with bins in 5cm intervals, so let's see how our data fit.*

Have students help you fill in columns of the grid on **slide C** for your class data set.

ADDITIONAL GUIDANCE	You may choose to have students enter their own arm spans by keeping **slide C** posted and having individuals fill in squares on the grid as they are measured. Alternately, each student could place a sticky note with their arm span length (no name needed) onto the projection screen on the slide grid showing where their measurement would fall.

Discuss the arm span line plot.

Suggested prompt	Sample student response
What do you notice about the shape of the graph?	*It's lower at the edges and higher in the middle.* *It looks like a mountain.*
When scientists see this sort of distribution in a data set, they refer to it as a "bell-shaped" curve. What about its shape would lead someone to call it that?	*It has a shape like a bell.*

✱ ATTENDING TO EQUITY

It is possible that you have students who cannot picture the type of bell referenced in the term "bell-shaped curve." There is a photo of a bell on **slide G** so you can skip ahead and point it out, if needed. (Students may be picturing a round jingle bell, or the electronic "bell" that many schools use between class periods.)

Suggested prompt	Sample student response
What does the difference in shape (or height) of the curve near the edges vs. the middle represent?	*It means there are fewer of us with the smallest and largest arm spans, and more of us with arm spans somewhere in the middle.*
Do you think each class that does this activity will see the same bell-shaped curve?	*Maybe there will be some changes to the exact numbers, but it seems like the shape would be about the same.*

ALTERNATE ACTIVITY

If you think it would be helpful to model using the histogram website that students will use to graph sunflower seed data in the next activity, you can follow the steps on *Generating Histograms from Large Data Sets* for the arm span data while projecting your computer for the class to see.

Say, *Let's try this again with another trait we've already discussed and see if we get the same shape in our graph. We also can gather more data because we have more of them available: let's measure the lengths of sunflower seeds.*

3 · COLLECT AND GRAPH SUNFLOWER SEED LENGTH DATA

10 min

MATERIALS: 10 sunflower seeds, science notebook, ruler, internet-connected computer, blank spreadsheet for sunflower seed data

Discuss the advantages and disadvantages of a larger data set. Display **slide D**.

Suggested prompt	Sample student response
Why would it be helpful to have more measurements in our data set?	*I remember from math class that a larger sample size more accurately predicts for a whole group. So if we're trying to think about variation in all the people's arm spans in the school/country/world, just our class is not a very big sample. So if we can measure more sunflower seed lengths, a bigger sample will be a closer estimate of what the lengths of sunflower seeds usually are.*
What challenges will we face when collecting and organizing a larger data set?	*It will take longer to make more measurements.* *We will have more numbers to try to keep track of before and during the graphing, and we'll need to graph them for sure to make sense of them.*
What tools or strategies could we use to overcome these issues?	*Let's use a computer to organize the data - there's gotta be an easier way than having to enter each of the numbers onto the graph one at a time.* *We can all measure some sunflower seeds and then pool our data together.*

Give directions for gathering sunflower seed lengths. Display **slide E**.

Say, *If we each measure the length of ten sunflower seeds, we will have a lot of data very quickly. Share your ruler and computer with a partner, and enter your data into our shared spreadsheet. I will give each of you a specific "batch" of row numbers to fill with your data (1-10, 11-20, and so on).*

Be sure each partnership has a computer and ruler to use. Distribute ten sunflower seeds to each student, and tell them which "batch" of row numbers to fill in on the spreadsheet.

Use a digital tool to analyze the sunflower seed data set. Display **slide F**. When students have finished their measurements and data is entered into the shared spreadsheet, bring everyone's attention back for a moment.

Say, *We've got a great list of data here! You suggested that we use our computers to organize this large data set. I've got directions here for you - see how this works compared to our "do it yourself" way from earlier.*

Distribute *Generating Histograms from Large Data Sets* and direct students to work with their partner and follow the steps so they can make their own histograms of the class sunflower seed length data. Let them explore the slider and/or number entry field to change the size of the "bins" for the histogram.

4 · DISCUSS SUNFLOWER SEED DATA

5 min

MATERIALS: half-piece of paper to add "population" to our word wall

Discuss the histogram(s) of sunflower seed data. Since everyone used the same data set to create their histograms, you can project just one, and/or **slide G** to refer to during the following discussion.

