ADAPTATION INTRODUCTION

Students think about and discuss why animals have certain traits, then use the fossil record to examine how the structure of a giraffe's neck provides an adaptive function.

SOUTH CAROLINA STATE STANDARD	8-LS4-1 Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operated in the past as they do today. *Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.* *State Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.* 8-LS4-2 Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer their ancestral relationships. *Clarification Statement: Emphasis is on explanations of the ancestral relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.* *State Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures.*
NEXT GEN STANDARD	MS-LS4-1 Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past. MS-LS4-2 Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.
LEARNING OBJECTIVE(S)	- Students will be able to evaluate fossil records to determine patterns and evaluate evidence. - Students will be able to recognize the impact of the environment on structure and how this relationship affects organism ability to survive and reproduce. - Students will be able to engage in discussion where they

	can ask questions, defend their interpretations, and work collaboratively. - Students will be able to determine how changes in structure can impact function. - Students will be able to identify cause and effect relationships and provide evidence for these relationships.
ESTIMATED TIME	Two 45 minute class periods

WHAT YOU'LL NEED:

This activity requires a set of adaptation cards. Two sets of laminated cards are provided with the box.

WHAT YOUR STUDENTS SHOULD KNOW BEFORE:

Some general knowledge of adaptation and evolution may be helpful, but not necessary since this activity is designed for students to hypothesize and figure out what effects adaptation and evolution have.

WHAT TO DO BEFORE YOUR CLASS:

Make sure you have adaptation cards, which are available to print in the appendix or are provided as laminated cards in the box.

HOW TO SET UP YOUR CLASS:

Students will work individually, and then discuss their findings in small groups. This may include the grouping of desks if desired.

WHAT YOU NEED TO KNOW FOR YOUR SAFETY:

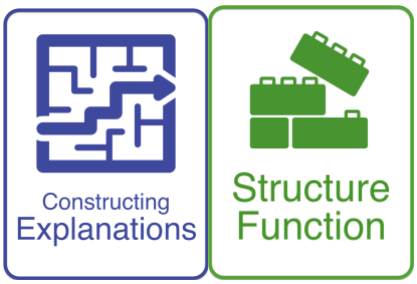
None

This lesson has been designed to follow three dimensional learning, as described in NGSS standards. In this teacher version, we annotate the associated Science and Engineering Practices and Cross-Cutting Concepts using icons (from these NGSS Planning Cards) before the relevant student question and blue and green text, respectively, within the student instructions. Additionally, content and questions that specifically address the Disciplinary Core Idea is represented in orange text. Sample student responses, classroom recommendations, and other hints are in *red italicized text*. See https://scienceweb.clemson.edu/beakerbox/ for additional files such as non-annotated student versions, Spanish versions of student materials, and slides.

ADAPTATION INTRODUCTION

Student activity instructions:

1. Randomly choose one adaptation card from the set of cards.



2. Think about the question on the card. In 3-4 sentences, write down how or why your animal or plant has this feature. Include in your explanation below why you think this structure might help this animal or plant function in its environment.

This activity allows students to begin thinking about adaptations of different organisms and how they benefit from these different traits as they work toward constructing an explanation.

There are 16 unique adaptation cards, so several students may have the same cards.

Some examples of student responses may include coloration, camouflage, spines for protection, size of certain structures, etc.

