

Unit 5

Genetics:

Why are living things different
from one another?

Student Procedure Guide



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Genetics:

Why are living things different from one another?

Student Procedure Guide

Core Knowledge Science



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Genetics

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Lesson 1: How do organisms get their differences?

Get ready to make some observations.

In your notebook



1. Make a T-chart in your science notebook where you can record your noticings and wonderings.

What is different between the animal on the top vs. bottom?

In your notebook



2. Use the T-chart in your science notebook and record what you notice and wonder about the animals pictured on the slides.

Share observations with a partner.

Turn and talk



3. As you share with a partner, be sure to reference specific details in the photos.
 - What differences did you observe between these two animals?
 - What are you wondering about?
 - Be ready to share your thinking with the whole class in a minute.

Initial Ideas Discussion

With your class



4. As you share your ideas with your class, refer to specific details in the photos so everyone understands your thinking.
 - What did you notice?
 - What are you wondering?
 - Your teacher will record these initial ideas on a classroom Notice and Wonder chart.

Observe more animals.

With your class



5. That one animal is not the only one with these extra-big muscles. With your class, observe images on the slides of more animals that also have extra-big muscles: other cattle, dogs, fish, mice, and rabbits.
6. What patterns do you notice with all these animals?

Develop initial models: choose your animals.

On your own



7. Choose an animal we have seen that has bigger-than-usual muscles. On *Initial Model*, develop an initial model to explain your ideas about this question: "What do you think caused this animal to get such big muscles compared to typical animals of the same kind?"
 - In your notebook, record questions that come to mind as you are constructing your model. Be ready to share these questions with your class later in this lesson.

Compare initial models.

With a partner



8. Share your model with a partner. Look for similarities and differences between your models. Make a T-chart in your science notebook to keep track of these similarities and differences.
 - Be prepared to share your thinking with the whole class.

Initial Consensus Model Discussion

Scientists Circle



9. Develop a whole-group record of what we agree on and where we have competing ideas across our initial models.
 - What do we all seem to agree on?
 - What do we disagree on?
 - What are some new ideas that we may want to consider?

Are "extra-big" or "typical" the only options for muscles?

We developed a model to explain extra-big versus typical muscles, but do we think there are just these two sizes of muscles cattle can have? Could there be other sizes of muscles, too?

Turn and talk



10. Turn and talk with a partner about these questions:
 - Do you think cattle come in just two sizes of muscles: extra-big and typical?
 - Why or why not?

Observe more cattle.

With your class



11. Look at the photos of cattle your teacher has displayed or distributed.
 - What do you notice about the muscles of these cattle?
 - How could you organize them?

12. Work with your class to define “trait” and “variation” and find examples of those in the cattle you are observing.

Observe differences in tulips.

With your group



13. Look at the photos of tulips your teacher has given your group. Choose a trait these tulips have and then organize the photos by the variations of that trait. If you have time, reorganize the tulips by variations in another trait.

In your notebook



14. Record in your notebook the trait(s) and variations you see.

Share observations as a whole group.

With your class



15. Discuss the following questions with your class:

- What were some traits and variations you saw?
- What can you say about the amount of variation you saw?

Where have you seen something else like this?

In your notebook



16. Add a “Related Phenomena” page to your science notebook and jot down other experiences you have had that relate to what we have observed so far. Use this question to guide your brainstorming: *What other examples have you seen of living things that are basically similar but have different variations in a characteristic or trait?*

Home Learning

Home Learning



17. Go into your community and find a type of organism that has differences between individuals in some characteristic or trait. Look for two (or more) of that type of organism to show variations. Share what you found by
- taking pictures or video of the differences and bringing the pictures to class,
 - drawing the differences you notice, and/or
 - writing about the organism in your notebook or on scratch paper and bringing the paper to class.

Share related phenomena.

With your class



18. We will list our related phenomena on a chart to refer to later. While you listen to others' ideas, be thinking about these questions:

- Which examples stand out to you the most? (Why?)
- Which examples had you never encountered before?

What questions do you have?

On your own



19. Write any questions you have that relate to what we have observed so far—one question per sticky note. Write in marker—big and bold. Put your initials in pencil on the back. To help you brainstorm your questions, look back at these resources:

- your Notice and Wonder chart
- your initial model
- our chart of related phenomena
- the class's consensus model

Driving Question Board (DQB)

Scientists Circle



20. Bring your sticky notes with questions to our Scientists Circle, along with your science notebook. Work with your class to build your Driving Question Board.

Develop ideas for investigations.

In your notebook



21. What kinds of investigations could we do and/or what additional sources of data might we need to figure out the answers to our questions? Add your ideas to a new notebook page titled "Ideas for Future Investigations and Data We Need".

With a partner



22. Share your ideas with a partner. Be prepared to share these ideas with the whole class.

Share ideas for investigations.

With your class



23. Share ideas for investigations with the whole class, using these questions as a guide:

- What do you think we can do to investigate some of our questions?
- What data will we need to find or collect to answer our questions?

Lesson 2: How do extra-big muscles compare to typical ones up close?

Navigation

With your class



1. If we were to zoom in to look at extra-big muscles versus typical muscles, how would this type of investigation help us make progress on our questions on our Driving Question Board?

Observe muscles.

Turn and talk



2. With a neighbor, observe images on the slide of different magnifications of muscle tissue that came from a human donor.
 - low magnification
 - medium magnification
 - high magnification
3. How would you describe these muscles?

Let's look closer at muscles.

With your class



4. With your class, observe a video that looks closer at muscles during contraction.
 - Watch for information in the video that connects to something you predicted, that we already discussed, or that is new to you.
 - Fill in the "Video animation" column of part 1 on your *Muscle Protein Questions* handout.

Summarize the main ideas.

With your class



5. As you share your ideas with your class, refer to specific details in the video so everyone understands your thinking.
 - What did you see or hear in the video that you expected or that was familiar?
 - What did you see or hear in the video that was new or surprising to you?
 - Summarize: What is inside muscles? How do they move?

Muscle Protein Images

On your own



6. Read the *How Muscles Contract* article and study the images, then fill out the last column in part 1 of *Muscle Protein Questions*.
7. Watch the video again, then answer the questions in parts 2 and 3 of *Muscle Protein Questions*.

How important are proteins?

With your class



8. Look at the graph on the slide your teacher has displayed.
 - What ideas about protein do you have from looking at this graph?

How do these structures help muscles function?

With your class



9. Discuss the different muscle structures you saw in the video and article. How do these structures help muscles function?
 - muscle cells
 - protein
 - actin protein
 - myosin protein

Progress Tracker: What have you figured out?

In your notebook



10. Create a T-chart under the heading “Progress Tracker.”
 - Keep track of the important discoveries you make during this unit.
 - Write the question we are working on in the left column: “What do muscles look like up close?”
 - Write what you have figured out so far in the column on the right. You can use pictures and/or words. Take as much space as you need to record your thoughts.

Gallery Walk

In your notebook



11. Create in your science notebook a chart like the one on the slide.
12. Participate in a gallery walk.
 - Consider the question, “How do big muscles compare to typical ones?”
 - Take notes in the chart you created as you observe each of the four sources of information.

Building Understandings Discussion

With your class



13. Discuss the following questions with your class:

- What did you discover about how the cells of the extra-muscled animals compare to typical animals' muscle cells?
- What evidence did you find to support your ideas?

How do extra-big muscle cells compare to typical ones?

On your own



14. Complete the handout to revise your model and show what you figured out today.

Navigation

With your class



15. Discuss the following questions with your class:

- What question(s) are you still wondering about?
- Where do you think the matter could be coming from to build these extra-big muscles?
- What should we investigate next to keep figuring out why the cattle got these extra-big muscles?

Lesson 3: How do diet and exercise affect muscle size?

Navigation

With your class



1. Discuss the following prompts with your classmates.
 - Who remembers where we ended last time?
 - What did we find out is different between the extra-big muscles and the typical ones?
 - What questions do you have about the muscle differences between the bigger muscles and the typical ones?

How do you think people build bigger muscles?

Turn and talk



2. Discuss the following prompt with a partner:
 - Do you have any personal experiences with increasing your own muscle mass? Or have you heard how others have built bigger muscles?

With your class



3. Share with the rest of the class the ideas you talked about with your partner.

What do you notice about these athletes who race wheelchairs?

With your class



4. Share with your class your observations of the athletes.

Before You Read

Before we take a look at this article, let's think about our purpose as readers. We have practiced reading informational texts before, so what should we be looking for to see if a source is credible?

With your class



5. Think about the following questions and share your ideas with the class.
 - What should we be looking for to see if a source is credible?
 - What else do we need to pay attention to as we read?

While You Read

On your own



6. Look for the items the class listed as you read to help determine if you are using a credible source. Additionally, pay attention to the following information:
 - central ideas or claims
 - whether the claim makes sense with our ideas about muscle growth
 - evidence supporting the author's claim
 - sources the author cites
 - the goal of the text
 - methods the author used to study or test their ideas

Determining the Author's Purpose

With your class



7. Think about what you have read so far. Why would someone write this particular article? Be prepared to share your ideas with the class.

Whole-Group Discussion

With your class



8. Discuss with the class the cause-and-effect relationship between protein in food, exercise, and muscle growth.
9. Discuss with the class how diet and exercise play a role in muscle growth. Consider the following questions and be prepared to share your ideas with the class.
 - How much does each factor (protein and exercise) influence muscle building?
 - How could we figure out how important protein is for muscle growth?
 - How could we figure out how important exercise is for muscle growth?

As You Read

On your own



10. As you read your article, mark the text to keep track of your thinking related to the checklist that helps us determine credible sources.

After You Read

With your class



11. Share your ideas about the following prompts.

- Were your articles from credible sources? How could you tell?
- Team Protein, what did your article say about the cause-and-effect relationship between protein in food and muscles?

Building Understandings Discussion

With your class



12. Discuss the following question with your class.

- Team Exercise, what did your article say about the cause-and effect relationship between exercise and muscles?
- How do protein and exercise work together to build muscle?

Professional Tennis Players' Muscles

With your class



13. Examine the photos of professional tennis players that your teacher has displayed.

- What do you notice about the muscles of these tennis players?
- How do these images support what we just figured out about the roles of diet and exercise on muscle growth?

Can we apply what we figured out to cattle?

With your class



14. Consider the following question and prepare to share your ideas with the class:

- What could we look for in images of cattle muscle tissue and human muscle tissue to see if they are similar, that they might work in similar ways?

How do human muscles compare to cattle muscles?

Turn and talk



15. Turn and talk with a partner about the similarities (and any differences) you see between the images of human muscles and cattle muscles shown on the slide.

With your class



16. Share with the class the ideas you discussed with your partner.

Can we apply what we figured out to cattle?

Examine the evidence your teacher has presented on the slide.

With your class



17. Discuss the following question with your class:

- Do we agree that human muscle tissue and cattle muscle tissue are similar enough that we can apply to cattle what we have figured out about diet and exercise in humans?

What have you figured out?

On your own



18. Answer the following questions on your exit ticket:

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

Lesson 4: What is different about the food and exercise for cattle with extra-big muscles?

Consensus Discussion to Update our Model

Scientists Circle



1. Move into a Scientists Circle around the classroom consensus model.
2. Be prepared to share ideas from the last class as we update the classroom consensus model.

Update Progress Tracker.

In your notebook



3. Add to the Progress Tracker in your science notebook what we have figured out so far.

Apply our model to the cattle.

With a partner



4. Discuss the following question with a partner:
 - What does our model predict the cattle should be doing in order to get the extra-big muscles?

Ask a farmer.

In your notebook



5. Make a T-chart in your science notebook to record your noticings and wonderings as you prepare to listen to the interview.
6. As you listen, record any important information in your T-chart.
7. Place a star next to the two most important ideas you heard during the interview.
 - Be prepared to share your thoughts with the whole class.

Scientists Circle



8. Share with the rest of the class the important ideas you recorded.

Cattle Feed Nutritional Information

In your notebook



9. Examine the slide and prepare to share what you notice.
10. If it is helpful, you can record in the T-chart in your science notebook notes about the amount of protein in these foods.
 - Be prepared to share your thinking with the whole class.



11. Share with the rest of the class the important ideas you recorded.

Interview with a Cattle Farmer

In your notebook



12. Listen to the audio recording of an interview with a cattle farmer discussing the diet of these extra-big cattle.

13. Record what you notice and wonder in the T-chart you started earlier.

- Be prepared to share your thinking with the whole class.

Scientists Circle



14. Share with the rest of the class the important ideas you recorded.

Observe baby calves.

In your notebook



15. Add a new T-chart in your science notebook and record your noticings and wonderings as we observe baby calves.

- Be prepared to share your thinking with the whole class.

Scientists Circle



16. Share with the rest of the class the important ideas you recorded.

Navigation

Turn and talk



17. Turn and talk with a partner about the following questions:

- Why are some baby cattle born with big muscles and others are not?
- Where do such differences in babies come from?

Lesson 5: Where do the babies with extra-big muscles get that trait variation?

Navigation

With your class



1. Discuss the following questions with your whole class:
 - Why are some baby cattle born with big muscles and others are not?
 - Where do the babies with big muscles get that trait variation?

Develop symbols to describe the musculature in cattle.

With your class



2. Work with your class to discuss how to identify and describe the musculature of the cattle and develop symbols that you can use to easily show those descriptions. Also plan symbols to identify the sex of the cattle.

Consider how to identify phenotypes.

With your class



3. Work with your class to define the three phenotypes of cattle musculature and practice identifying them.

Prepare to collect observations of cattle families.

In your notebook



4. Add the family organizer to your science notebook and title it according to the name of the target offspring for the family you were assigned. Add a key to show the symbols your class agreed to use.

Build family trees using cattle family photos.

With your group



5. Collaborate with your group to organize your pedigree and to decide which symbols each animal should have with regard to sex and muscle phenotype.
 - Record these data on the graphic organizer in your science notebook.

What patterns did we see in families?

With your class



6. Share about your pedigree with your class:
 - What patterns did you see between parents and offspring?

- Were those patterns the same in each generation of a family?
- How could you describe a general pattern about where offspring get the phenotype of being heavily muscled?

Build a model to show family relationship.

With your group



7. Work with your group to add more symbols to your graphic organizer to show these parent-offspring relationships so it is clear who are the parents for whom.

Make predictions using the patterns seen in families.

With your class



8. Let's check our thinking. Look at the pedigrees displayed on the slide and decide: Would you expect to find these relationships within cattle families?

How does the trait get passed on?

With your class



9. With your class, discuss these questions:
 - What do parents do to pass on their trait variations?
 - What actually happens in that process?

Investigate what is inside egg and sperm cells.

Scientists can test to determine the composition of different cells. Here is a list of components found in egg and sperm cells as well as muscle cells.

- Muscle cells: glucose, water, and these proteins: tubulin, histones, actin, and myosin
- Egg cells: glucose, water, and these proteins: tubulin, histones, albumin, and lysin receptors
- Sperm cells: glucose, water, and these proteins: tubulin, histones, spermosin, and lysin

In your notebook



10. Add what you notice and wonder to a chart in your science notebook.

Zoom in - look at egg and sperm cells under a microscope.

In your notebook



- 11.** The images on the slide show what you would see if you used a microscope to zoom way in on egg and sperm cells. Add what you notice and wonder to your chart in your science notebook.

Zoom in - look at egg and sperm cells under a microscope.

In your notebook



- 12.** 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. Add what you notice and wonder to your chart in your science notebook.

Predict what muscle cells look like at the same scale.

Turn and talk



- 13.** Turn and talk with a partner about this question:
- If we zoomed in on one of Lorenc's muscle cells, what would we see?

Test predictions about chromosomes number.

With your class



- 14.** As a whole class, discuss these questions:
- Are you able to test your predictions using this view of the nucleus of one of Lorenc's muscle cells?
 - What are some ways that might help you investigate this better?

Describe patterns in the karyotype.

With a partner



- 15.** Work with your partner to examine the chromosomes using these directions:
- Turn the sperm and egg cells page to portrait layout. Place it beside the karyotype so you can examine both.
 - Label the cells on your page with "sperm" and "egg".
 - You can move the pages around as you work if it helps you.
 - Examine the karyotype showing the chromosomes in Lorenc's muscle cell.
 - Compare the chromosomes to those you find in Sparkle's egg cell and Jim's sperm cell.

- Make note of any similarities and differences and keep track of where the chromosomes are located by highlighting, circling, labeling, listing patterns, and so forth.

Discuss what we discovered.

With your class



16. As a whole class, discuss these questions:

- What patterns did you see? How are these chromosomes organized?
- Do you have any new questions about these chromosomes?
- What new questions does this raise for us?

Use patterns to predict chromosome numbers in more cells.

With your class



17. Make predictions based on what we figured out so far about chromosomes.

In your notebook



18. Update your pedigree graphic organizer one more time.

Update Progress Tracker: What have you figured out?

In your notebook



19. Add an entry in your Progress Tracker. You can use pictures and/or words. Take as much space as you need to record your thoughts.

Question	What I figured out in words and/or pictures
Where do babies with the extra-big muscles get that trait variation?	

Navigation

With your class



20. Discuss the following as a class:

- Let's explain step by step how calves with extra-big muscles get that trait variation.
- What did the patterns we saw tell us about where the babies with extra-big muscles get their muscles from?
- What new questions does this raise for us?

Lesson 6: How do chromosomes cause cattle to be born with extra-big muscles?

Where are we going today?

With your class



1. Discuss the following questions with your class:
 - What did we figure out last time about chromosomes?
 - What are we trying to figure out today?

What are chromosomes made of?

With your class



2. Compare the different chromosome images on the slides.
3. Share your initial ideas in the class discussion.

Visualize similarities and differences.

With your class



4. View an image of chromosome pair 2 from one individual cow. Colors were added to show where three corresponding dark bands are found on each chromosome in this pair.
 - What additional patterns does this visualization help us see in these chromosomes?
5. Symbols were added to help keep track of these patterns.
 - What do the colors represent?
 - What do the shapes represent?

Symbols can help us compare.

Since we want to compare several different sets of chromosomes to look for patterns, let's plan on using colors and symbols to represent the structures of the different chromosomes, rather than the images of the chromosomes themselves.

With your class



6. Work with your class to remind ourselves what these lines, colors, and symbols represent.

How could more information help us?

With your class



7. Share with your class how looking at more cattle's chromosomes could help the class understand how chromosome structures could be related to heavily muscled cattle.

Look at proteins.

With your class



8. Reflect on the images of the proteins actin and myosin from Lesson 2.
 - What do actin and myosin do?
 - What are they made of?
 - How does their structure help them do their job?
9. Consider these questions as you view a simulation to compare the sizes of chromosomes and the proteins, antibody, and hemoglobin.
 - Are chromosomes bigger or smaller than proteins?
 - How would you describe the sizes of proteins and chromosomes to a friend?

A New Protein

With your class



10. Look at and compare the images of two versions of the protein myostatin your teacher has displayed.

Prepare to look for patterns.

With your class



11. Work as a class to identify the goal when comparing the chromosome and protein data while looking at the cattle information cards. Discuss ways the class should organize this information to make sense of it.

Group cattle by musculature.

In your notebook



12. Look at the cattle photo you have and record the animal's phenotype on #1 of *Guiding Questions for Chromosome and Protein Data*.

With your group



13. Relocate yourself in the classroom with other people who have cattle of the same phenotype.
 - Work with your group to find patterns in the chromosome symbols for your cattle. Record these patterns on #2 on *Guiding Questions for Chromosome and Protein Data*.
14. Relocate yourself in the classroom with other people who have cattle with the same versions of myostatin as yours.
 - Work with your group to find patterns in the cattle and record them on #3 on *Guiding Questions for Chromosome and Protein Data*.

Identify patterns.