Suggested prompt	Sample student response
Now that you've had a chance to work with this data, what do you notice about the shape of this graph? (How did it compare to the arm span histogram?)	*This histogram has a mountain shape - higher in the middle and lower on the outside edges.* *This one had a bell-shaped curve, too, just like the arm span one did.*
(Name "bell-shaped curve" if not already done.) Since we have the bell-shaped curve, what does this mean for the length of most of the sunflower seeds?	*It means that most of the sunflower seeds' lengths were somewhere in the middle of the range - not very short and not very long.*
Do you think this data represents well how all sunflower seed lengths are distributed? Can we predict that if we were to add many more seed lengths to this data set, our graph would still be curved like this?	*Well, maybe... are there different kinds of sunflower seeds, though? Like the ones in my dad's birdfeeder look different than this - they're much smaller and totally black.* *And are we assuming that they all came from the same farm, since they're from the same company? Would it matter where they were grown?*
Okay, we should add the word "population" to our word wall. A population is a group of the same kind of organisms living in the same place at the same time. So how could that apply to our sunflower seeds?	*Well they seem to be the same kind - they look alike.* *The place could be specific (one farm) or broad, like the whole country (the bag says "American grown").* *I think they were grown at the same time, though, like the same season, to be harvested and sold at the same time.*

Suggested prompt	Sample student response
Okay, so if we're within this population of American-grown snack-food sunflower seeds, do we think our sample pretty well represents the range of different sizes of the whole population?	*Yeah, probably.*
Now I'm thinking about that word "typical" that we keep using. How would you describe a "typical" sunflower seed? What length do you think we could categorize as typical?	*Well, somewhere in the middle, because that's where the most are.* *Maybe around ___ mm (whatever your class mode was) because that's how long most of them are.*
Is it kind of hard to pick just one length? Should we consider typical to be a range instead?	*Yes, that makes sense.*
What happened when you moved the slider or changed the number for "Interval Size?" *Why?*	*The bars on the histogram either got wider and there were fewer of them or narrower and there were more of them.* *I think that was adjusting the "bin" size - how wide (or narrow) the ranges were to be included in each bar.*
How did adjusting that bin size affect the shape of the graph?	*Unless we went really wide, like just one or two bars, we could still see a bell-shaped curve.*
So that bin size could help us think of the range of typical, maybe - most of the lengths under the middle of the "bell" could be our "typical" seeds. And the seed lengths on the extreme ends of the graph are the most atypical.	*Okay.*
How did using this website to make your histogram compare with making our own in class?	*Way faster! It would have taken forever to organize and plot all those data one by one.* *It was cool to just be able to slide a bar to change the bin size and not have to recreate the graph ourselves.*

5 · EXPLORE OTHER LOCALLY COLLECTED DATA SETS

10 min

MATERIALS: locally collected materials to measure for variation data, ruler, scale (optional), internet-connected computer

ALTERNATE ACTIVITY

If your class has already measured arm spans and sunflower seeds, maybe they have enough examples of trait variation graphs and you can skip right to the discussion about how we could consider cattle musculature in this same data pattern.

Prompt exploration of other data sets.

Say, *We've looked at the distribution of phenotypes in sunflower seed length and in our class's arm spans. We saw a bell-shaped curve in both cases when we made a histogram of our findings. Let's explore a few more traits to see if this pattern continues. Then, maybe we can make more sense of our cattle phenotypes.*

ADDITIONAL GUIDANCE	Use your discretion about how student-directed you want to make this exploration. You may decide in advance which other data set(s) to have your class measure, or you may let students generate ideas for what to collect. Ideas for possible data sets might include the following: • length or width of leaves (collected from outside or measured without removing them from a houseplant in the classroom) • diameter or length of flower petals (from outside or the floral department of a grocery store) • length, width, or mass of pinecones or other seeds found outside • length, width, or mass of fresh fruit (maybe the school cafeteria will let your students take data before that food is served for lunch) • length or width of insects, possibly found in an online collection or database • other natural specimens your class thinks of

HOME LEARNING OPPORTUNITY	Students might have access to other measurable trait variation data sets at home, such as acorns in the yard or a seashell collection from a family vacation. You might suggest that students look for other examples of data to gather tonight and bring back tomorrow to graph (or graph right away, if they can access the histogram site).

Work to collect and graph other data sets. Decide which groups will collect what data, or maybe the class will work together to measure a larger data set, as we did with the sunflower seeds. Once groups know their task, display **slide H** and set them to work, ready to come back to share their histograms of these other examples to discuss before the end of the class period.

6 · SHARE AND DISCUSS OTHER EXAMPLES OF VARIATION DATA

10 min

MATERIALS: internet-connected computer

Bring the class together to share other examples of variation data. Display **slide I**. Depending on how many groups measured different data sets, you may want to project the histogram(s) or simply have groups adjust the zoom on their computers so others can see the shape of their graphs when looking around the group. Discuss patterns in the data.