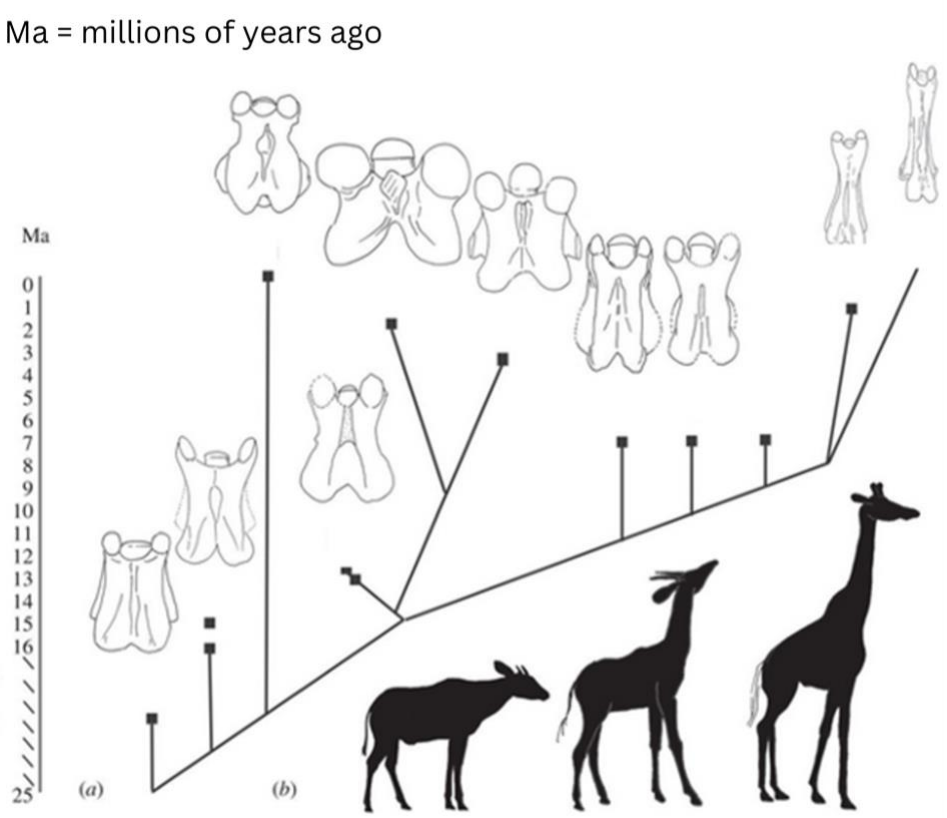


3. Share your thoughts with one or two classmates.
    a. Do you agree or disagree with your classmates' thinking?
    b. What questions do you have about your or your partner's animal's adaptations in general?
    c. What information would help you better evaluate their thinking?

NOTE: This can be done in small groups or as a class. Use these students' questions to create a driving question board.

#1-3 can be repeated for as many adaptation cards as you would like.

Figure 1: Fossil Record of Giraffe



(c)

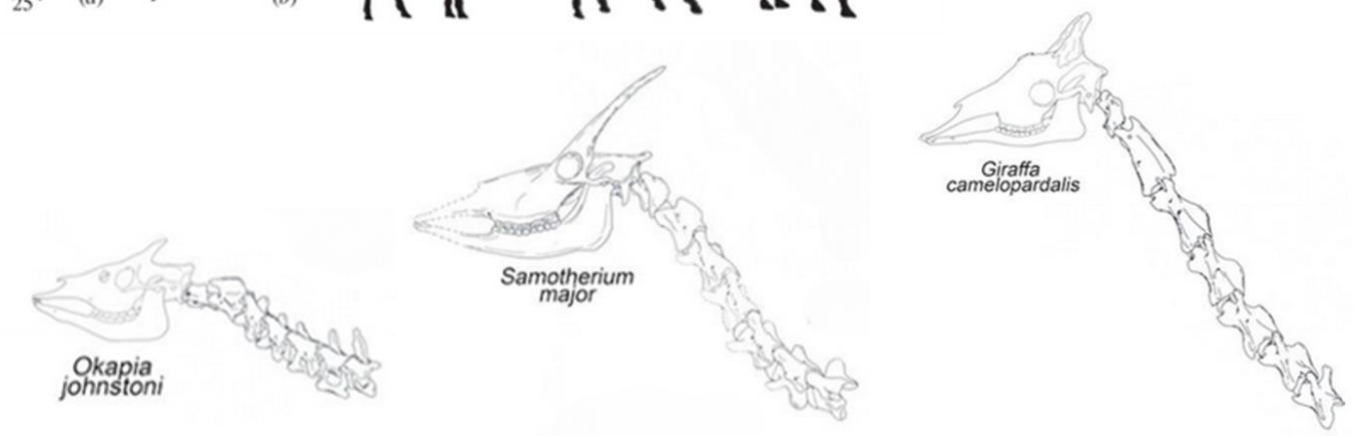
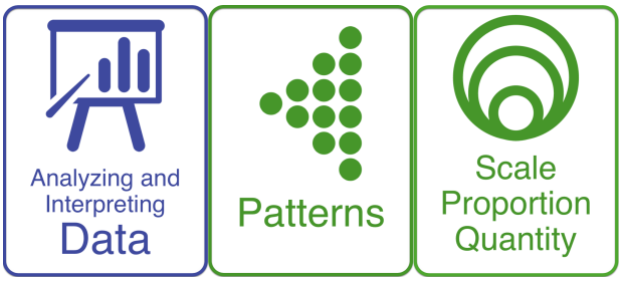


Figure from Danowitz, Vasilyev, Kortlandt, and Solounias. 2015. Fossil evidence and stages of elongation of the *Giraffa camelopardalis* neck. *Royal Society Open Science* 2(10): 150393. doi:10.1098/rsos.150393

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4. The above data shows a fossil record of a giraffe. The image shows how their vertebrae (back and neck bones) have changed (adapted) over time. The oldest giraffe ancestor species called *Okapia johnstoni* is shown at the left of part c, and the most recent giraffe species called *Giraffa camelopardalis* is shown on the right of part c.
    a. When you analyze the data in these images, what parts of the giraffes' neck stayed the same and what parts changed? Write your observations in the box provided.
    b. How does the size of vertebrae in the neck relate to the overall proportion of the body? Write your observations in the box provided.