With your group



15. Work with your group to answer the remaining questions on *Guiding Questions for Chromosome and Protein Data*.

Small Group Initial Model

With your group



16. Develop an initial model with your group to show the relationships among the following:
 - chromosome information
 - proteins
 - the cattle's muscle phenotype

Silent Gallery Walk

In your notebook



17. Make a T-chart in your science notebook where you can record similarities and differences.
18. Look around at the initial models the groups created. Record what they have in common and what is different among them.

Develop a consensus model.

Scientists Circle



19. Work together as a class to come to consensus about the relationships among the following:
 - chromosome information
 - proteins
 - the cattle's muscle phenotype

How could we investigate a cause-effect relationship?

Turn and talk



20. Turn and talk with a partner to predict the cause-effect relationship(s) we will observe if each of the following statements in the chart is true.

			Change to the system (<u>cause</u>)		The <u>effect</u> on the system
If	the chromosomes cause the muscles	then when we ...		we will observe	
If	the chromosomes cause the protein	then when we ...		we will observe	
If	the muscles cause the protein	then when we ...		we will observe	
If	the proteins cause the muscles	then when we ...		we will observe	

Is there support for a cause-effect relationship?

In your notebook



21. Read and annotate your article to look for and identify evidence of cause-effect relationships. Obtain information and evaluate the text by paying attention to the following:

- central ideas or claims
- questions you have about the text
- whether the claim makes sense with our ideas
- evidence supporting the authors' claim
- sources the authors cite
- methods the authors used to test their ideas

With a partner



22. Share with your partner your evaluation of the text and some of the new information you obtained.

- Did the authors have evidence to support their claims?
- Did they cite reliable sources and/ or their own scientific tests?
- Did you find any new words while you read?
- Did you have any questions about the text?

23. Discuss with your partner evidence of cause-effect relationships.

	Change (cause)		Effect on the system
When ...		we/they observed	
When ...		we/they observed	

Consensus Discussion

Scientists Circle



24. Bring your copy of *Version 1: New Protein Linked to the Heavily Muscled Phenotype* or *Version 1: Function of the Myostatin Protein* and gather in a Scientist Circle to have a Consensus Discussion about what we figured out.

- What new words did we just see in these texts?
- What evidence did we find for cause-effect relationships?
 - When _(change)_, we/they observed _(effect on the system)_.
- How was using both articles important for finding evidence to support cause-effect relationships?

Genetic Modification for and Naturally Occurring Heavily Muscled Animals

With your class



25. In addition to mice, the genes of all these animals have been changed by scientists to produce extra-big muscles. With your class, observe images on the slides of more animals that also have extra-big muscles:

- rabbits
- pigs
- fish
- goats

26. In addition to cattle, sheep and dogs have been found to have extra-big muscles without scientists changing their genes. With your class, observe images on the slides of these animals that also have extra-big muscles.

Progress Tracker: What have you figured out?

In your notebook



27. Draw a line under your last Progress Tracker entry to add today's thinking.

- Keep track of the important discoveries you make during this unit.
- Write in the left column the question we are working on:
 - How do chromosomes cause cattle to be born with extra-big muscles?
- Write in the column on the right what you have figured out so far. Use pictures and/or words. Take as much space as you need to record your thoughts.

Lesson 7: How does an animal get extra-big muscles?

Revisit our classroom consensus model.

With your class



1. Discuss with your class: How can we update our classroom consensus model to show what we have figured out recently?

Brainstorm components for our Gotta-Have-It Checklist.

With a partner



2. With a partner, think about the components and interactions we need in our model to answer this question: How can an animal's musculature be influenced by its phenotype?
3. Record your ideas in the first column on your handout *Gotta-Have-It Checklist*.

Build on to our classroom consensus model.

Scientists Circle



4. Work with your class to add to the classroom consensus model to show what we have figured out.
 - What components and interactions are important to helping us understand how an animal's musculature can be influenced by its genotype?
 - What components have we learned about recently? How are they related?
 - How should we arrange or organize the components we will need in our model?
 - How can we model our ideas about what causes both the heavily muscled and typically muscled phenotypes?

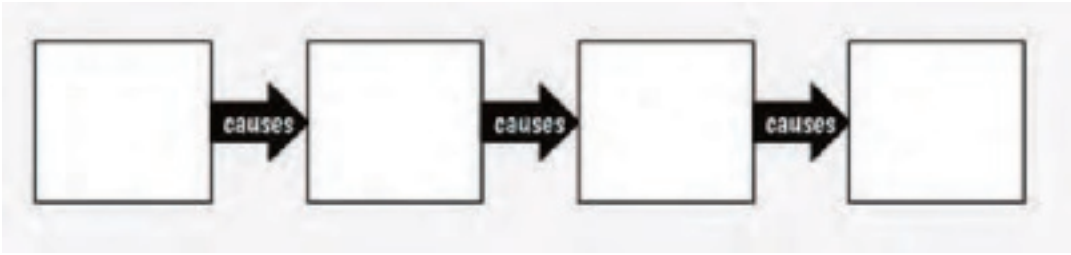
Consider the scales of our classroom consensus model.

Scientists Circle



5. Discuss with your class:
 - What scales are represented in this model we have been developing?
 - Recall the organization of an organism you figured out from the *Inside Our Bodies Unit*: organism = system > subsystem > organ > tissue > cell.
 - What other scales do we need to add to this list to align it with our current model?

A Cause-and-Effect Chain



Scientists Circle



6. Recall the cause-and-effect chain graphic that you used in the *OpenSciEd Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)*, similar to the one shown here. What do we need to change about this cause-effect chain graphic so we can use it to explain the relationships that lead to the phenotype we see?

Update Progress Tracker and Gotta-Have-It Checklist.

In your notebook



7. Work with a partner to capture today’s work in a 3-box Progress Tracker entry.
8. Update your Gotta-Have-It Checklist to include all the components we discussed.

Question	Sources of evidence
How does an animal get extra-big muscles?	
What I figured out in words and/or pictures	

Revise your initial model.

On your own



9. Look back at your initial model. Reflect on how your thinking has changed based on what we have figured out.
10. Create a revised version of your initial model (for an animal other than cattle) to explain how an individual’s phenotype is influenced by its genotype. Use your Progress Tracker and Gotta-Have-It Checklist to make sure you are not missing anything from your model.

Predict the phenotype of a sibling.

With a partner



11. Look back at our classroom consensus model. Your teacher will assign you an individual (heavily, medium-, or typically muscled).
 - In your notebook, work with your partner to use our model to predict: What phenotype would a sibling of your individual have?
 - Be ready to share your prediction with others.

Share the prediction from your model.

With a partner



12. Stand Up, Hand Up, Pair Up around the room to switch partners.
 - Use the model you sketched in your notebook to share your prediction with your partner: What phenotype would a sibling of your individual have?
 - Be ready to share your thinking with the class.

What phenotypes did we predict siblings would have?

With your class



13. Share and discuss the prediction you made based on your model: What phenotype would a sibling of your individual have?

Observing siblings.

With your class



14. Look at the photos your teacher shows of a cow named Fiona and her siblings. Individually observe their phenotypes.
15. Share your observations with the class.

Navigation

With your class



16. Discuss with your class: What could be the problem with our model? How could it be that animals who have the same parents end up with different phenotypes?

Lesson 8: Why don't offspring always look like their parents or their siblings?

Navigation

With your class



1. Think about the questions we were wondering about in the last class.

Decide how to investigate.

Turn and talk



2. Look back in your notebook to find ways we could investigate patterns in families.
3. Share your ideas with an elbow partner about how we should investigate our questions.
4. Share your partner's ideas with the class about how we should investigate our questions.

With your class



Organize family cards.

With your group



5. Get together with your group and organize the cards for your family into a pedigree.
6. Review what all the symbols mean.
7. Think about how we could use this information to answer the questions we have about why all offspring do not look like their parents or exactly like each other.

Ground our ideas about genotype symbols.

With your class



8. Observe the images your teacher shares on the slides to remind yourself what all the symbols represent.

Simplify family pedigrees.

In your notebook



9. Get a copy of *Traditional Pedigree Graphic Organizer*, fold it in half, and attach it in your notebook. Add a title that corresponds to the family you are studying and the trait we are studying.
10. Add circles and squares as needed to the bottom row of your family's pedigree.
11. Fill in the correct phenotypes for the individuals in your family.
12. Create a key for the pedigree.
13. Record each individual's genotype using "E" and "e".
14. Create a Notice and Wonder chart on the next page in your notebook. Make notes in the chart as you record the information in your pedigree.
15. Look for patterns between parents and offspring or between siblings in the same family. Finish adding to your Notice and Wonder chart.

Make sense of patterns in pedigree.

Turn and talk



16. Share with a partner at least one key idea and one question from your Notice and Wonder chart.

With your class



17. Share with your class your ideas about these questions.
 - What patterns did you see between parents and offspring?
 - What patterns did you see between siblings?
 - Have we answered our questions completely yet about why parents and offspring do not always look the same or why siblings do not always look the same?
 - What else do we need to know to answer these questions?

Collect more data from pedigree.

With your group



18. Collaborate with your group members to count up the number of offspring with different phenotype variations from several different cow/bull crosses taken from herd books.
19. Collaborate with your group members to calculate the proportion of offspring with different phenotypes for each type of cow/bull cross.

Turn and talk



20. As you share with a partner, discuss these questions:

- What patterns do you see in the proportions for different crosses?
- Do these patterns match what we saw with our cattle families?
- What questions do we still need to answer?

21. Share your ideas with the class.

Connect back to egg and sperm.

Turn and talk



22. Look back through your notebook and discuss these questions with your partner:

- Where did these offspring get the *E* or *e* alleles?
- Is it possible that a parent could pass on different alleles to their individual offspring?
- How would that happen?

23. Make some notes in your notebook about how you think that might happen so you can share your ideas during the next class period.

Trace what happens to alleles at different scales.

With your class



24. Observe the images your teacher shares on the slides.

25. Help your classmates explain what is represented on each slide and what is happening to the alleles that are getting passed on to individual offspring.

26. Discuss these questions:

- What happens to alleles during fertilization?
- How is it determined which sperm combines with which egg?

Prepare to collect data from breeding pairs.

With a partner



27. Rejoin your small group and split into pairs.

28. Set up your notebook:

- Use the genotypes of the individuals you were assigned to create a title.
- Record the alleles in the eggs and the sperm.
- Create a table to collect data about 10 offspring.
- Include space to record both the genotype and phenotype of each resulting offspring.

29. Set up your “coins” by writing one allele on tape on each side.
30. Make a plan for generating and collecting data.
31. Conduct your investigation and record your data.

Use mathematical thinking to simplify predictions.

With your class



32. Discuss how we might be able to use mathematical thinking to help us predict the outcome of different crosses.
33. Work through the steps we are using to determine probabilities.

Identify the algorithm.

Turn and talk



34. Identify the algorithm, by listing the steps in order, we can use to determine the probabilities of the genotypes of the offspring of two parents.

Figure out probabilities using a visual representation.

With your class



35. Work through an algorithm that uses a Punnett square to determine probabilities.

Practice making predictions.

In your notebook



36. In your science notebook, use a Punnett square or the probability calculations to make predictions about the probability of the following crosses:

- $EE \times ee$
- $Ee \times Ee$

Be sure to show all your work.

37. Complete and turn in your exit ticket.

Where do farmers get these cattle?

With your class



38. Think about where heavily muscled cattle come from.
39. Listen to your teacher’s description of where the allele for extra-big muscles came from.

Turn and talk



40. Discuss these questions with your partner:

- What do you think a mutation in a gene does to the protein that gene makes?
- Do you think mutations are common or rare? Why?

With your class



41. Use the table on the slide to determine how common mutations are.

Revisit the Driving Question Board.

With your class



42. Using what we have learned, can we rephrase any of our DQB questions as questions about alleles?

43. Add any new questions to the DQB.

Navigation

With your class



44. How do you think farmers use this information to get the kind of cattle they want?

Lesson 9: How do farmers control the variation in their animals?

Predictions

Turn and talk



1. Discuss with your partner: What are the farmers doing to make sure certain parents get crossed?

Read articles about selective breeding cattle.

In your notebook



2. You will read three different articles about selective breeding in cattle. Jot notes in your science notebook about what you read as you compare and evaluate the three articles.

Building Understandings Discussion

With your class



3. Discuss the following questions with your class and develop a whole-group record of what we agree on about the information presented in the articles.
 - What was similar among the articles?
 - What was different among the articles?
 - Are the conclusions in the articles valid based on what we already know?
 - What can we say about the validity of the articles?

Brainstorm

Turn and talk



4. Discuss with your partner:
 - What are other types of organisms you think people may have tried to selectively breed besides cattle?
 - Do people selectively breed organisms other than animals?

Predictions

Turn and talk



5. The simulation we use next time will give you a chance to selectively breed virtual birds. Discuss with your partner:
 - If we are breeding birds to see if we can get certain desired traits, what kinds of things would we want to keep track of in our simulation as we do breeding?

Plan our investigation.

On your own



6. Open the Bird Breeder simulation. Read the directions and explore the simulation for a few minutes.
7. Pause to discuss with the class how to determine the initial distributions in the starting population.
8. Conduct your investigation with the simulation, then record your results and answer the questions on your handout.

Building Understandings Discussion

With your class



7. Discuss your discoveries with your class:
 - What sorts of strategies did you use in the simulation?
 - How could people use these same strategies to change the characteristics over time of any sexually reproducing organism?
 - In the simulation and readings, there were traits that we selected for and traits that we did not want to select for. What are some variations of traits you think breeders try to avoid in our pets?

Update Progress Tracker.

In your notebook



8. Add to your notebook:
 - Keep track of the important discoveries you make during this unit.
 - Write in the left column this question we are working on:
 - How do farmers influence the trait variations of their animals?
 - Write in the column on the right what you have figured out so far. You can use pictures and/or words. Take as much space as you need to record your thoughts.

Lesson 10: How can we use our model to explain a different trait variation?

Navigation

Turn and talk



1. Turn and talk with a neighbor: What did we figure out in our last class?
2. Share your thinking with the whole class.

Explain what causes goldfish colors.

On your own



3. Complete the assessment about goldfish breeding.

Navigation

With your class



4. Next time, we will revisit our DQB to
 - celebrate what we have figured out so far and
 - decide where to go next based on the questions we still have.

Lesson 11: How can we answer the rest of our questions?

Navigation

With your class



1. Recall where we left off last time.

Evaluate our DQB questions.

On your own



2. Evaluate which questions you think we have answered on our DQB. Record any additional questions you have. Use these symbols:

- We did not answer this question or any parts of it yet: ○
- Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
- Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓ +

With a partner



3. Take turns sharing answers to the DQB questions you checked off your list. Be sure to use evidence from our investigations so far to support your answers.

What questions have we answered?

With your class



4. Do the following with your class:
 - Share a question you think we can now answer and briefly tell your response.
 - If the class agrees that we have answered it, move it to a Questions We Have Answered poster.
 - Add any new questions we have to the DQB.

What trait seems to be showing variation?

With your class



5. Observe photographs of other organisms with your class. For each organism, identify a trait that is showing variation.
 - planaria
 - strawberries
 - wheat kernels
 - flamingos
 - humans
 - apples

What are possible categories of these variations?

With your class



6. Observe the photographs again and share with the class how we could categorize examples of each organism by their variations.

Sort organisms by phenotype.

With your group



7. Gather with your group.
 - Sort or organize your photos into categories based on the phenotypes we expected.
 - When you are finished, leave your cards organized on your workspace for others to observe.

Gallery Walk

With your group



8. Circulate around the room to see how other groups sorted or organized their trait variation examples.
 - Do you notice any similarities or differences in how the phenotypes are arranged?

Initial Ideas Discussion

Scientists Circle



9. Discuss the following question with your class:
 - What did you notice about sorting your organisms into categories of types of variation?

Collect new questions.

Turn and talk



10. Discuss the following questions with your partner.

- What are you wondering about these organisms and traits?
- What would we have to know in order to decide if our model could explain these other variations?

Scientists Circle



11. Post new questions to investigate onto our classroom consensus model or DQB.

Compare these organisms' traits to cattle muscles.

Scientists Circle



- 12.** Construct a chart to compare these organisms and help us decide what to investigate next.

Navigation

Scientists Circle



- 13.** Which organism and trait do you think is the most different from cattle musculature?

Lesson 12: Do plants have genetic material?

Navigation

At the end of last class we were thinking about whether we thought plants had genetic material like we saw in animals.

Turn and talk



1. Turn and talk with a partner, then share your ideas with your class.
 - What did we decide we should investigate, and why?

Initial Ideas Discussion About Chromosome Location

With your class



2. Your teacher will draw your ideas on the board as you talk about the following question as a class.
 - Where are chromosomes found inside living things?

Brainstorm ideas about how to get at genetic material.

Turn and talk



3. Turn and talk with a partner, then share your ideas with your class.
 - If we want to get at the chromosomes inside the nuclei of cells, what kinds of things might we have to do?
 - Think of the **scale** of chromosomes. What might we have to do to visualize them?

Observe and discuss extraction of genetic material.

In your notebook



4. Prepare to record your observations:
 - Create a data table in your science notebook with the title "Characteristics of Extracted Material".
 - Label columns with "fish eggs", "fish muscle", and "beef muscle".
 - Watch the video. Record your observations.

Turn and talk



5. Turn and talk with a partner, then share your ideas with your class.
 - Does this investigation do the things we thought needed to be done to pull out or "extract" the genetic material from cells?
 - Do you think we might be able to use this same procedure for our investigation of plant cells?
 - If so, what would we change to test the question we are interested in?

Analyze substances to extract genetic material.

With a partner



6. Look through the substances scientists use and talk about the following:
 - Could we use these same substances in our class?
 - What questions do you have about these substances?

Think about what makes up different cells.

Turn and talk



7. Turn and talk with a partner, then share your ideas with your class.
 - How can we be sure the material that was isolated is actually genetic material and not just a reaction among the soap, salt, and alcohol?

Prepare to test the protocol on other substances.

In your notebook



8. Prepare to record your observations:
 - Add two more columns to your existing data table.
 - Label these columns with “water” and “protein drink”.

Think about what makes up different cells.

Turn and talk



9. Turn and talk with a partner, then share your ideas with your class.
 - If this protocol is truly isolating genetic material and is not just creating a reaction that results in a similar substance, what do you expect to see when we use this protocol on this sample of water or protein drink?
10. Now observe your teacher carry out the protocol for water and protein drink.

Prepare to test the protocol on plant tissue.

In your notebook



11. Prepare to record your observations:
 - Add one more column to your existing data table.
 - Label this column “plant tissue”.
 - Follow the protocol to complete the investigation.
 - Record your observations.

Prepare to test plant tissue.

Writing in Science



12. In your notebook:

- Write down our question: Do plant cells have genetic material like animal cells do?
- Make a prediction: Will your sample contain genetic material? Why or why not?
- Record your predictions on the handout.

Create a hypothesis.

On your own



13. Use the following format to create and record your hypothesis on *Lab v1: Extracting Genetic Material*.

- If _____,
- then when we _____,
- we will observe _____.

Carry out the protocol.

With your group



14. Work with you group to do the following:

- Create a table to record your observations.
- Work with your group on your experiment.
- When you are finished, record your data in the class data table too.

Safety Guidelines

Safety Precautions



15. Follow these Safety Guidelines as you carry out your investigation:

- Wear safety goggles, nitrile gloves, and an apron during setup, investigation, and cleanup.
- Secure loose clothing, remove loose jewelry, tie back long hair, and wear close-toed shoes.
- Avoid touching your face (so substances do not get near your nose or mouth). Never taste any substance in the lab.
- Move carefully so that we do not spill anything. Immediately wipe up any spills that do happen.
- Follow instructions for cleanup and wash your hands with soap and water after cleanup is complete.
- Use caution when working with heated liquids—they can burn skin.