Suggested prompt	Sample student response
What population did you collect data from?	*(Responses will vary depending on local data sets, but may include something like the following: We collected leaves from the same kind of trees that are growing in front of the school.)*
What did you notice about the histograms we generated about these other traits?	*They are all bell-shaped curves. No matter what trait we are looking at, there is a bell-shaped curve to the phenotype.*
So, what does this middle part of the histogram tell us?	*That is the middle of the range of phenotypes, and the graph is higher there because there are more individuals with those phenotypes there in the middle.*

Suggested prompt	Sample student response
What about the edges? Why is the graph lower there?	*The edges are the extremes, like the really small and really big sunflower seeds. There aren't as many as the middle of the range, so the graph is lower there.*

Connect the discussion back to cattle and the heavily muscled phenotype.

Suggested prompt	Sample student response
I know we said that it would be hard to measure and graph the musculature of cattle. But let's imagine we could, that we could graph the range of musculature for the whole world's cattle population. What do you think that graph might look like?	*It would be a bell-shaped curve.*
Let's remember the statistics we learned about how common the heavily muscled cattle are. If the entire curve represents our cattle population's musculature, where would the 0.15% that are heavily muscled be on that graph?	*They'd be way off on the end - they're the extreme.*
And like we said for the sunflower seeds, even the "typical" cattle are part of that bell-shaped curve, right? Even the ones that are not heavily muscled we know have a range of musculature.	*Right.*
So how do we get this range, even in what we'd call a "typical" phenotype? What's causing these differences?	*Well we know from our model that their musculature is caused by the MSTN alleles they get from their parents and their diet and maybe even by how much they "exercise" (like how much they use their muscles, at least).*

Say, *Scientists have wondered for a long time how we have such a range of "typical." Take height, for example. Scientists discovered long, long ago that people's arm spans are typically the same as their height. They tend to be in a one-to-one ratio. Cool, right? But more recently they started investigating what genes might contribute to a person's height. Twenty years ago scientists had produced a line of evidence suggesting that there were at least three genes that contribute to a person's height. Then as they gathered more data and and used other statistical tools, they started to notice that the patterns were more complex, and there might be as many as 50 genes that contribute to height. In just the past few years, with the help of computers to analyze patterns in the data from larger and larger data sets, scientists have figured out that more than 700 alleles influence the proteins that influence the bone growth for this trait.*

Say, *I'm thinking this is a trend in how we people make discoveries about ourselves. When it comes to making sense of trait variation in a population, we tend to see simple patterns first, right? Like the basic categories, or the biggest "bins." But as we get more data and have better tools to analyze those bigger data sets, the story becomes more complex.*

Suggested prompt	Sample student response
So I'm wondering what you think about muscles... we know changes to the MSTN gene can cause extra-big muscles, but do you think that is the single, only gene that influences muscle development? Or is it like pigeon crests and there are a couple of genes involved? Or are muscles more like height, where there might be hundreds of genes involved?	*Probably hundreds... muscles are pretty complicated.* *Maybe just that one, since it makes such a difference.* *Don't we need more data? When we have more data, we can see more of the complexity, right?*
So if we're thinking about the musculature of all the world's cattle, we have a range of "typical" just from their genes, or is there more to it?	*We said what they eat and how much they exercise (or not) plays a role, too.* *So it's all of those things? Like a combination of the genes they have and what they eat and do?*
Oh, but might there be different combinations of those factors for different phenotypes?	*Yeah, maybe that's how we get that range of differences.*

Say, *That sounds like what we should investigate next time. Is the musculature of these cattle mostly decided by genes or environmental factors? Could it be different for different phenotypes? We'll try to figure that out next!*

7 · PROGRESS TRACKER

5 min

MATERIALS: science notebook

Update Progress Trackers. Say, *Let's use our Progress Trackers to summarize what we figured out today.*

Display **slide J** 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 common are other trait variations?	• Graphing the variation we can see in a population of living things results in a bell-shaped curve. • Most phenotypes are in the middle of the graph, so "typical" isn't just one phenotype or another - it's a range. • A few phenotypes are in the extremes of the graphs.

Additional Lesson 14 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH	CCSS.MATH.CONTENT.7.SP.A.1: Understand that statistics can be used to gain information about a population by examining a sample of the population; generalizations about a population from a sample are valid only if the sample is representative of that population. Understand that random sampling tends to produce representative samples and support valid inferences. In this lesson, students use skills from 7th grade math to make sense of their examples of trait variation. They consider the size of the sample they're using (for instance, a class-sized group of students' arm spans versus a couple hundred sunflower seeds) in regard to how well that data might represent the population as a whole.