This question prepares the students to write an explanation in question 5

Some concepts to point out here would be the way giraffes don't have more vertebrae than other animals, they are simply larger in size (they have gotten larger over time). This is what creates their very long necks.



5. Explore one or more of the resources provided by your teacher to answer this question.

See the youtube videos, articles, and images below.

    a. How does the structure of the modern giraffe neck provide advantages or disadvantages to how the animal lives and functions?
    b. How do you think the changes over time in the giraffes' necks have affected a giraffe's ability to survive?

Provide explanations 5a and 5b below. Be sure to include evidence to back up the explanations!

Class discussion is possible here (feeding, battling for reproduction rights, battling predators, etc.)

- *A concept to point out here is Structure before function. The change in structure allowed for greater survival (greater function) and therefore more reproduction of those genes*
- *Class discussion is helpful to hear student thinking and address misconceptions*

RESOURCES FOR QUESTION 5

(1) Youtube videos showing giraffes using their necks for various functions in the wild:

- https://www.youtube.com/watch?v=ZKL87WUPAks
- https://www.youtube.com/watch?v=uIquHbS3wHg

(2) Reading about a scientific study on giraffes, including hypotheses about the evolution of neck length:

New Study on Giraffe Neck Evolution: AMNH. American Museum of Natural History. (2022, June 3). https://www.amnh.org/explore/news-blogs/research-posts/giraffe-neck-evolution

Reading Support option: For students with lower Lexile levels, students can read the lower Lexile level article and then read the upper Lexile level article. The two copies of the article cover the same content but with different vocabulary. Students can identify and circle new terms in the higher Lexile article to support new vocabulary development and reading comprehension.

Lexile Level	1410-1600 (HS+ Level)	1010-1200 (8th Grade-HS level)	810-1000 (5th Grade-7th Grade)
Copy of Article	PDF of Original Article	Adapted Article Copy 1	Adapted Article Copy 2

(3) Images of giraffes using their necks:









OPTIONAL EXTENSION AFTER STUDENTS COMPLETE QUESTION 5:



Students have been exposed to two hypotheses about why giraffes have evolved long necks. Engage students in a class debate where they discuss the merits of each hypothesis. Have students conduct additional research and list evidence under each hypothesis. *Note: This would be a good opportunity to teach students how to determine source credibility.*

Hypothesis 1: Giraffes evolved long necks in response to food pressures.	Hypothesis 2: Giraffes evolved long necks in response to reproductive pressures.

Appendix: Adaptation cards

Why do pufferfish expand in size?



Why do giraffes have long necks?



Why do hummingbirds have long beaks?



Why do cacti have spikes?



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Why do dart frogs have bright colors?



Why do only male peacocks have large, colorful feathers?



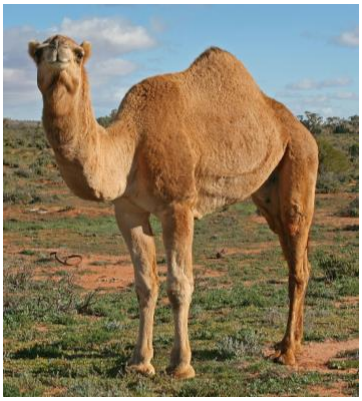
Why do turtles have a hard shell?



Why do chameleons change colors?



Why do camels have humps?



Why are polar bears white?



Why do pelicans have large, deep beaks?



Why do sloths move slowly?



Why do cheetahs run so fast?



Why do zebras have stripes?



Why do squid shoot ink?



Why don't snakes have legs?



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BIRDS AND THEIR BEAKS PART 1

Students experience first-hand how different characteristics can provide an advantage to individuals by "eating" with distinct "beaks," graph and analyze this data, and apply their results to explain the effects of adaptations on changes in the ecosystem or environment.