Discuss the results of the investigation.

Scientists Circle



16. Discuss your findings as a class. Refer to your collective data table as needed.

- What patterns do we see in our data?
- What have we figured out about the question we had for this lesson?
- Do the data we collected serve as evidence to support your hypothesis?

Make sense of your results.

On your own



17. Consider the following as you are responding to the prompts in part 4 of *Lab v1: Extracting Genetic Material*.

- Claim = explanation or theory (comes after the “if” clause in the hypothesis.)
- Evidence = When we changed the independent variable we observed the following pattern in the dependent variable.
- Reasoning = Explain why the evidence supports the claim.

Explore the length of genetic material.

Every human cell contains 6 feet of genetic material.

Scientists estimate that humans have 10 billion miles of genetic material inside of them.

Earth is about 93 million miles away from the Sun. So your genetic material could stretch to the Sun and back 54 times!

With your class



18. Discuss with your class.

- Why do you think our genetic material is so long?

Update Progress Tracker.

In your notebook



19. Create a new row in your Progress Tracker.

- Write the lesson question on the left: Do plant cells have genetic material like animal cells do?
- Write or draw in the column on the right what you have figured out so far. You can use pictures and/or words. Take as much space as you need to record your thoughts.

Lesson 13: How do plants reproduce?

Navigation

With your class



1. Review what we have learned and what we are wondering now.

In your notebook



2. Write the lesson question on the next blank page in your notebook.

Turn and Talk

Turn and talk



3. Share with your partner what you know about how plants reproduce and what their offspring are.
4. Get a lima bean seed from your teacher and follow the instructions on the slide to observe what is inside the seed.

Investigate seeds.

With your class



5. Look at the seeds in the fruits your teacher has prepared for you to see.
6. Watch a video about how seeds form on a pepper plant.

Turn and talk



7. Share your ideas about how flowers are involved in making seeds.

Prepare for flower dissection lab.

With a partner



8. Join the partner your teacher assigns you. Get the materials for the flower dissection lab.
9. Examine the flower you have been given and discuss these questions with your partner:
 - How would you describe the structures you see?
 - What do you think is the function of those structures?
 - Which of the structures do you think have to do with reproduction?
 - What questions do you have?

Flower Dissection Lab

With a partner



10. Get a copy of *Flower Diagram* and look over the diagram.
11. Follow the instructions on the slide to slowly and carefully dissect the flower and locate all the parts that are labeled on the diagram.
12. Arrange the structures neatly and attach them to the paper. Leave plenty of room to label and describe the structures.
13. Write on the paper to label the structures you have identified.
14. Now write next to each structure's label the name of what you think the human equivalent would be. Be prepared to explain why you think the flower structure is similar to that human part.
15. Work with your partner to describe what you think would need to happen in order for the flower to produce a seed. Be prepared to share your ideas with your class.

Describe the process of reproduction in a flower.

With your class



16. Share your ideas with your class.
17. Listen to others' ideas and your teacher's description of how the structures of a flower participate in producing a seed (reproduction).

Add to your Progress Tracker.

In your notebook



18. Turn to your Progress Tracker in your notebook.
 - Write the lesson number and the question we are working on in the left side.
 - Record your thinking in words and/or pictures on the right side.

Investigate tulip variations.

With your class



19. Look at the pictures of tulips on the slide your teacher is sharing.

Turn and talk



20. Talk with your partner to answer this question:
 - How do you think we got all these different kinds of petals on the tulips people can buy?

On your own



Turn and talk



21. Get a copy of the *Reading: How do we get new tulip variations?* handout.
22. Set a purpose for reading the article. Then read to answer your questions.
23. Talk with your partner to share what you learned in the reading and what you are wondering about.

Investigate plant breeding.

With your class



On your own



24. Share any questions you have about the reading.
25. Watch the video your teacher shows you.
26. Participate in a discussion about plant breeding.
27. Get a copy of the *Breeding Tulips* handout.
28. Complete the questions on the handout using one of the algorithms we use to determine offspring probabilities.
29. Share your answer to question 3 with your class.
30. Watch a video about how a strawberry farmer grows all those strawberry plants.

With your class



Explain how plants reproduce.

On your own



31. Answer the questions on the slide by making a few notes in your notebook.
32. After you have answers to all the questions, decide how you would explain the process of how plants reproduce to someone who does not know how it works.
33. Be prepared to share your explanation.

Give and receive feedback.

With a partner



34. Follow your teacher's instructions to give or receive feedback on your explanation from a partner. Then switch partners. (Be sure you get a chance to act as "explainer" with one of your partners and "responder" with your other partner.)
 - **Explainer**
 1. Explain the process of how plants reproduce sexually.
 2. Give an example of how plants reproduce asexually.

- **Responder**
 1. Listen carefully to the details of your partner's explanation.
 2. Give them constructive feedback about any details that were missing.
 3. Use these sentence starters:
 - a. I noticed you did not include . . .
 - b. Do you think _____ is important?
 - c. Can you explain more about . . .?

Exit Ticket

On your own



35. Complete the exit ticket and turn it in.

How do other organisms reproduce?

With your class



36. Participate in a discussion about how other organisms we have seen might reproduce and produce variations.

Lesson 14: (How) do other organisms reproduce without sperm and eggs?

Our Purpose for Today's Work

With your class



1. We can get genetic information out of living things that reproduce asexually (like strawberries). But how do asexual organisms pass on genetic information if they do not have sperm and eggs (or pollen and ovules)? In this lesson, you will work with a group to do research about an organism that reproduces asexually, and then you will communicate what you learned with your class in a quick (2-minute) presentation.

Obtain and evaluate information.

With your group



2. Recall how to obtain and evaluate information by paying attention to the following:
 - Central ideas or claims
 - Questions you have about the text
 - Whether the claim makes sense with our ideas
 - Evidence supporting the author's claim
 - Sources the author cites
 - Methods the author(s) used to test their ideas
3. You will find information online about how your group's organism reproduces, and you will need to evaluate whether the sources you have found are reliable.
4. If you trust your source, read that information in a way that helps you make sense of it. Usually we mark up the text to help us focus on our purpose for reading, but today you will have to use different strategies or tools to read closely and carefully on a screen.

Communicate information.

With your class



5. In this lesson you are going to communicate science information with others. Discuss the following questions with your class to help you plan your communication:
 - Who is your audience?
 - What is your purpose?

- What are the constraints for your communication?
- How will you communicate this information? Why have you chosen that method?

Example Slide: Strawberry

With your class



6. Your teacher will show you an example slide about how strawberries reproduce asexually to help you plan what and how you will share about your group's organism.

Organisms That Reproduce Asexually

With your group



7. Below is a list of organisms that reproduce asexually. Your group and your teacher will work together to decide which organism your group will research.
 - coral
 - planaria
 - aphids
 - potatoes
 - bananas
 - hydra
 - bacteria
 - marbled crayfish
 - spider plants
 - echeveria

Research and Presentation Expectations

With your group



8. Search online about how your assigned organism reproduces asexually. While you are researching,
 - evaluate your sources for reliability and
 - read for meaning: find main ideas and key details.
9. Create a slide to share with the class. Include the following on your slide:
 - name of the organism
 - picture of the organism
 - what it is and where it lives
 - how it reproduces without combining sperm and egg (or pollen and ovules)

Find patterns among asexual organisms.

With your class



- 10.** As each group shares, look for patterns about asexual reproduction. Record your ideas in your science notebook.

Obtain, Evaluate, and Communicate Information—Self-Assessment

On your own



- 11.** Independently reflect on how you obtained, evaluated, and communicated information for your group’s presentation by completing *Self-assessment for Obtaining, Evaluating, and Communicating Information*.

Building Understandings Discussion

With your class



- 12.** Discuss with your class what we have figured out about asexual reproduction.
- 13.** Your teacher will help you use a Punnett square to model what genotype offspring of asexual reproduction will have.

Progress Tracker: What have you figured out?

In your notebook



- 14.** Add a line under your last entry. Write today’s question in the left column. Take as much space as you need to record your thoughts about today’s work.

Question	What I figured out in words and/or pictures
14. How do asexual organisms pass on genetic information if they don’t have sperm and eggs?	

Treat living things with respect.

With your class



- 15.** Discuss with your class how to treat living things with respect.
- Be respectful and gentle.
 - Appreciate that these organisms are helping us learn.
 - Say “Wow” or “Interesting” or “Amazing” when reacting to what you see.

Observe planaria.

In your notebook



16. Record your responses to the following questions as you watch the planarian regeneration video.

- What do you notice when the planaria were growing back?
- Is there any new genetic information being introduced? Explain.
- Do the planaria all look the same at the end of the video?

Navigation

With your class



17. Discuss the following questions with your class:

- In what ways are these planaria similar and different from one another?
- What could be causing the differences?

Lesson 15: How do we get variations if the genetic information is exactly the same?

Navigation

With your class



1. Discuss the following questions with your class:
 - Who can restate our question from last class?
 - What ideas do you have about possible causes of the color variation we are seeing?

Gallery Walk: Planaria Data

In your notebook



2. Move around the room silently to read and view data about planaria.
3. Record key ideas in your notebook to answer the question: What caused the range of color variation in planaria?

Building Understandings Discussion

With your class



4. Discuss with your class: What did you figure out from integrating the information in text and images? What caused the color variation in the planaria?

Which might be influenced by environmental factors?

With your class



5. If we want to investigate another variation that is influenced by environmental factors, which of our organisms might be good to investigate next?
 - human arm span length
 - flamingo color
 - apple color
 - wheat kernel color

Predict environmental influences.

With your class



6. What environmental factors do you think could be influencing the range of color variation in apples and flamingos?

Read about apples and flamingos.

On your own



7. Read about the causes of color variation in flamingos and apples. Use strategies of your choice to make sense of the text and find key ideas.

Construct explanations.

With a partner



8. Work together to construct explanations using models.
 - Have one partner record your explanation for flamingo color and the other for apple color.
 - Be sure your explanations communicate the relationships involved: Use your model to explain the causes for the range of color variation we see, and then listen while your partner explains theirs.

Navigation

With your class



9. Discuss with your class: What do you predict is causing the variation we see in wheat kernel color and human arm span length?

Lesson 16: How much of trait variation in a population is controlled by genes or by the environment?

Navigation

Turn and talk



1. Discuss with a partner: What did you predict is causing the variation we see in wheat kernel color and human arm-span length? Why?

Discuss evidence needed to make predictions.

With your class



2. Look at the photo on the slide. Do you think these wheat kernels will be easy to categorize?

How can we sort or group the wheat kernels by color?

With your group



3. Sort or group the wheat photos by kernel color.
4. Respond to #1 on *Data Collection: Wheat Kernels*.
5. Share your ideas as a whole class.
6. Respond to #2-4 on the handout.

Make some predictions.

With your class



7. Discuss with your class: What do you expect the results of these crosses to look like if the wheat kernel color trait is controlled only by the environment? Only by genes?
 - Plant with cream-color kernels X plant with cream-color kernels
 - Plant with deepest red kernels X plant with deepest red kernels
 - Plant with deepest red kernels X plant with cream-color kernels

Analyze the investigation results.

On your own



8. Use the Identify and Interpret strategy (I²) strategy to create three WIS (What I See) and WIM (What It Means) statements about *Wheat Kernel Environmental Factors Investigation*.

With your group



9. Share your statements with the rest of your group to make sense of the results.

Make sense of the investigation.

With your class



10. Discuss the following questions with your class.

- What did you notice about the data set?
- Does this evidence support the idea that the environment influences this trait or the idea that the alleles influence this trait?

Make a prediction based on your claim.

With your class



11. Can we use what we learned about how to predict an offspring phenotype with cattle musculature to make a prediction about what alleles might be present in the plants that make medium-red wheat kernels?

Use a mathematical model to make predictions.

With your class



12. Work through an example cross between two plants that both have medium-red kernels.

- Start by determining what kind of sex cells each plant can make.
- Figure out the probability of each of those sperm and eggs having an *R* or *r* allele.
- Use a Punnett square and/or probability calculations to determine the probabilities that an offspring would produce medium-red kernels, deepest red kernels, and lightest cream-colored kernels.

Analyze the results of the investigation.

With your class



13. Compare your predicted outcomes to the actual results of that cross, as shown on the slide. Were these the results we predicted?

Obtain information about wheat kernel color.

On your own



14. Read *Color of Wheat Kernels*, highlighting important ideas so you are prepared to share them with the rest of the class.

Discuss the genetics of wheat kernel coloration.

With your class



15. Share what you learned with the class.
16. Discuss the histogram of wheat kernel color distribution.

Use what we learned to make predictions.

Turn and talk



17. Look on the slide at the chromosome images for two different plants.
Can you use what you learned to make a reasonable determination about which of these plants would produce kernels that are more red? Turn and talk with a partner about that.
18. Look at the slide that includes colored spots by the chromosomes to help you visualize the connection between the genotype and relative production of pigment. Which of these plants would produce kernels that are more red?

With your class



19. Discuss your predictions and reasoning with the class.
20. Make predictions for another example of two different plants.

Connect to our cattle musculature.

With your class



21. Discuss with your class: Do you think what we just learned about kernel coloration in wheat might impact how we could explain the variation in musculature we see in cattle?

Navigation

With your class



22. Discuss where we left off last time and what we want to figure out next.

Collect arm span data.

With your group



23. Work with your group to measure everyone's arm span, across the back, middle fingertip to middle fingertip.
24. Follow your teacher's directions for recording your arm span measurement.

Analyze arm span data.

With your class



25. Use an online tool to create a histogram of the class arm span data.

Obtain, evaluate, and communicate information.

With your class



26. Discuss how you will obtain, evaluate, and communicate information about the causes of trait variation.

Read and create your model.

On your own



27. Read the article your teacher assigned you.
28. Draw a model on *Arm Span Reading and Modeling*.
29. Plan what you will say to explain your model.

Compare and communicate about your models.

With your group



30. Lay your copy of *Arm Span Reading and Modeling* so others can see it.
31. Find and discuss similarities and differences among the models in your group.
32. Turn and talk with a neighbor in your group to explain the reasoning behind your model.

Provide peer feedback.

On your own



33. Exchange models with that same neighbor and use sticky notes to provide feedback and ask clarifying questions. Focus on whether your partner's model clearly shows what causes are resulting in the trait variation. Consider using sentence frames similar to those below to help focus your feedback.
- How did _____ affect the _____ compared to _____?
 - I really liked how you showed how _____ had more of an effect on _____ than _____ did.
 - I wonder if there are any other factors that affect _____.

Consensus Discussion

Scientists Circle



34. Discuss with your class: What have we figured out about how genes and environment influence different traits?

Calculate the percentage of heavily muscled cattle.

With your class



35. Using the data on the slide, calculate the percentages of heavily muscled cattle and those that are not in the world cattle population.

36. If we imagined a graph of the distribution of cattle muscle variations, what do you think it would look like?

Update our model.

Turn and talk



37. We need our model to show the different impacts of genes and environment on different cattle muscle phenotypes. How should we revise our model to show those ideas?

Scientists Circle



38. Share your ideas with the whole class to revise our consensus model.

Progress Tracker: What have you figured out?

In your notebook



39. Add to your Progress Tracker. Record what you have figured out using words and/or pictures. Take as much space as you need.

Question	What I figured out in words and/or pictures
How much of trait variation in a population is controlled by genes or the environment?	

Lesson 17: Why are living things different from one another?

Navigation

Turn and talk



1. Discuss the following question with your partner:
 - What did we figure out in the last lesson?

Evaluate our DQB questions.

On your own



2. Evaluate whether you think we have answered the questions on our DQB. Record any additional questions you have. Use these symbols to mark your ideas on the handout:
 - We did not answer this question or any parts of it yet: ○
 - Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
 - Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓ +
3. Then, choose three questions and write your answers with supporting evidence.

Share answers to your questions.

Turn and talk



4. Discuss with a partner your answers to three questions you think the class made progress on. Give suggestions and feedback to refine each other's answers with evidence collected during the unit.

What questions have we made progress on?

On your own



5. Bring your handout and 5 dot stickers to the Driving Question Board.
6. Place your dots on 5 sticky notes with questions you think we have made progress on.
7. After you have placed your 5 dots, move to the Scientists Circle.
8. As you are waiting for others to place their dots, be prepared to share your evidence for what the answers to the questions might be and look for patterns to identify which questions have the most dots.

Revisit our Driving Question Board.

Scientists Circle



9. Discuss with your class:
- Which questions have we made the most progress on?
 - What have we figured out?
 - What questions do you have about any of the ideas that have been shared?

Add to our Progress Trackers.

Add to your Progress Tracker additional ideas you want to review. Also, revise any previous rows.

In your notebook



10. During your time revisiting the DQB, new ideas may have surfaced that you want to include on your Progress Tracker.
- Write in the left side the question we are working on: 17. Why are living things different from one another?
 - Record on the right side your thinking in words and/or pictures.

Coast Redwoods: The Tallest Tress in the World

With your class



11. Get oriented to the context of the assessment.

Coast Redwoods: Characteristic Information

With your class



12. Listen to information (or read) about the coast redwood characteristics.

Characteristic	Information
Range	Along the Pacific coast from the middle of California to the southwest corner of Oregon
Average height	200 to 240 ft (60-70 m) tall, some around 350 ft (100 m)
Lifespan	800 to 1,500 years, some live up to 2,000 years
Genetic information	Almost the largest set of genetic information cataloged by scientists, coast redwoods contain 9 times the genetic information a human has.

Coast Redwoods: Reproduction

With your class



13. Listen to information (or read) about the Coast Redwood Reproduction.

Sexual reproduction	Asexual reproduction
• Many seeds are produced in cones and drop from the tree. • Up to 75% of the seeds cannot actually produce seedlings. • Even if a seed might be able to produce a seedling, ground conditions often prevent growth (e.g., not enough light, too difficult to get roots into the soil). • Trees with the most successful seeds are between 250 and 1,200 years old.	• The parent tree sprouts new trees from its roots near the trunk. • This allows offspring trees to use resources from the parent’s roots. • This next generation of offspring trees forms a circle around the parent tree. • Asexual reproduction is usually more successful than sexual reproduction.

Mapping Heights of Coast Redwoods

With your class



14. Use the slides and/or *Reference Images for Redwoods Assessment* to observe the heights of coast redwoods in Humboldt State Park using LiDAR maps.

15. Observe the graph of redwood height measurements in and around Humboldt State Park.

16. Discuss with your class:

- What factors might affect how tall a redwood tree can grow, in general?

Demonstrate understanding.

On your own



17. Work silently and independently on the assessment task.

Reflect on our experiences (optional).

On your own



18. Complete a quick write about any or all of the following questions.

- What was most challenging in this unit?
- What was most rewarding?
- Think about how you engage in sensemaking discussions and experiences with classmates. How would you want to engage with those experiences the next time around?
 - What would you do the same?
 - What would you do differently?

Student Support for Probability Work

This document will support your thinking while you work with these thinking tools to make predictions about the likelihood of offspring inheriting certain genotypes from parents. There are two methods to try (plus some alternate options for once you have a good understanding for how this works). While you may use whichever method you are most comfortable working with, this document will help you see the similarities in the methods; so you may see them as interchangeable. There is plenty of space for notes here, so you may annotate this and record any questions you have to help make sense of these tools.

Making Predictions Using Probability Calculations

It is important to always remember what is happening during the process of making eggs and sperm and what is happening when a sperm fertilizes an egg.

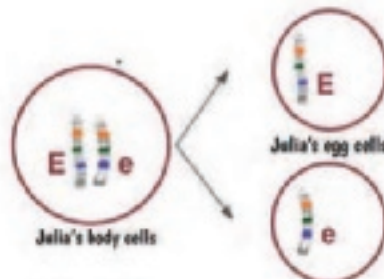
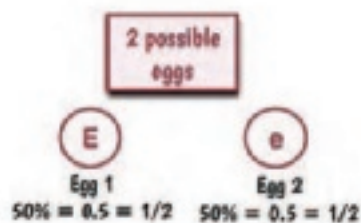
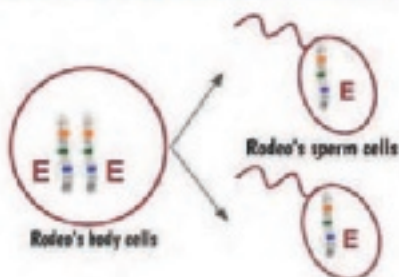
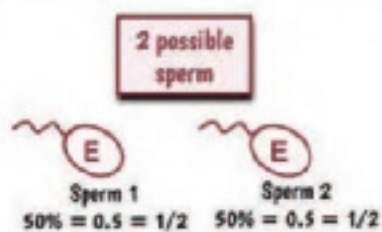
Whenever you are thinking about alleles, picture where they exist on a chromosome.



The body cells of organisms have 2 of each kind of chromosome. That means the body cells will have two alleles for each gene. An individual may be homozygous or heterozygous for any given gene.

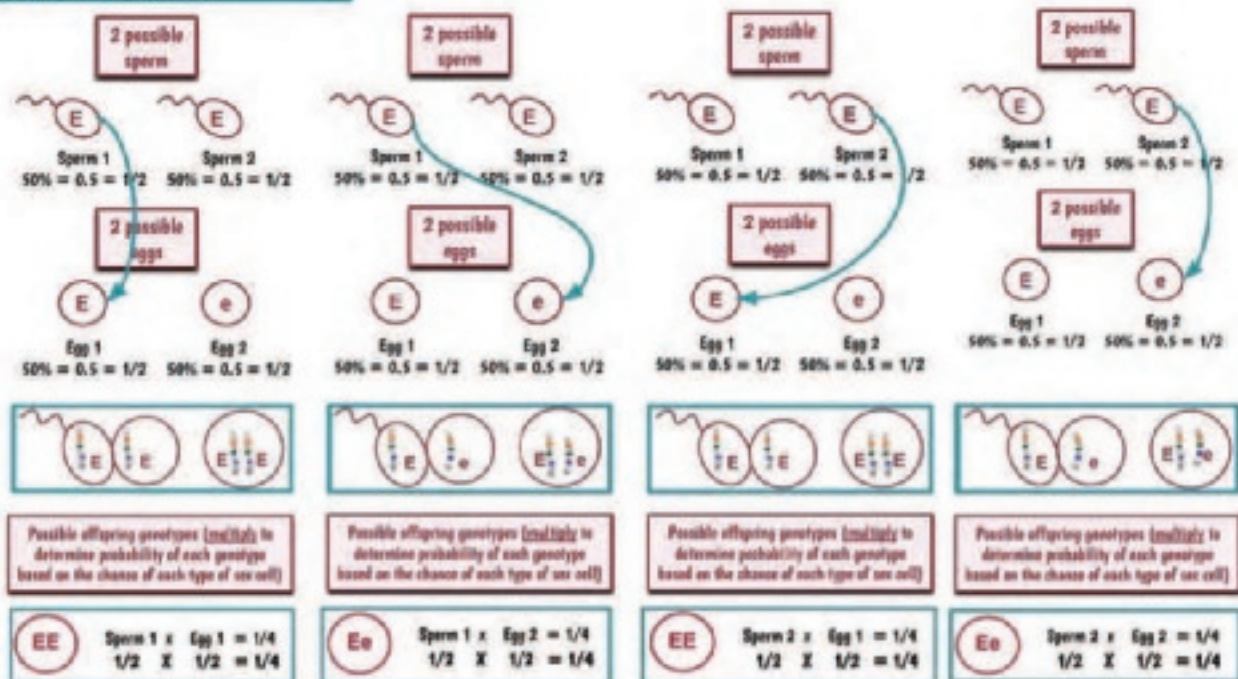
Step 1: Consider the genotype of each parent and create the eggs and sperm that each parent is capable of creating.

Another way to show this (to help visualize what is going on a little better) would be to include the chromosomes inside the eggs and sperm.



When eggs and sperm are made, they get only 1 chromosome from each pair, therefore they also have only 1 allele for each gene.

Step 2: Determine the genotype of the possible offspring for each possible egg/sperm combination.



When an egg and sperm combine to form an offspring, the chromosomes combine to give that cell 2 of each kind of chromosome. One chromosome was provided by the female parent through the egg cell and the other by the male parent through the sperm cell.

Step 3: Determine the probabilities of offspring with the same genotypes by adding.



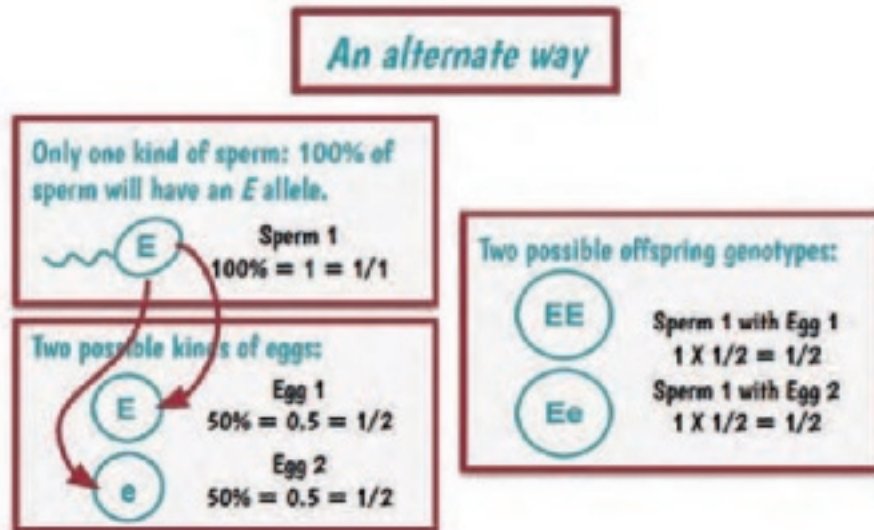
$$EE = 1/4 + 1/4 = 2/4 = 1/2 \text{ or } 50\%$$



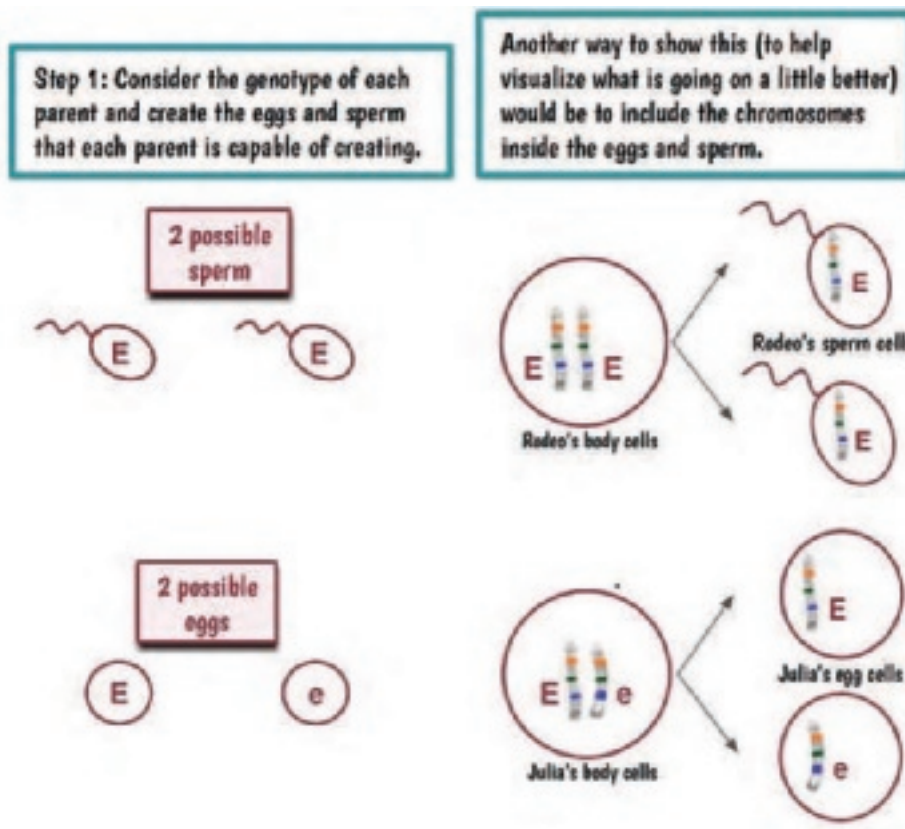
$$Ee = 1/4 + 1/4 = 2/4 = 1/2 \text{ or } 50\%$$

$$ee = 0/4 + 0/4 = 0 \text{ or } 0\%$$

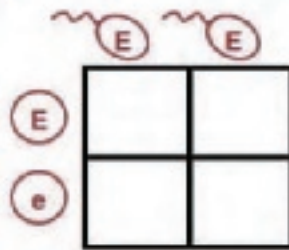
Here is an alternate way to think about these predictions using the probability algorithm:



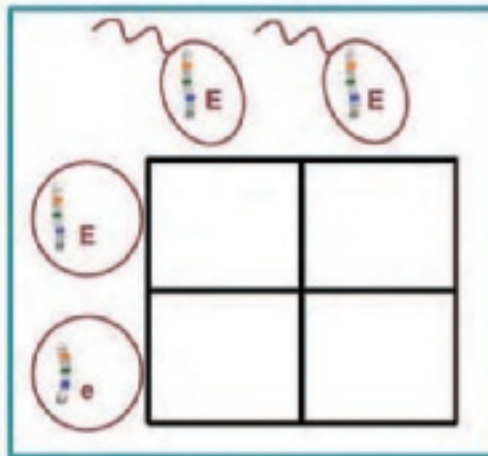
Making Predictions Using Punnett Squares



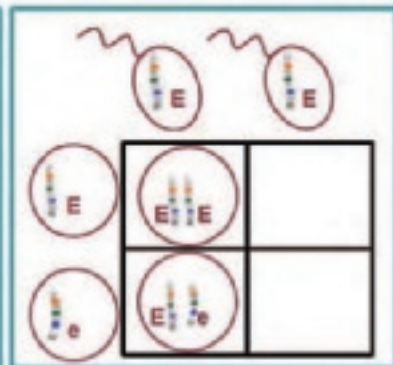
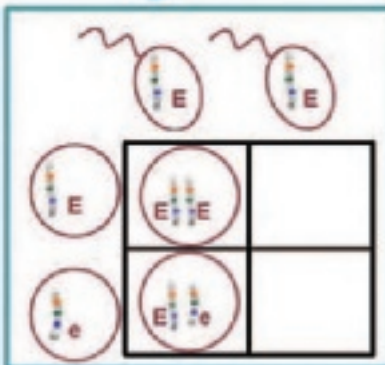
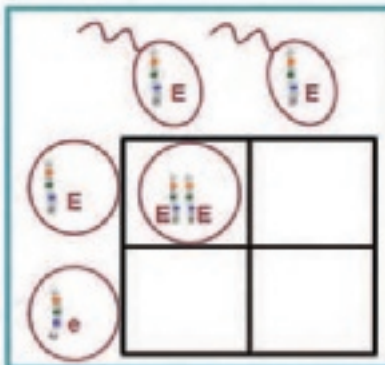
Step 2: Create a grid and arrange the possible sperm cells along the top of the grid and the possible egg cells down the side of the grid.



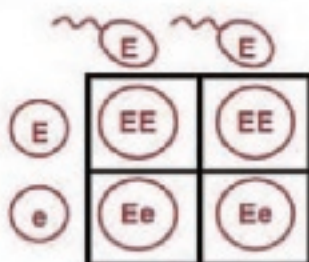
The grid that helps visualize these probabilities is called a "Punnett square".



Step 3: Use the grid to determine the genotype of the offspring for each possible egg/sperm combination.

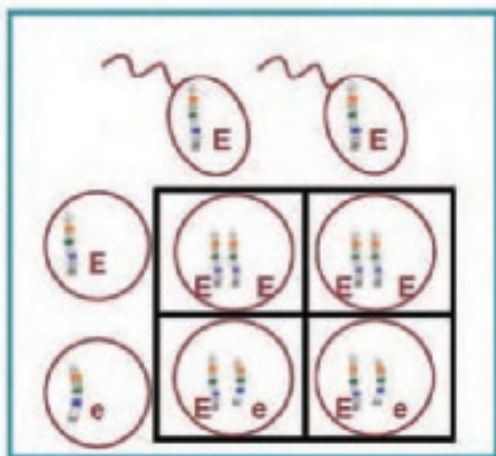


Step 4: Count the offspring that have the same genotype and then divide by the number of total offspring to get the probability for each genotype.



Determine the predicted proportion (probability) of each genotype by counting the offspring of that type and dividing by the total.

$EE = 2/4$ which is equivalent to $1/2$ or 50%
 $Ee = 2/4$ which is equivalent to $1/2$ or 50%
 $ee = 0/4 = 0\%$



Here is an alternate way to think about these predictions using a Punnett square:

An alternate way

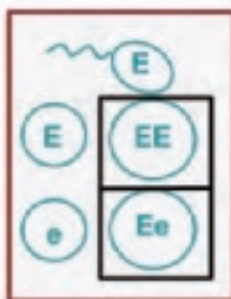
Only one kind of sperm: 100% of sperm will have an E allele.



Two possible kinds of eggs:



Find the possible zygotes by setting up a not-square Punnett square.



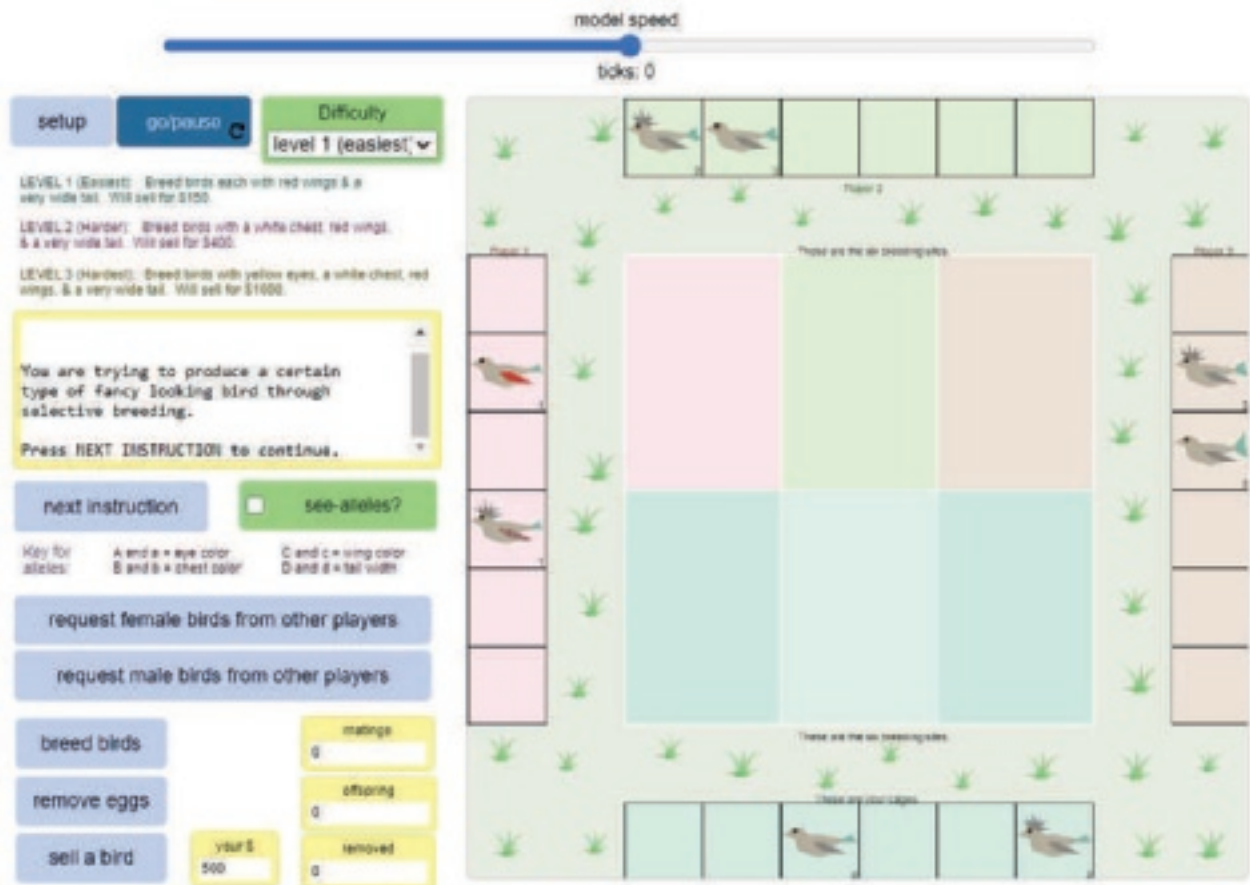
Determine the expected proportion (probability) of each genotype by counting the offspring of that type and dividing by the total.

$EE = 1/2$
 $Ee = 1/2$
 $ee = 0/2$

$EE = 1/2$ or 50%
 $Ee = 1/2$ or 50%
 $ee = 0/2$ or 0%

Instructions for Bird Breeder Simulation

To run the simulation, go to this web address <https://www.openscienced.org/general/bird-breeder/> . Once the simulation loads, read through the directions as indicated in the image below.



Advance through each step in the instructions by pressing the "next instruction" button. Once you have read through them all, begin to run the simulation as outlined by those instructions.

- Click on "setup" to load the screen.
- Start with "level 1" difficulty.
- If you wish to see the alleles, check the "see-alleles?" checkbox.
- If you want to adjust the difficulty you can do so, but then you will need to restart the simulation by pressing the "setup" button again for those changes to take effect.
- Read the instructions in the text box and press "next instruction" to learn the rules of the simulation.
- Press "go/pause" when you are ready to begin running the simulation.

Wheat Kernel Environmental Factors Investigation

Scientists noticed there was a large range of wheat kernel color that resulted from crossing different wheat plants. They wondered if the environment played a role in influencing the color of the wheat kernels or if the variation was related to genetics. They set up three simple experimental crosses:

1. They crossed plants that produced the lightest cream-colored kernels with each other.
2. They crossed plants that produced the deepest red-colored kernels with each other.
3. They crossed plants that produced the lightest cream-colored kernels with plants that produced the deepest red kernels.