SOUTH CAROLINA STATE STANDARD	8-LS4-4 Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individual's probability of surviving and reproducing in a specific environment. *Clarification Statement: In a specific environment impacted by different factors, some traits provide advantages that make it more probable that an organism will be able to survive and reproduce there.* *State Assessment Boundary: Assessment is limited to using simple probability statements and proportional reasoning to construct explanations.* *Birds and their Beaks Part 1 works towards this standard. It introduces the idea of variation within a population and survival within the environment. If you also do Birds and their Beaks Part 2, the standard will be fully addressed. Birds and their Beaks Part 2 can be done without Birds and their Beaks Part 1.*
NEXT GEN STANDARD	MS-LS4-4 Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individual's probability of surviving and reproducing in a specific environment. *Birds and their Beaks Part 1 works towards this standard. It introduces the idea of variation within a population and survival within the environment. If you also do Birds and their Beaks Part 2, the standard will be fully addressed. Birds and their Beaks Part 2 can be done without Birds and their Beaks Part 1.*
LEARNING OBJECTIVE(S)	- Students will be able to recognize and explain the interaction between the environment and an organism's traits. - Students will be able to explain how some traits increase some individuals probability of surviving - Students will graph data and recognize patterns across multiple repetitions.
ESTIMATED TIME	Two 45 minute class periods

WHAT YOU'LL NEED:

All of the items can be purchased from a local craft store, big box store, or online. Example products from Amazon are provided as links. The box provides the materials for 30 students, with a single bag per student containing the below:

1. 5 soft pom poms. The box includes 0.75 to 1 inch pom poms as we found this to be the most useful size (example product).
2. 15 pony beads (example product).
3. Approximately 15 rice grains (a generous pinch). *We find arborio rice to work the best* (example product). *White rice and other thin grains are not able to be picked up with binder clips.*
4. Any container ("stomach") to collect pom poms, beads, and rice. For example, this can be a lunch size paper bag (example product), plastic cup ~7oz or larger (example product), or a sandwich size reclosable bag (example product).
5. One small 0.75" binder clip (example product) and one large 1.25" binder clip (example product). *Alternatively, using fingers or clothespins may be more accessible for students with mobility limitations: mini clothespin* (example product) *and large clothespin* (example product).
6. You may want paper plates or lunch trays to help students keep their materials contained.

WHAT YOUR STUDENTS SHOULD KNOW BEFORE:

Some general knowledge of how certain characteristics serve a certain function may be helpful, but not necessary since this activity is designed for students to hypothesize and experiment with this concept.

WHAT TO DO BEFORE YOUR CLASS:

Here is an example of a student's materials including pom poms, beads, and rice, and two "beaks." Not pictured is a bag or cup.



HOW TO SET UP YOUR CLASS:

This activity can be completed by students working individually or in pairs to collect the data.

WHAT YOU NEED TO KNOW FOR YOUR SAFETY:

Small beads could be a choking hazard.
Binder clips can pinch skin.

This lesson has been designed to follow three dimensional learning, as described in NGSS standards. In this teacher version, we annotate the associated Science and Engineering Practices and Cross-Cutting Concepts using icons (from these NGSS Planning Cards) before the relevant student question and blue and green text, respectively, within the student instructions. Additionally, content and questions that specifically address the Disciplinary Core Idea is represented in orange text. Sample student responses, classroom recommendations, and other hints are in *red italicized text*. See https://scienceweb.clemson.edu/beakerbox/ for additional files such as non-annotated student versions, Spanish versions of student materials, and slides.

BIRDS AND THEIR BEAKS PART 1

Student Activity Instructions:

Phenomenon:



Green anole lizards are common in South Carolina. Recently, scientists have observed that the green anole lizards in Florida have larger toepads and more scales than previous generations of lizards.

Image: "Strawberry" redux- wild green anole, Vicki DeLoach, https://www.flickr.com/photos/vickisnature/6481619097



Another scientist was interested in guppies. He moved a population of guppies into a predator-free stream to see what happened. The guppies grew larger, matured later, and reproduced slower. However, the guppies in the stream with predators matured earlier and reproduced faster.

Image: Trinidadian guppy (Poecilia reticulata) male and female.png
https://commons.wikimedia.org/wiki/File:Trinidadian_guppy_%28Poecilia_reticulata%29_male_and_female.png#/media/File:Trinidadian_guppy_(Poecilia_reticulata)_male_and_female.png



Bedbugs are pesky animals. When DDT (a powerful pesticide) was introduced after WWI, bedbugs seemed to go away for a while. Now, they are back and more resistant to (unaffected by) pesticides.

Image: bedbugs, Charles LeBlanc, https://www.flickr.com/photos/httpoldmaisonblogspotcom/4244054615

From these examples, it is evident that sometimes populations change. The driving question for this lesson, which you will work to answer throughout the activity is, how do populations change and why?

Note for teachers: We are emphasizing that populations change over time. Individuals themselves do not change.