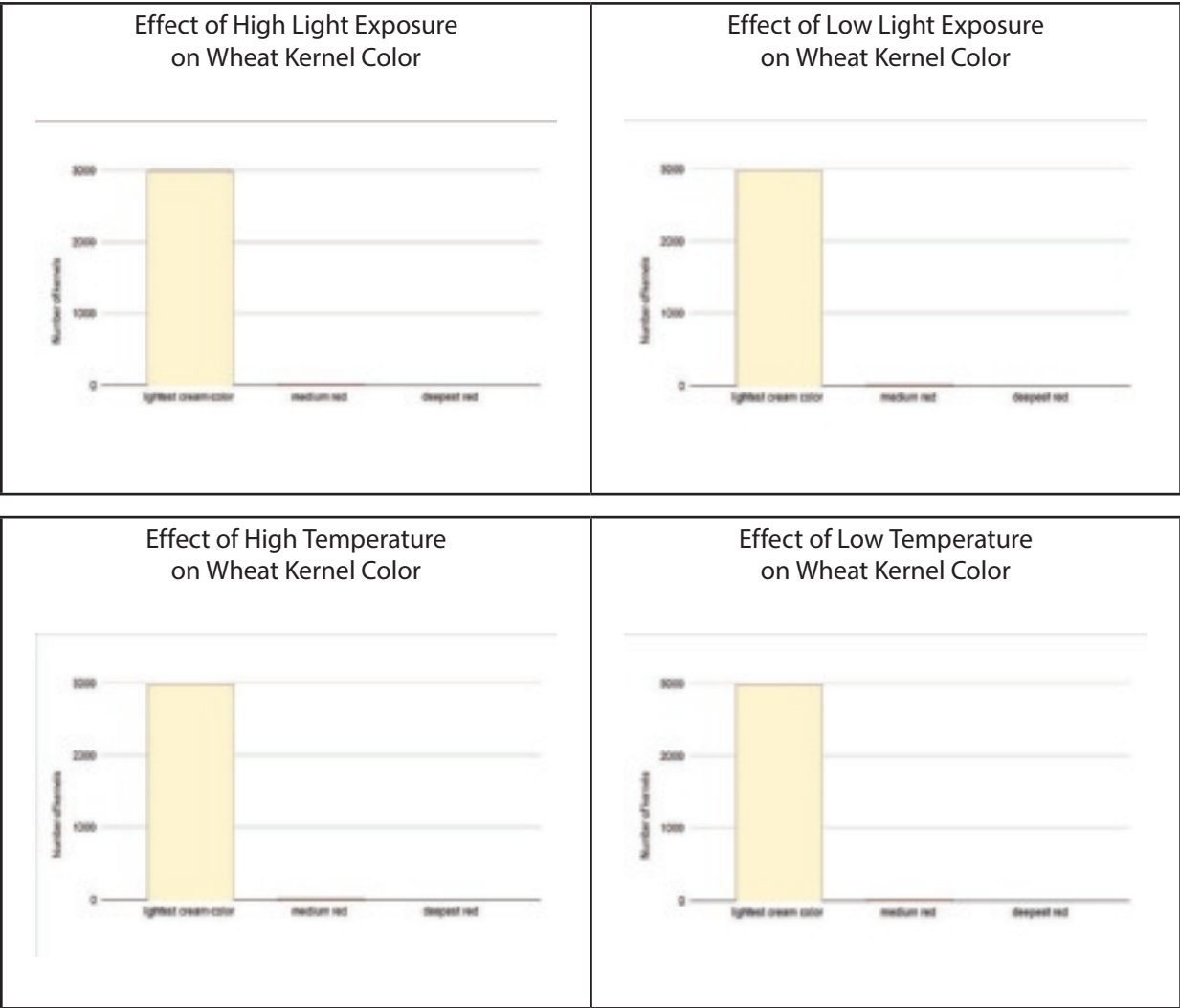
Then the scientists collected the seeds from plants resulting from each cross and planted them to grow offspring plants under different environmental conditions. Offspring plants from each cross were divided into four groups and were raised under four different conditions:

- A. High levels of light
- B. Low levels of light
- C. High temperature
- D. Low temperature

When the offspring plants were mature, seeds were collected from 3,000 plants in each group. These seeds were sorted and counted. The following data represent the results of these investigations.

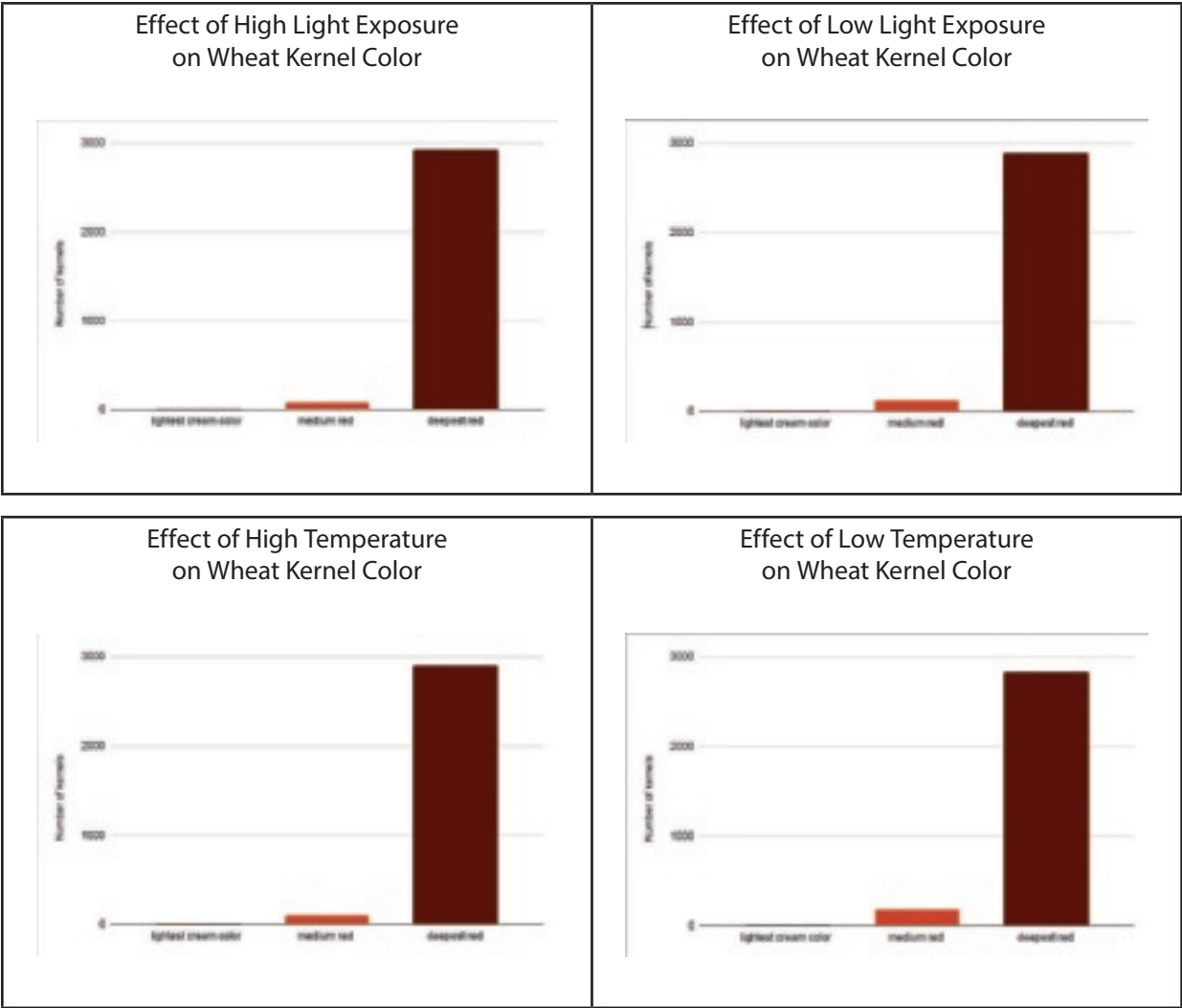
Experimental cross #1

Plants that produced the lightest cream-colored kernels were crossed with each other.



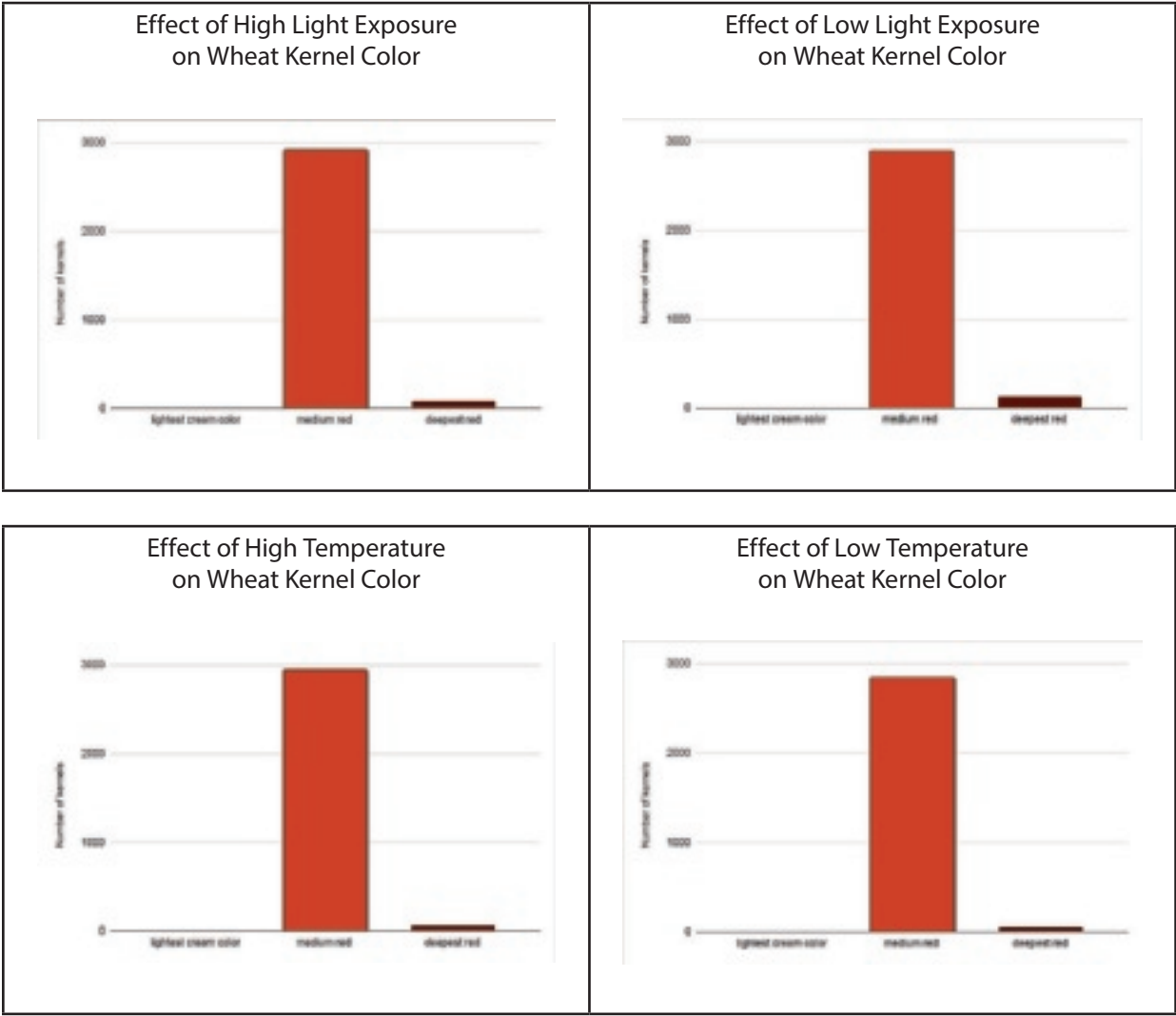
Experimental cross #2

Plants that produced the deepest red-colored kernels were crossed with each other.



Experimental cross #3

Plants that produced the deepest red-colored kernels were crossed with plants that produced the lightest cream-colored kernels.



Sources

- Baker, R. J. (1981). Inheritance of seed coat color in eight spring wheat cultivars. *Canadian Journal of Plant Science*, 61(3), 719–721. <https://doi.org/10.4141/cjps81-100>
- Dupont, F. M., & Altenbach, S. B. (2003). Molecular and biochemical impacts of environmental factors on wheat grain development and protein synthesis. *Journal of Cereal Science*, 38(2), 133–146. [https://doi.org/10.1016/s0733-5210\(03\)00030-4](https://doi.org/10.1016/s0733-5210(03)00030-4)
- Hayes, H. K., & Robertson, D. W. (1924). The inheritance of grain color in wheat 1. *Agronomy Journal*, 16(12), 787–790. <https://doi.org/10.2134/agronj1924.00021962001600120007x>
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- Kniewel, D. C., Abdel-Aal, E.-S. M., Rabalski, I., Nakamura, T., & Hucl, P. (2009). Grain color development and the inheritance of high anthocyanin blue aleurone and purple pericarp in spring wheat (*Triticum aestivum* L.). *Journal of Cereal Science*, 50(1), 113–120. <https://doi.org/10.1016/j.jcs.2009.03.007>

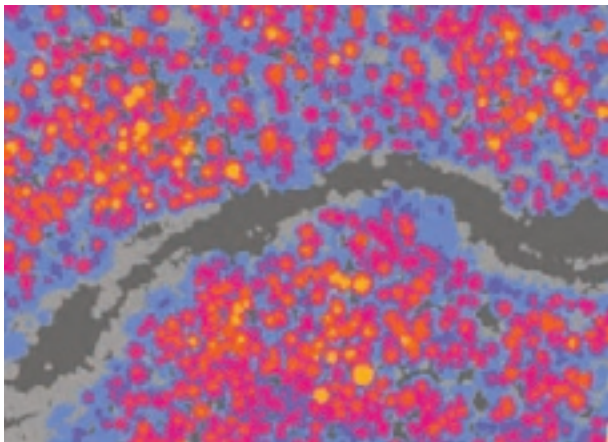
Steps for Using Probability to Make Predictions

Algorithms we use to determine offspring probabilities	
Option 1	Option 2
Step 1: Consider the genotype of each parent and create the egg and sperm that each parent is capable of creating. Step 2: Determine the probability of each type of offspring genotype by <u>multiplying</u> the probability of each type of sex cell. Step 3: Determine the proportion of offspring with the same genotypes by <u>adding</u> the proportions.	Step 1: Consider the genotype of each parent and create the egg and sperm that each parent is capable of creating. Step 2: Create a grid and arrange the possible sperm cells along the top of the grid and the possible egg cells down the side of the grid. Step 3: Use the grid to determine the genotype of the offspring for each possible egg/sperm combination. Step 4: Count the offspring that have the same genotype and then divide by the number of total offspring to get the proportion for each offspring genotype.

Reference Images for Redwoods Assessment

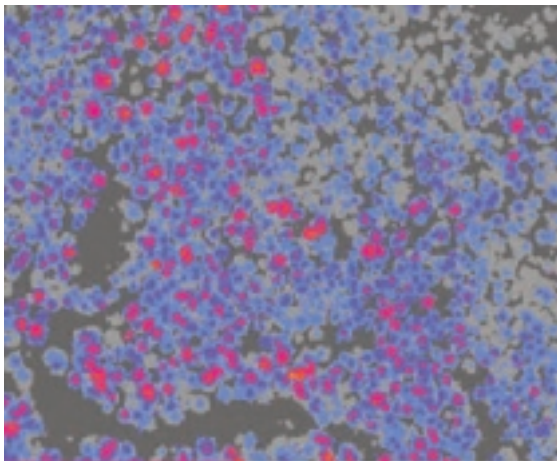
The maps below show the heights of the redwood trees in two different areas of about 62 acres each. Both maps show old-growth areas where the trees are more than 100 years old and do not get much taller each year.

Map 1: Along Bull Creek



Mark Graham

Map 2: In a creek valley

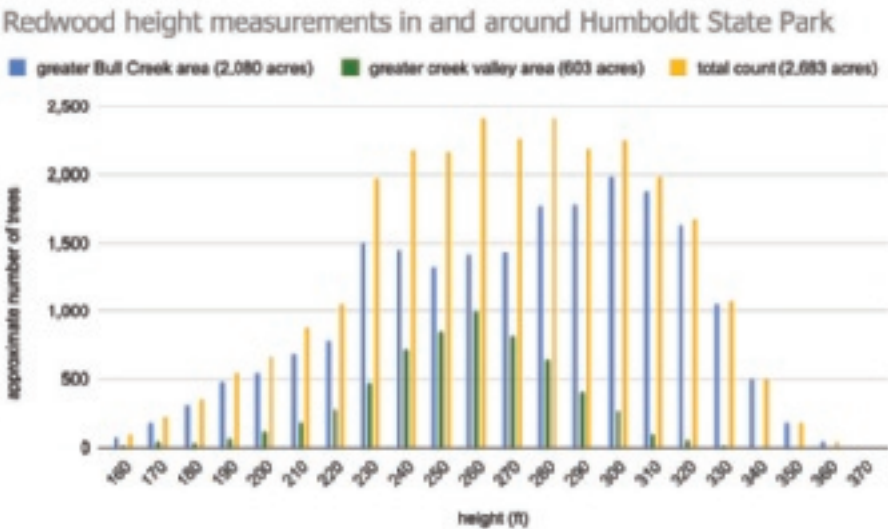


Mark Graham

map key

yellow	orange	pink	purple	blue
over 328 ft (100 m) tall	over 295 ft (90 m) tall	over 262 ft (80 m) tall	less than 262 ft (80 m) tall	

This graph shows the tree heights measured in these mapped areas plus additional surrounding areas, for a total of 2,683 acres of redwood forest in and around the state park:

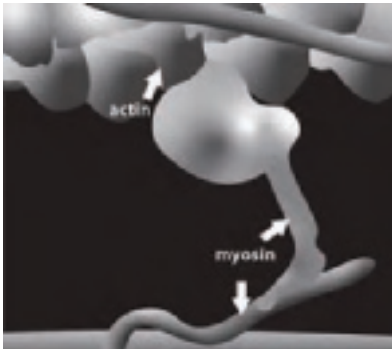
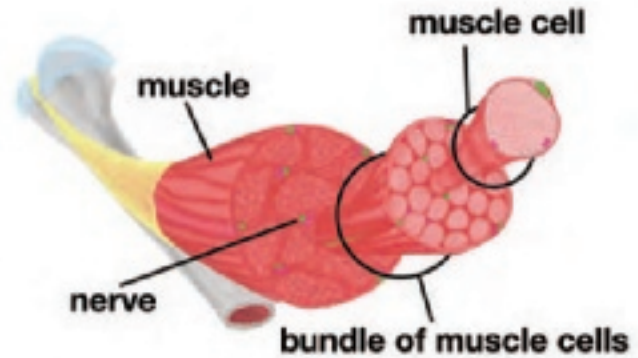


Data Source: Canopy height distribution in old growth redwood forests from www.verylargeandtallredwoods.com

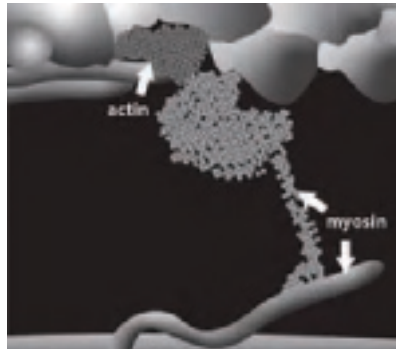
How Muscles Contract

Skeletal muscles are the type of muscles that connect to and move different bones in the body. Skeletal muscles are made up of bundles of muscle fibers that cause the muscles to look stringy. Muscle fibers are long, round cells that are made up of thick and thin strands that give muscles their striped appearance.

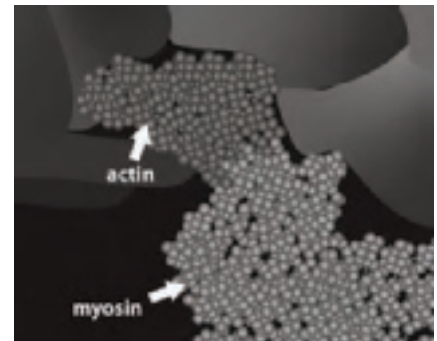
The muscle contraction begins when the brain sends a signal through nerves. This signal causes the thick and thin strands to slide past one another. The thick strands are made up of a protein called *myosin*. The thin strands are made up of a protein called *actin*. These different strands are anchored at opposite ends. This allows the whole muscle fiber to contract (pull together) when actin strands slide along the myosin strands. Although the action between the strands is described as “sliding,” the myosin protein actually pulls the actin protein along its length. The round side of the myosin protein, known as the head, extends and attaches to the actin protein.



This model of myosin and actin molecules has been “filled in” to make the whole molecules easier to see.



However, myosin and actin molecules, like all proteins, are made up of many atoms (represented in this image as tiny spheres arranged and connected together).



If we move even closer, we can see the structure of how the atoms are arranged that gives these proteins their unique shape. The shape of each protein structure allows them to connect and fit tightly together along one of their edges.

Once the myosin is attached, it pulls along the actin protein, shortening the muscle fiber. The myosin will then “let go” of the actin protein. Then the myosin protein is free to either repeat the pulling process or stay unattached and allow the muscle to relax.

Reading: Version 1: How to Build Muscles

From: <http://atheletehelp.com/blog>

In today's post, we are talking muscle growth! Many people want to get that body-builder look, but they do not understand how muscles actually develop, so I am here to help!

There are two factors to consider in muscle growth: diet and exercise. Makes sense, right? You have probably already heard that what you eat affects how your body looks, and you have heard that using muscles makes them stronger. So, this post will give you details about both, and you can be growing muscles in no time.

I am living proof that exercise helps muscles grow. I have been a runner for a long time, and I can tell you, running has given me great-looking muscles. I average about 3 miles every morning on flat terrain, and on weekends I like to do a longer run in a hilly nature reserve nearby. I think what has really helped my muscles develop is the stretching I do before and after my runs. Obviously the cells in our muscles need to stretch out to grow, so taking the time to do a lying hamstring stretch, a gluteal stretch against a wall, and a standing quadriceps stretch is what really makes a difference in muscle growth. I like to use the Move-It Cord brand exercise band to make my stretches really count, and it is only \$9.99—a great deal!

When it comes to your diet while you build muscles, be sure you reduce the calories in your daily meals and snacks. You want to make your body use up the nutrients you already have stored inside rather than adding anything extra or new. It is also helpful, though, to be sure you are taking a vitamin supplement, such as Strongro, which contains calcium, iron, and vitamin C. You may think calcium is just for strong bones and teeth, but your muscles need calcium, too. Iron is an important component of your blood, which carries oxygen to your muscles from your lungs while you are exercising. Vitamin C has been found effective in preventing infections, and you cannot build muscles if you are sick. So, Strongro is a highly recommended product for you to try as you grow your muscles!

Thanks for taking the time to read today's post about muscle growth! Now get out there and get moving!

(This site uses affiliate links, and the writer may receive a commission if you purchase the items mentioned above.)

Reading: Version 1: Greek Yogurt + Resistance Training (Study 1)

Increased exercise and increased protein intake resulted in increased muscle thickness. Twenty-eight untrained males, ages 18-25, were randomly assigned to one of two groups: fat-free Greek yogurt or a pudding which has the same calories as Greek yogurt (as a control, called a *placebo*). Both of the groups participated in a resistance-training program 3 days a week for 12 weeks. They consumed either Greek yogurt (20 g protein/serving) or placebo pudding (0 g protein/serving) daily. They ate their yogurt or pudding 3 times a day on training days and 2 times a day on nontraining days. The results of muscle thickness measurements (using ultrasonography) are shown in the table below.

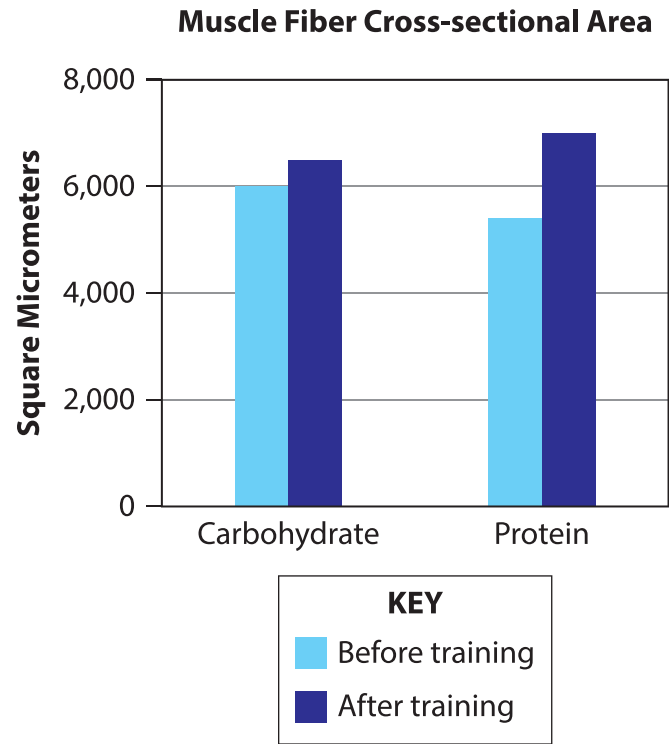
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Bridge, A., Brown, J., Snider, H., Nasato, M., Ward, W. E., Roy, B. D., Josse, A. R. (2019). Greek Yogurt and 12 Weeks of Exercise Training on Strength, Muscle Thickness and Body Composition in Lean, Untrained, University-Aged Males. *Frontiers in Nutrition*, 6, p. 55. doi:10.3389/fnut.2019.00055

Reading: Version 1: Carbs or Protein with Exercise (Study 2)

Increased exercise combined with increased protein intake resulted in more muscle growth than increased exercise combined with increased carbohydrate (carb) intake. This study included twenty-two young, healthy men, all around age 23. They had not been regularly exercising and were not taking any kind of nutritional supplements. They were split into two groups. One group was given carbohydrate supplementation (25 g carb, 0 g protein/dose). The other group received protein supplementation (0 g carb, 25 g protein/dose).

Both groups completed resistance training focused on leg muscles 3 times a week for 14 weeks. They took their supplements before and after each training session and once daily on nontraining days. Specimens were taken and measured pretraining and posttraining from the right side of the right thigh muscle.



Source: Lars L. Andersen, L. L., Tufekovic, G., Zebis, M. K., Crameri, R. M., Verlaan, G., Kjær, M., Suetta, C., Magnusson, P., Aagaard, P. (2005). The effect of resistance training combined with timed ingestion of protein on muscle fiber size and muscle strength. *Metabolism*, 54(2), pp. 151-156. Retrieved from <https://doi.org/10.1016/j.metabol.2004.07.012>

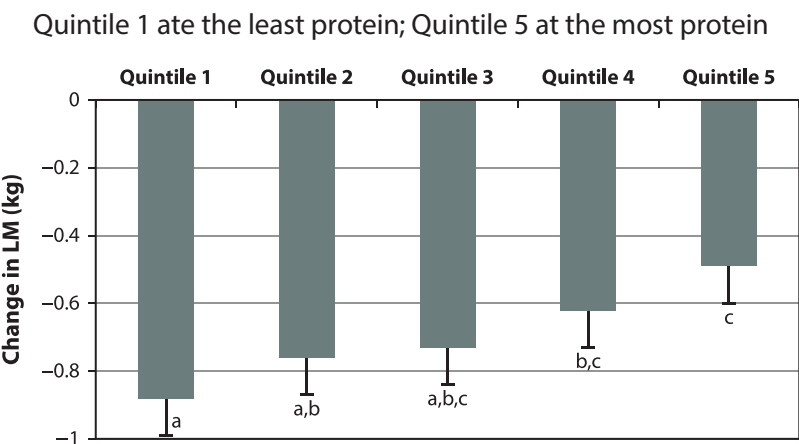
Reading: Version 1: Protein’s Effect on Muscles

This study set out to find a connection between the amount of protein people ate as part of their regular diet and changes in skeletal muscle mass. The study surveyed 2,066 people ages 70-79. About half were women and the other half were men. Everyone was able to walk ¼ mile and climb 10 stairs.

Scientists asked the participants to estimate how much protein they usually ate. Then, the scientists organized the participants into 5 groups (called “quintiles”) based on their usual protein intake. People in quintile 1 ate the least protein per day, near or just below the current recommended daily value for protein (0.8 g per kg of body mass). People in quintile 5 ate the most protein per day (about 1.2 g per kg of body mass). The scientists calculated each participant’s muscle mass. The study participants ate what they usually ate (no protein supplements were given). Then, the scientists did the same calculation of muscle mass again 3 years later.

At the end of the three years, scientists found that participants who usually ate the most protein lost about 0.50 kg of muscle mass over the three years. However, participants who ate the least protein lost about 0.88 kg of muscle mass over the three years.

Adjusted lean muscle mass (LM) loss by quintile of energy-adjusted total protein intake.



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Reading: Version 1: Effect of Resistance Exercise on Muscles

Resistance exercise is the kind of movement that causes muscles to contract against a force or weight. Resistance exercise has been shown to build muscle mass. This type of exercise causes damage to the muscle fibers. Then the body repairs those fibers, which can increase their thickness and length.

The lengthening of muscles under a load, such as lowering a heavy weight or walking downhill, is the type of resistance exercise that has been shown to damage muscle fibers. During any contact force, the objects experience forces of equal strength. The muscle fibers share the load of this tension (the stress or strain of being stretched tight) with other nearby fibers. However, intense exercise can cause so much tension on these strands of myosin and actin that there is no more overlap on some of them.¹ Tears may occur in the structures that hold them together and allow them to contract.² When the tension is released, the myosin and actin strands may not be able to return to their normal function—they have been too disrupted and can no longer line up correctly.¹ These injuries to the muscle fibers can cause some of those cells to die, which leads to possible swelling and soreness after this kind of intense exercise.^{1,2}

After the muscles have been injured by resistance exercise, they begin to repair themselves. The body makes new cells to do this, and those new cells attach to the damaged parts of the fibers.³ This addition to the muscle fibers can make them thicker (increasing the area of the cells) and/or longer (by adding sections to the myosin and actin strands).⁴

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1. Proske, U., & Morgan, D. L. (2001). Muscle damage from eccentric exercise: mechanism, mechanical signs, adaptation and clinical applications. *The Journal of Physiology*, 537(2), pp. 333–345.
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Reading: Version 2: How to Build Muscles

From: <http://atheletehelp.com/blog>

Today, we are talking about muscle growth! A lot of people want big muscles but do not understand how to get them. I am here to help!

Two things help you grow muscles: diet and exercise. Makes sense, right? The food you eat affects how your body looks, and using muscles makes them stronger. So, this post will give you details about both, and you can be growing muscles in no time.

I am living proof that exercise helps muscles grow. I have been a runner for a long time, and I can tell you, running has given me great-looking muscles. I run 3 miles a day during the week, and I run further than that on the weekends.

I think stretching also helped my muscles develop. Obviously, the cells in our muscles need to stretch out to grow. So take the time to do a lot of stretches, which is what really makes a difference in muscle growth. I like to use the Move-It Cord brand exercise band to make my stretches really count, and it is only \$9.99—a great deal!

When it comes to your diet while you build muscles, be sure you reduce the calories in your daily meals and snacks. It is also helpful to take a vitamin supplement, such as Strongro, which contains calcium, iron, and vitamin C. Your bones and teeth need calcium, but so do your muscles! Your blood needs iron to carry oxygen to your muscles while you are exercising. Vitamin C helps prevent infections, and you cannot build muscles if you are sick. So, Strongro is a highly recommended product for you to try as you grow your muscles!

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Both of the groups participated in a resistance-training program 3 days a week for 12 weeks. All participants ate their assigned food daily: 3 times a day on training days and 2 times a day on nontraining days. The results of muscle thickness measurements are shown in the table below.

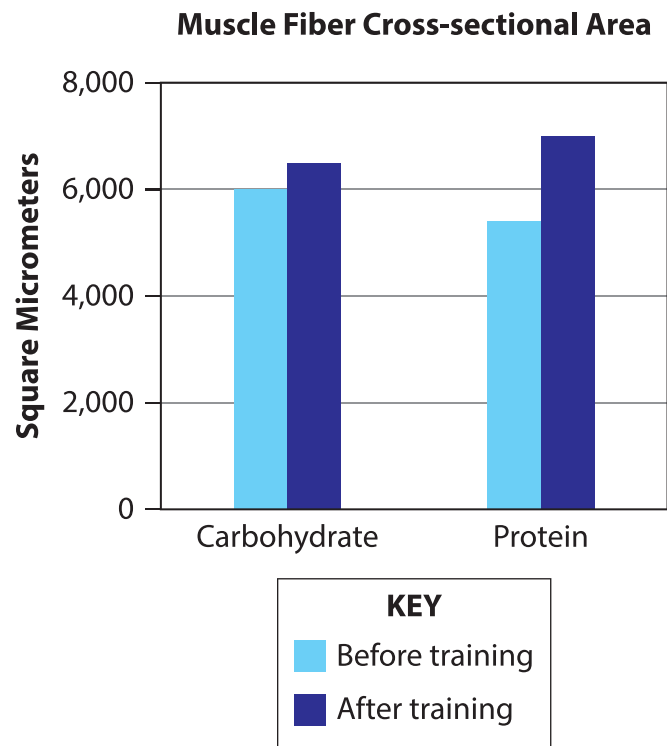
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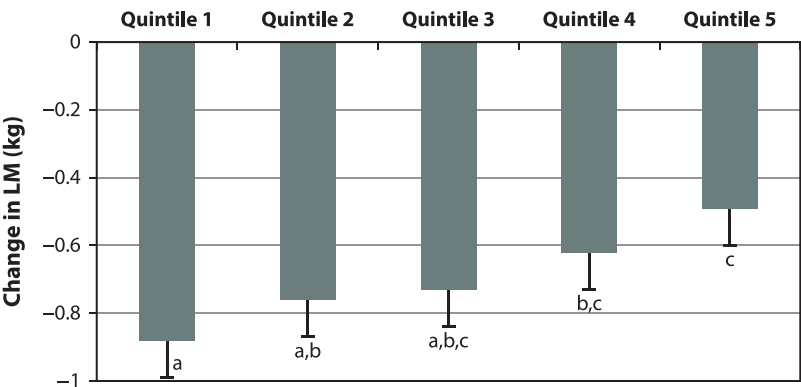
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Adjusted lean muscle mass (LM) loss by quintile of energy-adjusted total protein intake.

Quintile 1 ate the least protein; Quintile 5 at the most protein



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Reading: Exercise: Ask a Farmer Transcript

Interviewer: So you'd said, like, you had the. . . we'll just call them heavily muscled cows for about twenty. . .

Farmer: Oh, yeah, about twenty, twenty-five years.

Interviewer: OK. Alright. And then, have you always had that breed of cow or. . . ?

Farmer: That has been our specialty, but we, but we've, we've had all kinds of cows. We've had Simmentals, we've had—right now we've got a couple of Herefords, but it was—our commercial herd was a little bit of everything. And that was one of the things that we liked, was putting the purebred Belgian Blue bull in there to see how each breeds. You know, how—how they would have, you know, what their calves would look like.

Interviewer: Right, right, OK. Alright. So for Lesson 4 we get into a little bit with exercise and the lifestyle of the cattle. So, one of the questions that comes up often, just looking at those and looking at the heavily muscled cattle compared to regular-muscle cattle, and knowing, like, humans. Like, do you give your cattle steroids?

Farmer: No, no. Absolutely not.

Interviewer: Alright. And then, what type of workouts do your cattle do? Like, what do they normally do during the day?

Farmer: Belgian Blues are—because of their heavily—and then, because they're—and they're very docile animals. I used to be able to go out in the pasture with two or three of my cows and actually lay on them and read a book. They wouldn't even move. They're very slow moving. They're not—they don't do a whole lot of exercise if they don't have to.

Interviewer: OK.

Farmer: But the calves do, but the moms are pretty do-to-do-to-do, you know? And so, but I don't—we never exercise them more for anything. I mean, they just were with the regular cows.

Interviewer: OK. Alright. Yeah, so could you have—so, thinking of a non-heavily muscled cow, could you have a typical cow do a workout to try and build larger muscle?

Farmer: I don't think so. You know, I really don't know that answer. You feed them a lot of grain and they get bigger, but I don't know if that has anything to do with, you know, I just, I don't know that one. If you find the answer to that one let me know.

Interviewer: OK.

Reading: Diet: Ask a Farmer Transcript

Interviewer: So did the heavily muscled cow require, like, a special type of diet compared to a typical?

Farmer: No, and that's—that's interesting. The only thing that we would do different with the Belgian Blues when they are born—now this is just for our area—we would give them a shot of selenium because our area is very low in selenium, and with the heavily muscled that seemed to affect them. So as soon as they're born, we always gave them a shot of just two cc's, I think, of selenium. I would assume with other areas that are higher in selenium wouldn't do that. And then the diet part is funny because the cattle we bought out of Canada, when they came down, I was appalled! I went to feed them ground corn, which are corn and oats, and they wouldn't eat it. I found out that up there they eat barley. That's their diet. So, the next time we bought them, he sent—and they got on to corn after a while, but at first when they were putting it in front of them, they were like, "I am not eating that." So, the next time we bought cattle from him he sent barley down with him. And we had gone to a conference up in Canada, and I was so excited to talk to other people that, from Europe, that fed their animals and what they fed them . . . well, it's where your region is. They feed a lot of beet pulp. Yeah, over there. It's, I guess, whatever is in your region is what you feed your cattle. The same with the hay crop. We had sold bulls down south, and they had trouble with their—they had to supplement them more. We weren't supplementing them. They were just getting grain. But our hay up here is so much better quality than theirs. So as far as diet goes, I guess the Belgian Blues would go with whatever there is in the region.

Interviewer: And then you mention a little bit how long it took for them to start to get the big muscles, and so it just kind of depended, right? So if they were—

Farmer: If they're purebreds, they're going to be born with—they're going to be pretty—near always born heavy muscled. But if the cross-breds can be born—and you don't usually see anything for like, oh, three weeks to a month before they'll start to muscle up. But like I said, some of them don't even do it. If they take the trait of their mother and don't take that trait, they'll just look like a regular cow.

Interviewer: OK.

Reading: Version 1: New Protein Linked to the Heavily Muscled Phenotype

In 1997, scientists McPherron, Lawler, and Lee identified a protein in the muscles of animals. The protein is now called myostatin, though at the time they called it GDF-8. These scientists thought this protein was related to the heavily muscled phenotype in some animals. They decided to test their thinking using mice. They found the specific region of the chromosome—called a **gene**—that they thought was correlated with the myostatin protein and the trait of musculature. They changed the shape of this specific gene on the chromosome in a few cells from typically muscled mice using a technology called **gene targeting**. In gene targeting, scientists can replace just a specific region (the “target”) of a chromosome with a different structure.

This shape change to the gene created a different **allele** (a different version) of the gene. When the scientists carefully observed the cells that had the different allele, they found a different version of the myostatin protein in those cells. This new version of the protein looked similar to the usual myostatin, but its shape was slightly different. The scientists predicted that this differently shaped myostatin protein would function differently than the usually shaped one, and if animals’ bodies made this different protein, they would observe extra-big muscles instead of typical muscles.

To test their hypothesis, they raised mice who had this different allele of the gene for myostatin. Some of the mice in the study had only one changed allele (along with one allele found in typically muscled mice), some had two copies of the changed allele, and some had two copies of the allele found in typically muscled mice (which is how they were naturally without any copies of the changed allele). The combination of alleles an organism has of a certain gene is called its **genotype**. The mice in the study whose genotype at the myostatin gene was two copies of the changed allele had only the differently shaped version of the myostatin protein. They also weighed 2-3 times more than the mice with the genotype found in typically muscled mice. When the scientists counted the fibers in samples of the mice’s leg muscles, the mice with the two copies of the changed-allele genotype had 86% more muscle fibers than the typically muscled mice had. So, the scientists concluded that changing the structure of the gene resulted in the production of the differently shaped myostatin protein, which then resulted in mice with the heavily muscled phenotype.

Summarized from McPherron, A. C., Lawler, A., & Lee, S. (1997). Regulation of skeletal muscle mass in mice by a new TGF- β superfamily member. *Nature*, 387, p. 83–90. doi:10.1038/387083a0

Reading: Version 1: Function of the Myostatin Protein

The function of myostatin

Myostatin is a protein found in the skeletal muscles of many animals¹. The myostatin protein has a different structure and function than the muscle proteins myosin and actin, which have structures that help them build and move muscles.

The myostatin protein's function is to send a message in a cell like this: Cells have receptors on them. A **receptor** is a structure that sticks out of the outside of a cell membrane (see figure A) and relays messages from outside the cell to inside the cell. The myostatin protein is usually shaped so that it fits into one specific kind of receptor like a key fits into a lock. When it does, it causes a message to be sent to the inside of the cell (see figure B). At the scale of one cell, you may not notice this effect. However, the effect of fully formed myostatin proteins on an entire animal is that it has typical muscles².

Figure A

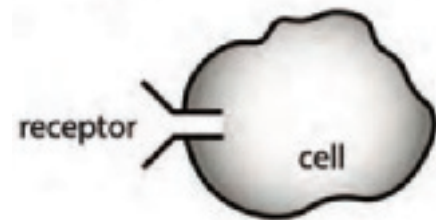
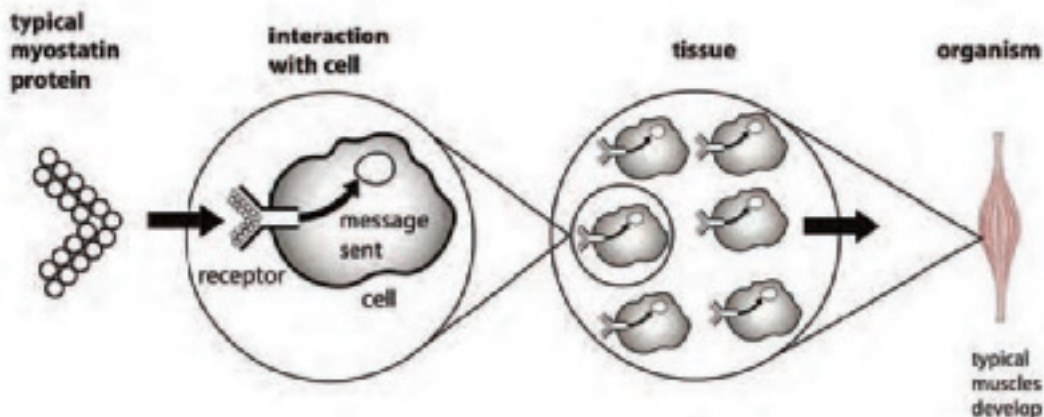


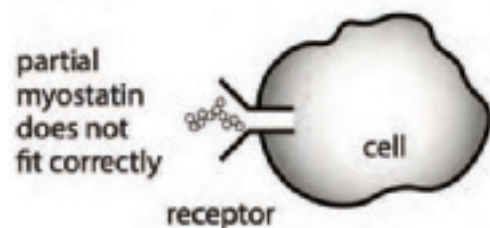
Figure B



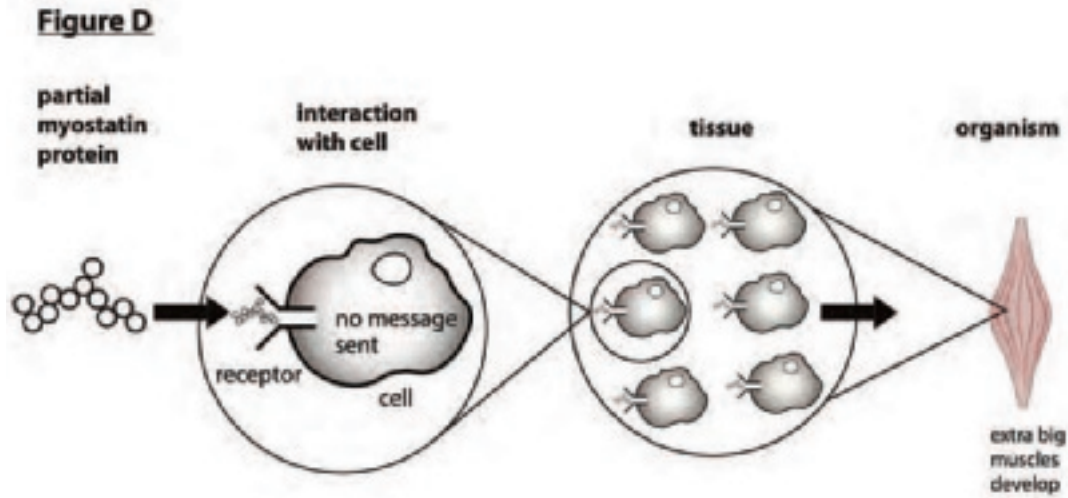
The effect of partial myostatin

Sometimes a myostatin protein is only partially formed. When this happens, it is not the right shape to fit correctly into a cell's receptor. It might fit partially in, like how a wrong key might fit into a lock, but it cannot unlock the door (see figure C). Since the partial myostatin protein does not fit correctly into the receptor, the message does not get sent to that cell. The result that we see from partial myostatin proteins is that the animal develops extra-big muscles (see figure D).³

Figure C



When an animal's body makes both full and partial myostatin proteins, some of that animal's cells get the message and some do not. Therefore, the animal develops muscles that are bigger than typical muscles but not as large as animals who have all partial myostatin proteins.



History of myostatin

Heavily muscled cattle were first discovered in Belgium in the late 1800s.⁴ Farmers had not seen this phenotype in cattle before then. By the 1970s, farmers in other countries, including the United States, were very interested in these heavily muscled cattle because of how much beef they produce.⁵

In 1997, scientists were able to investigate this phenotype in mice. They changed the structure of a specific region of a chromosome—called a **gene**—that they thought was related to the myostatin protein. When they raised mice who had this changed version of the gene in both copies of their chromosomes, their bodies produced partial myostatin proteins and had the heavily muscled phenotype.⁶ At the time, they called the protein "GDF-8", but it was renamed "myostatin" after its function was determined. The first part of the word, *myo*, comes from the Greek meaning "muscles". The second part, *statin*, comes from the Greek word *stasis* which means "to keep steady".

The gene related to the myostatin protein is known as the MSTN gene. The two different versions of the gene—called **alleles**—cause two different versions of the myostatin protein. In addition to cattle, the allele that leads to the heavily muscled phenotype has also been found naturally occurring in dogs, sheep, and one human.⁷ In addition to mice, scientists have been able to change the genetic material of pigs⁸, rabbits⁹, fish¹⁰, and goats¹¹ so they have the allele to produce partial myostatin proteins and have extra-big muscles too.

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Reading: Version 2: New Protein Linked to the Heavily Muscled Phenotype

Three scientists named McPherron, Lawler, and Lee were working together in 1997. They identified a protein in the muscles of animals. At the time, they called the protein GDF-8. Now we call it myostatin. These scientists thought this protein was related to the heavily muscled phenotype in some animals. They tested their thinking using mice. They did this by changing the structure of the mouse chromosomes in just one place. The specific region of a chromosome that directs the body to make a specific protein is called a **gene**. The scientists found the gene, that specific place on the chromosome they thought was related to the myostatin protein. They used a technology called **gene targeting** to change the shape of this gene in a few mice cells. In gene targeting, scientists can replace just a specific region of a chromosome with a different structure.

By changing the shape of the gene, the scientists created a different allele of the gene. Different forms or versions of genes are called **alleles**. The scientists carefully observed the cells that had the different allele. They found a different version of the myostatin protein in those cells. This new version of the protein looked similar to the usual myostatin, but its shape was slightly different. The scientists predicted that this differently shaped myostatin protein would function differently than the usual one. They thought that if animals' bodies made this different protein, they would observe extra-big muscles in those animals.

To test their hypothesis, they raised mice who had this different allele of the gene for myostatin. Some of the mice had two copies of the changed allele, and some had only one changed allele (along with one typical one). They also raised mice with two copies of the allele they usually have, with no changes to that gene. The combination of alleles an organism has of a certain gene is called its **genotype**.

The mice whose genotype was two copies of the changed allele had only the differently shaped version of the myostatin protein. They also weighed 2-3 times more than mice with the genotype found in typically muscled mice. The mice with the two copies of the changed-allele genotype also had 86% more muscle fibers than the typical mice had. So, the scientists concluded that changing the structure of the gene resulted in the production of the differently shaped myostatin protein. Then this differently shaped version of the protein resulted in mice with the heavily muscled phenotype.

Summarized from McPherron, A. C., Lawler, A., & Lee, S. (1997). Regulation of skeletal muscle mass in mice by a new TGF- β superfamily member. *Nature*, 387, p. 83–90. doi:10.1038/387083a0

Reading: Version 2: Function of the Myostatin Protein

The function of myostatin

You already know that actin and myosin are proteins with structures used to build and move muscles. Myostatin is another protein involved with animal muscles¹. However, it has a different function than actin and myosin.

Cells have receptors on them. A **receptor** is a structure that has a special shape and sticks out of the outside of a cell membrane (see figure A). Receptors take messages from outside the cell and bring them inside the cell. The myostatin protein's function is to fit into a receptor and send a message to the inside of the cell (see figure B). A myostatin protein usually has a shape that lets it fit into its receptor like a key fits into a lock.

Figure A

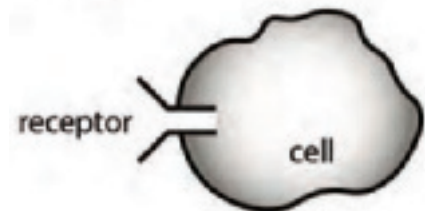
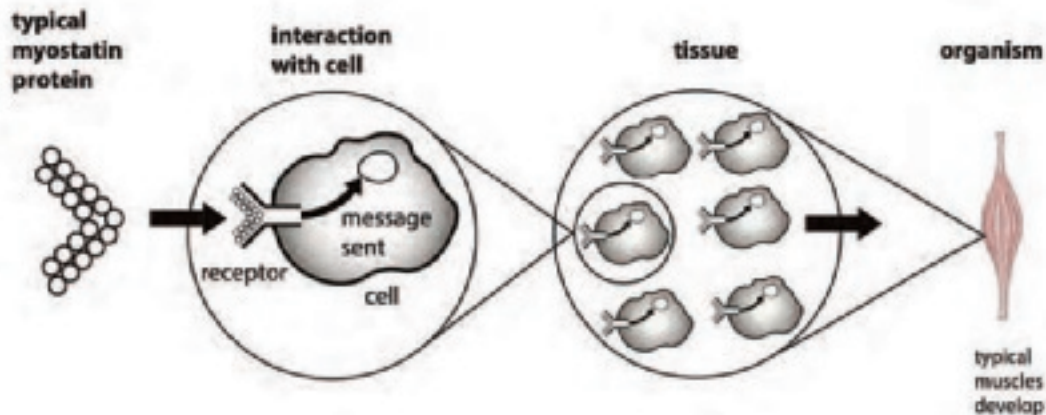


Figure B

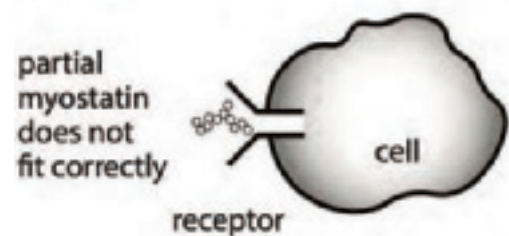


In just one cell, you may not notice the effect of myostatin's message. But, if you look at an entire animal with fully formed myostatin proteins, you will see that it has typical muscles².

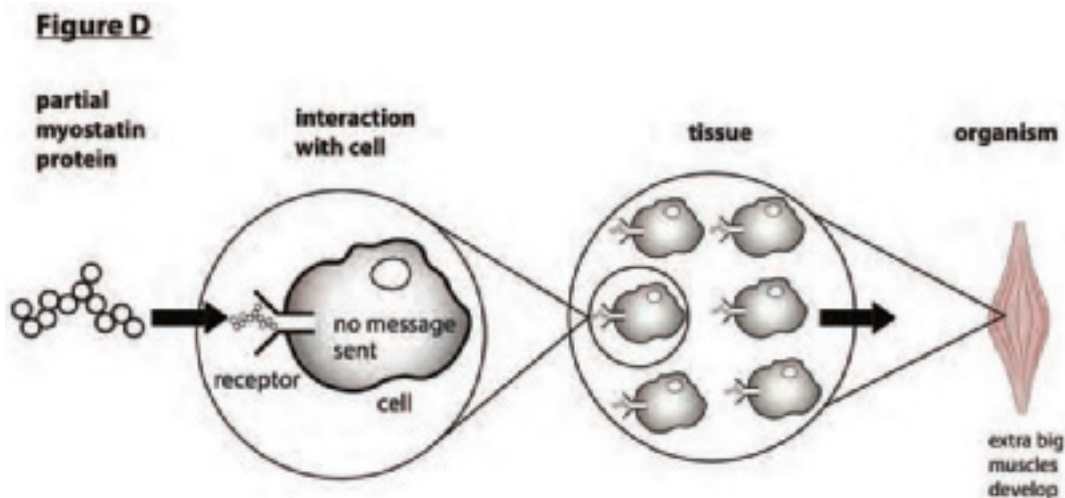
The effect of partial myostatin

Sometimes a myostatin protein is partially formed. A partial myostatin protein is not the right shape to fit correctly into its receptor (see figure C). If it cannot fit correctly, its message does not get sent into the cell. In just one cell, you may not notice the effect of not getting the message sent. But, if you look at a whole animal with partial myostatin proteins, you will see that it has extra-big muscles (see figure D).³

Figure C



Sometimes an animal's body makes both kinds of myostatin proteins, full and partial. This means some of the animal's cells get myostatin's message and some do not. If you look at an entire animal that has both types of myostatin proteins, you will see that it has somewhat bigger muscles than typical animals.



History of myostatin

Heavily muscled cattle were first discovered in Belgium in the late 1800s.⁴ Until then, farmers had never seen this phenotype in cattle. Heavily muscled cattle produce more beef than cattle with typical muscles. This made farmers interested in heavily muscled cattle. By the 1970s, heavily muscled cattle were being raised in countries other than Belgium, including the United States.⁵

In 1997, scientists were able to investigate the heavily muscled phenotype in mice. They thought the extra-big muscles were being influenced by a certain protein. We now call that protein "myostatin", but back then they called it "GDF-8". The scientists thought they could influence mice muscles by making changes to their chromosomes. Chromosomes are made of different regions or parts called **genes**. The scientists changed the structure of a gene that they thought was related to the GDF-8 (myostatin) protein. When the scientists raised mice that had the changed gene, their bodies produced partial proteins.⁶ These mice also had extra-big muscles. Mice that had the unchanged gene made fully formed myostatin proteins and had typical muscles.

After scientists figured out the function of the protein they called GDF-8, they renamed it myostatin. The word is made from Greek roots. The first part of the word, *myo*, means "muscles". The second part, *statin*, means "to keep steady".

The gene related to the myostatin protein is known as the MSTN gene. There are two possible forms of the MSTN gene, called **alleles**. These two alleles, or versions of the gene, cause the two different versions of the myostatin protein (typical or partial). The allele that leads to the heavily muscled phenotype in cattle has also been found in dogs, sheep, and one human.⁷ Scientists have been able to change the genetic material of pigs⁸, rabbits⁹, fish¹⁰, and goats¹¹ like they did with mice. So, in laboratory studies, those animals can also have the allele to produce partial myostatin proteins and have extra-big muscles.

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Reading: Interview with Penny, Cattle Farmer

Penny, the farmer we interviewed in Lesson 4 who bred heavily muscled cattle for 25 years, discusses which techniques they used when breeding their cattle, which included heavily muscled and typically muscled cattle. Here is what she said.

It depends on what traits you are working for in your animals. We were working for better hooves in our cattle than what the breed has in Europe. Here, our animals were more active and had to walk around more than in Europe. This really has to do more with what we are using them for versus what farmers in Europe use the cattle for. In Europe, the heavily muscled cattle are used for both meat and dairy production, while here, we only use them for meat. Our cattle need to be more mobile and are housed with non-heavily muscled cattle, but in Europe they really only live in a barn and don't move around much, so having good hooves and legs aren't as important to farmers there as it is here.

We also looked for pelvic readings in both the bulls and heifers (female cattle) because heavily muscled cattle need to be born by C-sections since they are so big. Over our time having cattle, around 25 years, we were able to selectively breed our cattle so that our last heifer could give birth to all her calves naturally. Our first heifer had to have C-sections for every birth. She had so many C-sections that the doctor was going to have to use her other side due to scar tissue to deliver any future calves. So we looked for bulls and heifers with wider pelvic readings to make sure they had easier births.

If we were breeding purebred heavily muscled cattle, we typically used AI, or artificial insemination, to make sure that we could get the two traits we were looking for. We did this a lot of time because many of the bulls were related to the heifers we wanted to breed, so we needed to avoid that or because we wanted to see what traits would happen if we used different bulls with our stock.

If our bull didn't have those traits we were selecting for, we'd let him out in the pasture with our commercial herd, or non-heavily muscled cattle. So sometimes we would end up with calves that were heavily muscled and other times they wouldn't be. For those that aren't purebred, you wouldn't know if they were heavily muscled until they were three or four weeks old. Some of them would look in-between, some weren't heavily muscled at all, and others looked purebred.

One of the best things about the heavily muscled cattle is the quality of their beef. Their meat is real low in cholesterol, it's up there with chicken breast. You also get a lot more meat from one heavily muscled cow than a non-heavily muscled cow. So it's a lot healthier than most other red meat, and because you get more meat from one cow, it's better economically for the farmer.

Reading: Raising Heavily Muscled Cattle to Reduce Environmental Impacts of Cattle

The cattle industry has been facing an ever-increasing dilemma—How can we increase supply of beef without further disrupting the environment?¹ While there are many possible solutions, one solution, raising heavily muscled cattle, has become increasingly popular. Many of the problems associated with these cattle, like increased birth weight resulting in C-sections, have been able to be reduced through selective breeding.

Early in the development of the breed, performing C-sections was considered normal as it was the least stressful on the mother and calf.² Farmers would register their animals after birth to be entered into a Herd-Book and were then ranked and categorized based on many selection criteria, including skeletal and muscular shape, leg soundness, ability to move, and absence of mouth defects.² This would give farmers a way to be able to shape their herd based on desired traits to improve the heavily muscled breed. Most of the registered births for heavily muscled cattle are the result of AI, or artificial insemination.² In AI, sperm from bulls is collected and can be sold or used by a farmer to breed a certain heifer, or unmated female. The sperm is inserted into the heifer using special tools to ensure successful fertilization.

In Denmark, the National Cattle Committee raised concerns over the high rate of C-sections in the breed, over 50%³. An action plan was created to reduce the use of C-sections to between 5% and 10% in 5-10 years³. The plan included selecting bulls that were known to not cause breeding difficulties and controlling the diet of pregnant heifers to reduce birth weight of the calf. Due to this plan, by 2013 the rate of C-sections in heavily muscled cattle in Denmark was below 10%. The use of selective breeding in the Danish cattle community was shown to reduce one of the negative effects of heavily muscled cattle. The use of AI has helped improve the breed, not only in Denmark but around the world, making it a more viable option for many farmers.

There are many benefits to raising heavily muscled cattle. They have a higher yield on meat than non-heavily muscled cattle.^{4,5,6} The meat yield from heavily muscled cattle has less marbling, or fat content, and was found to be almost as tender as meat from non-heavily muscled cattle.⁶ The heavily muscled cattle required less food and had a higher rate of gain than their non-heavily muscled counterparts.^{4,6} The lower fat content results in meat that is healthier since it is lower in cholesterol compared to meat from non-heavily muscled cattle. Increased yields and reduced feed requirements will help reduce the impact raising cattle has on the environment. Through the use of selective breeding, many of the issues that may have prevented farmers from choosing to raise heavily muscled cattle can be combated and can result in more farmers choosing to raise this breed.

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Reading: Interview with Wilbur, Cattle Breeder

Interviewer: My first question is, when you are deciding which of your cattle to breed, what traits or variations of those traits are you selecting for? What are you looking for in your cattle?

Wilbur: In our cattle, there are several things we're looking for. We're looking for longevity, we're looking for disposition. Now, if you don't have disposition in an animal, you might as well not have it. So if it passes that criteria, then we like to look at longevity and the muscle pattern.

Interviewer: Will you explain what you mean by longevity?

Wilbur: Longevity is how long the animal is in your herd. If they are structurally correct, if their feet and legs are right, they will be with you a long time. If they have problems in these areas, they will not last very long.

Interviewer: Tell us why. What are the benefits of the muscle patterns you're looking for? Why do you like the cattle with the heavy muscles?

Wilbur: The muscle pattern, it's very simple. We have an expanding population. We need to grow more food each year. It's important that we have protein in our diet. And whenever you can take an animal that will probably give you about 20% more meat on a carcass, it's extremely important.

Interviewer: So I hear you saying it's going to give us more meat from the cattle that you're raising versus another kind of cattle that doesn't have that heavy musculature. You're still raising as many animals, but you wouldn't get as much meat from them.

Wilbur: Correct.

Interviewer: Then I'm wondering if there are any drawbacks to the heavy muscles, to breeding those animals? Are there any negatives that you've seen to it?

Wilbur: The negatives would be if they were not structurally correct in their makeup and if the females had a problem with the birth procedure. That's why we have taken and modified the appearance a bit. We kept all the assets of the extremely heavy-muscle animals, but we put it in a package where it was acceptable to the American way of raising beef.

Interviewer: So you've been selecting for specific traits that make them more appealing to cattle owners here in the US. Tell us a little bit more about what things you're looking for specifically.

Wilbur: First off, I guess we looked at the characteristics that will add to longevity, and that's the correct placement of feet and legs. That is the correct structure of the rump area, because when you take a big animal, you need big feet to carry that animal. I guess that is the main thing that we have changed in Americanizing the Belgian blue cattle.

Interviewer: So, why do people want to raise these heavily muscled cattle? Why do people want to buy them? What are the benefits that you see to this breed?

Wilbur: Our society today on the average are having a weight problem. And to help correct that weight problem that we're having in our society, protein can make a tremendous difference in

that. So I guess we wanted to keep the taste and tenderness that our other breeds exhibit, but yet bring in more muscle, take out cholesterol and calories, have an eating experience that is as good as you can get—a lean hamburger, lean steaks that taste out of this world, and getting you fewer calories and less cholesterol than skinless chicken breasts, which are supposed to be the healthiest in the meat line.

Interviewer: So it seems like people who are trying to watch their weight or be careful with the food that they eat might choose to buy beef from these cattle instead because it's lower in, you said cholesterol, lower in calories than typical beef would be, but still tastes good?

Wilbur: Exactly. You don't want to lose the taste or tenderness in your eating experience. And if you can keep this with the healthy aspects, it's kind of a no-brainer, you need to do it.

Reading: How do we get new tulip variations?

This week's #TulipFact: One of the best features of tulips is their incredible variety. Look anywhere you can buy tulips to plant and you will be treated to dozens of unique colors, shapes, and sizes—all beautiful in their own right. What you will not see is the work behind every breed: each one can require decades of time and effort before being mature and robust enough to be shared with the world.

Every variation of tulips sold today was started when genetic material from different flowers combined to create a new, unique seed. Breeders in Holland and around the world will pick particular flowers to attempt to mix or cross them in the hope of creating new variations.

Then breeders take the freshly formed seeds, and this is where the long, patient adventure truly begins. After being planted in soil, a flower does not appear from the seed right away. Instead, the plant produces only leaves—capturing the Sun's energy and using it to grow and strengthen the bulb below. The bulb is the part of the plant underground that has roots at one end and a stem growing from the other end. The bulb continues to grow and produce only leaves for not one, not two, but for seven years before it makes a flower. Seven years during which a breeder does not yet know what the final flower even looks like.

Once a new flower emerges, healthy and robust, the work continues! A decision is made on whether the flower will appeal to the tulip lovers of the world—Is it something that, among the countless varieties already sold today, will stand out and be desired? This is not a decision to be taken lightly, and the vast majority of new variations will be turned down. Why? Because it can take approximately fifteen years of hard work to take a single flower and get it to a point of having enough tulip plants to sell.

The problem of getting more flowers sounds relatively simple—we have one flower we like, so now we need more. To do this, growers focus on bulb offshoots. Bulb offshoots are smaller bulbs that grow from the side of the original tulip bulb underground and can be separated from the main bulb and planted to grow into a separate flowering plant. In this way, growers can be assured of getting the same flower and appearance as the original bulb. If they relied on seeds, they would



likely get a mixture of different flower variations. It may take fifteen years, but the power of multiplication can turn the single flower into thousands of identical flowering plants. The first bulb generates 3-4 offshoots each season, which then mature and each generate 3-4 more offshoots, which then mature and do the same. Eventually, with thousands of flower bulbs available, the tulip variety will be ready for sale. Mature bulbs are sold to wholesalers and retailers, who then pass them on to consumers for use in gardens.

Reprinted with permission and modifications from: Amsterdam Tulip Museum. (2017). How do we get new tulip breeds? Retrieved from <https://amsterdamtulipmuseumonline.com/blogs/tulip-facts/how-do-we-getnew-tulip-breeds>

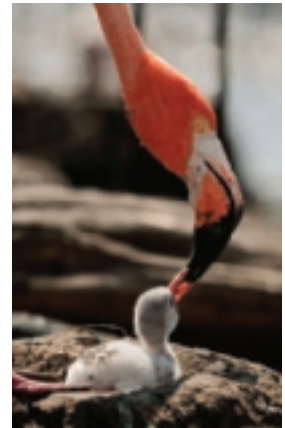
Reading: Two Examples of Environmental Influences on Trait Variation

Flamingo Coloring

Flamingos are born with gray feathers. They change color as they grow. Their color depends on what they eat. Some flamingos eat more algae and less brine shrimp in their diet, while others eat more brine shrimp and less algae.

The algae and brine shrimp that flamingos eat both contain pigment molecules called *carotenoids*. The carotenoids are broken down into pink and orange pigment molecules in the liver of the flamingo. Then these pink and orange pigments are absorbed by fats in the feathers, bill, and legs of the flamingos. Flamingos that eat brine shrimp are not as deeply colored as flamingos that eat algae.

Flamingo colors depend on the food available where they live. Flamingos that live in drier areas usually eat more shrimp and have a lighter pink color. More algae is available in wetter areas, so flamingos that live in those habitats have deeper colors. Flamingos in captivity are fed a special diet that includes prawns (that are also colored like brine shrimp) or their food has extra pigments added in. If they did not have these certain components of their diet, they would be white or very pale pink.



Apple Coloring

Apples get their red color from a pigment molecule called *anthocyanin*. The redness of an apple depends on how much of the anthocyanin pigment is in its peel. How much anthocyanin pigment develops in a ripe apple depends partly on the genes of the apple because genetic information gives directions to form the proteins that make the pigment. Some varieties of apples, such as Granny Smith, are more greenish-yellow than others. They do not develop as much red coloring because their genes do not influence the production of much anthocyanin. Varieties that are partly or fully red, such as Red Delicious and Honeycrisp, have genes that do influence the production of more anthocyanin. But exactly how red the apples become is influenced by environmental factors as well.



Temperature plays a significant role in how much anthocyanin an apple produces. Lower temperatures increase the amount of anthocyanin in an apple's peel, and higher temperatures reduce it. So, Honeycrisp apples from cooler northern areas have brighter-red blush or stripes than those grown in warmer climates.

The amount of light apples get as they grow also affects the redness of their color. More light on the fruit generally means they will have more red coloring. Farmers may prune off branches on an apple tree that are not producing fruit to avoid shading the fruit that is growing. Some farmers also place reflective materials below their apple trees to direct more sunlight onto the fruit.

Other environmental factors have less impact on apple color, but still can play a role. For instance, apples will not have as much red coloring if the tree is stressed by trying to grow too many fruits, if it has not had enough water, if insects are eating its leaves, or if it does not have enough nutrients.

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Reading: Arm Span Length

For many years, humans have been investigating why people come in different shapes and sizes. Scientists think that the length of people's limbs (arms and legs) is largely influenced by many different genes they have inherited. The inheritance of these gene alleles from one's parents helps explain why children usually grow to be approximately the same size as their parents, but different combinations of alleles can cause siblings to be different sizes.

Scientists only partially understand which genes affect the length of a person's arms or legs. For example, more than 700 genetic variations related to height have been discovered, and many more are expected to be identified. Some of these variations are in genes that affect growth plates, which are areas in the long bones of the legs and arms where new bone cells are produced, lengthening the bones as children grow. The function of many other limb-length-associated genes remains unknown.

Scientists have identified some very rare alleles that can have dramatic effects on people's limb length. For example, variants in the *FGFR3* gene cause a form of short-limbed dwarfism. Another example is the *FBN1* gene, related to Marfan syndrome. Individuals with Marfan syndrome are usually tall and slender, have elongated fingers and toes, and have an especially long arm span. However, these conditions, where a single gene can have such a dramatic effect on a limb length, are rare.

For most people, the size of their limbs is also influenced by environmental factors. Whether a mother smoked or ate nutritious foods while pregnant can impact the size of a child. A child who is well nourished, healthy, and active is likely to grow to have longer limbs as an adult than a child who had a poor diet, infectious disease, or inadequate health care.

Adapted from US National Library of Medicine, National Institutes of Health, Department of Health & Human Services. (2020). Is height determined by genetics? Retrieved from <https://ghr.nlm.nih.gov/primer/traits/height>

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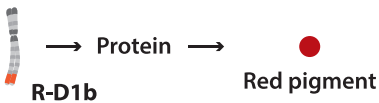
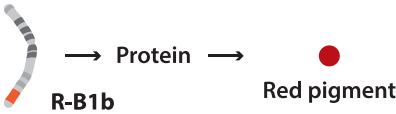
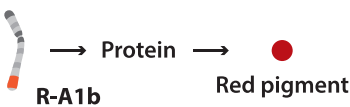
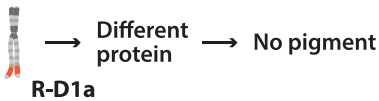
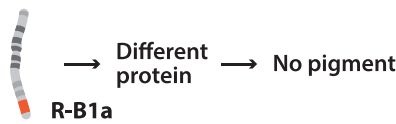
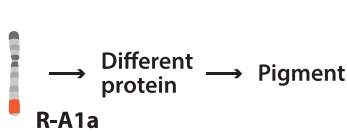
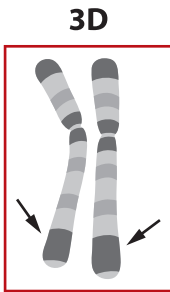
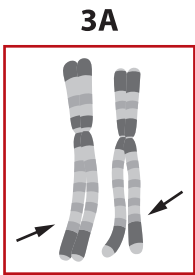
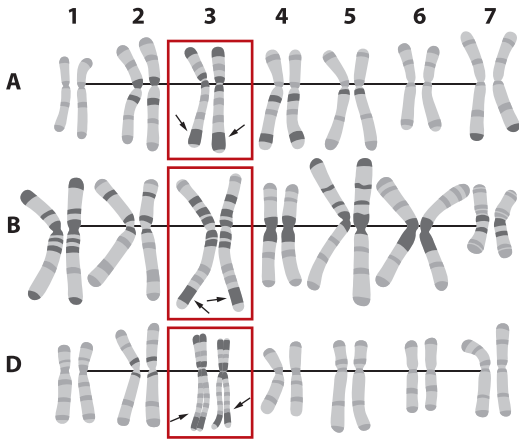
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Reading: Color of Wheat Kernels

The red seed coat color in wheat is a highly heritable trait that is determined by *R* genes located on the end of the long arms of chromosomes 3A, 3B, and 3D.

The alleles that are related to the red color in wheat kernels are designated *R-A1b*, *R-B1b*, and *R-D1b* (McIntosh et al., 1998). Plants having either *R-A1b*, *RB1b*, or *R-D1b* on a single chromosome is sufficient for their kernels to show some red color. The degree of red color is additive—the intensity depends on the number of pigment-producing *R* alleles found on an individual plant's chromosomes (Metzger & Silbaugh, 1970). The alleles related to a light-cream color are *R-A1a*, *RB1a*, and *R-D1a* (McIntosh et al., 1998). These alleles do not produce the protein that leads to the production of red pigment (Dupont & Altenbach, 2003). Since the red pigment is formed using a protein, if the protein does not have the proper structure, or is not produced at all, the pigment will not be formed.

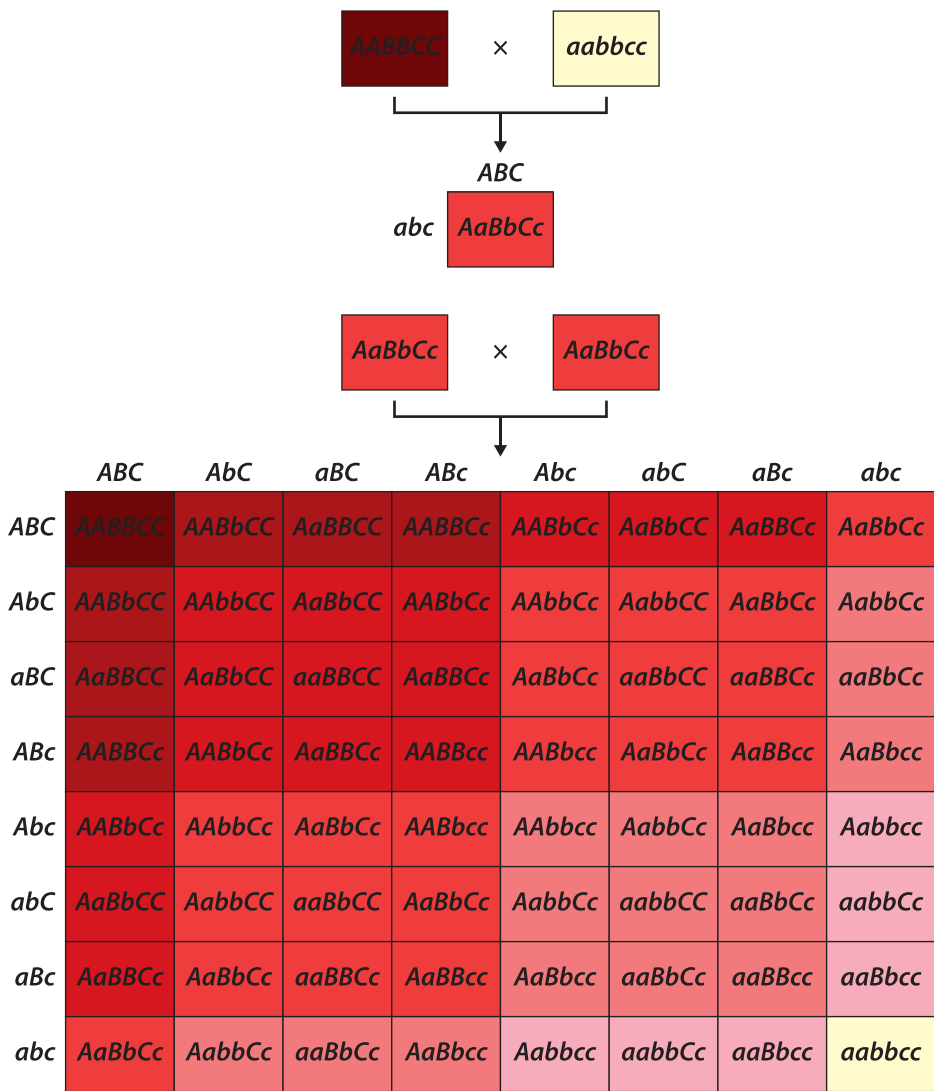


Possible allele combinations	Relative amount of pigment produced
R-A1b R-A1b	●●
R-A1a R-A1a	
R-A1a R-A1b	●
R-A1b R-A1a	●

Possible allele combinations	Relative amount of pigment produced
R-B1b R-B1b	●●
R-B1a R-B1a	
R-B1a R-B1b	●
R-B1b R-B1a	●

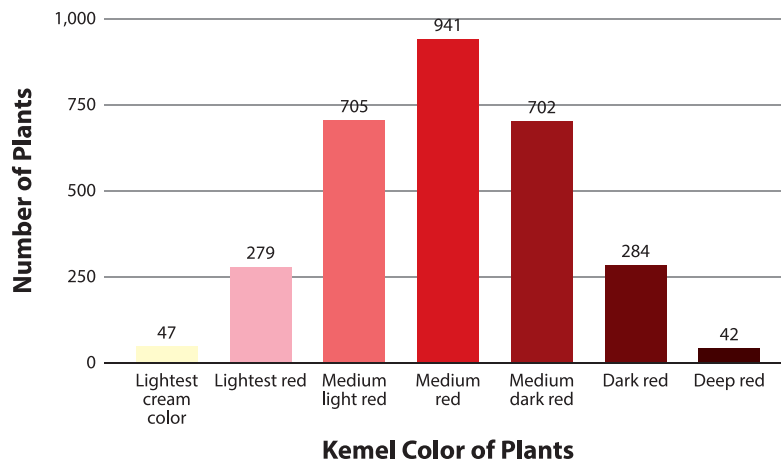
Possible allele combinations	Relative amount of pigment produced
R-D1b R-D1b	●●
R-D1a R-D1a	
R-D1a R-D1b	●
R-D1b R-D1a	●

As a result of each protein-producing allele having the capability of contributing a bit more pigment, the seed kernels could have many shades of red, all depending on which versions of the alleles the plant receives from its parents. When a plant that produces light-cream kernels is crossed with a plant that produces the deepest red kernels, all of the offspring plants produce medium red kernels. When two plants that produce medium kernels are crossed, the resulting plants have much more variation in kernel color.



Note: Capital letters (A, B, and C) are used to represent the alleles that produce a protein and lower-case letters (a, b, and c) are used to represent alleles that do not produce a pigment.

This now explains why when two medium-red plants are crossed, there is a much-smaller number of the deepest red-colored and the lightest cream-colored kernels. Through careful crosses scientists discovered there are many kernel color categories that result from crossing the plants with medium-red kernels.



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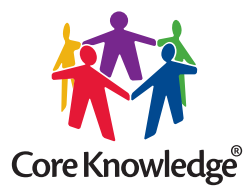
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Unit Development Team

Gail Housman, Unit Lead, Northwestern University

Tara McGill, Field Test Unit Lead & Reviewer, Northwestern University

Holly Hereau, Writer, BSCS Science Learning

Natalie Keigher, Writer, Lisle Junior High School

Karin Klein, Writer, Independent Contractor, Northwestern University

Wayne Wright, Writer, BSCS Science Learning

Michael Novak, Simulation Design, Northwestern University

Katie Van Horne, Assessment Specialist, Concolor Research

Ravit Golan Duncan, Advisory Team Chair, Rutgers University

Brian Donovan, Advisor, BSCS Science Learning

Carrie Tzou, Advisor, University of Washington, Bothell

Barbara Hug, Advisor, University of Illinois at Urbana-Champaign

Andrea Poppiti, Field Test Teacher and Advisor, Virginia Beach City Public Schools

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 Corey Baerlocher
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Kyle Kehrli and Wilbur Kehrli, American Blue Cattle Breeders, Winthrop, IA
 Connie Brooks, MNP Farm, Fair Grove, MO
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