In 1977 and 1978, Rosemary and Peter Grant noticed a change in the population of medium ground finches (*Geospiza fortis*) on the Galapagos Islands. They had been collecting data and studying these famous birds for a number of years when they noticed a dramatic shift in the size of bird beaks within the population of medium ground finches.

Additional questions to think about and add to the driving question board:
What caused this sudden change in the population of medium ground finches? How can we explain this change in the medium ground finch population and use what we learn to understand how other populations of other animals change?

You can have students generate additional questions for the driving question board or work together as a class to generate additional questions.

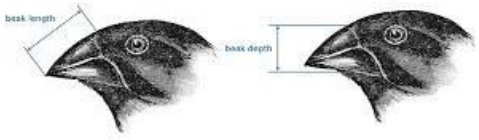


Figure 1: Beak Measurements Diagram
Image: retrieved from: http://bebi103.caltech.edu.s3-website-us-east-1.amazonaws.com/2019a/content/homework/hw3/hw3.2.html

In this activity, you will simulate a population of finches to explore the mechanisms that drive population change.

1. Make some initial predictions about why you think the birds' beaks may have changed.

Answers will vary.



Procedure Instructions:

1. Look at the materials provided by your teacher. You should have the following at your station to carry out your investigation:
    a. Three types of "food" (15 beads, 5 pom poms, 15 grains of rice)
    b. Two types of "beak" (large and small binder clips)
    c. One "stomach" (paper bag, plastic cup, or sandwich bag)

    You may want to have students put the "foods" on a paper plate or lunch tray.
2. You will use your "beak" to collect food, <u>one item at a time</u>, for 20 seconds. On your teacher's cue, begin collecting food using your beak, putting what you pick up in your "stomach."
    If you have a competitive class, consider reducing the time to 15 seconds. For a less competitive class, consider increasing the time to 30 seconds.
3. You can only use the "beak," black part of the binder clip to pick up the "food"
4. Once time is up, put down your "beak." Count and record how many beads, pom poms, and rice you collected during your investigation.
5. Repeat this process (steps 3 and 4) using the second type of beak.
    Conduct a practice round for 20 seconds to allow students to practice using the "beaks" before timing the "official" rounds.

Data Table: Record your data here

Small Binder Clip			Large Binder Clip		
Pom Poms	Beads	Rice	Pom Poms	Beads	Rice
2	3	5	3	9	2

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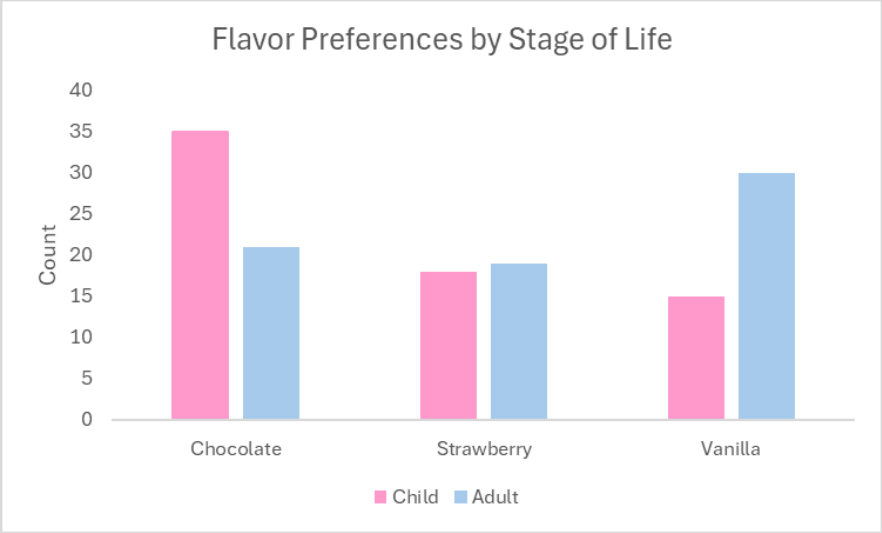
2. Determine your independent and dependent variables.

Use this to scaffold information about variables if needed

An **Independent variable** is the variable being changed or manipulated in an experiment. A **Dependent variable** is the variable that could change in response to changes in the independent variable.

Example: The number of people who like a flavor of ice cream (dependent variable) depends on the age of person asked (independent variable)

You may also have more than one independent variable. Here is a sample bar graph with multiple independent variables.



When graphing, your independent variable goes on the x-axis and the dependent variable goes on the y-axis.

In this investigation, your 3 variables are the type of beak, type of food, and the amount of food gathered. Using this information, determine which 2 variables are independent and which 1 variable is dependent.

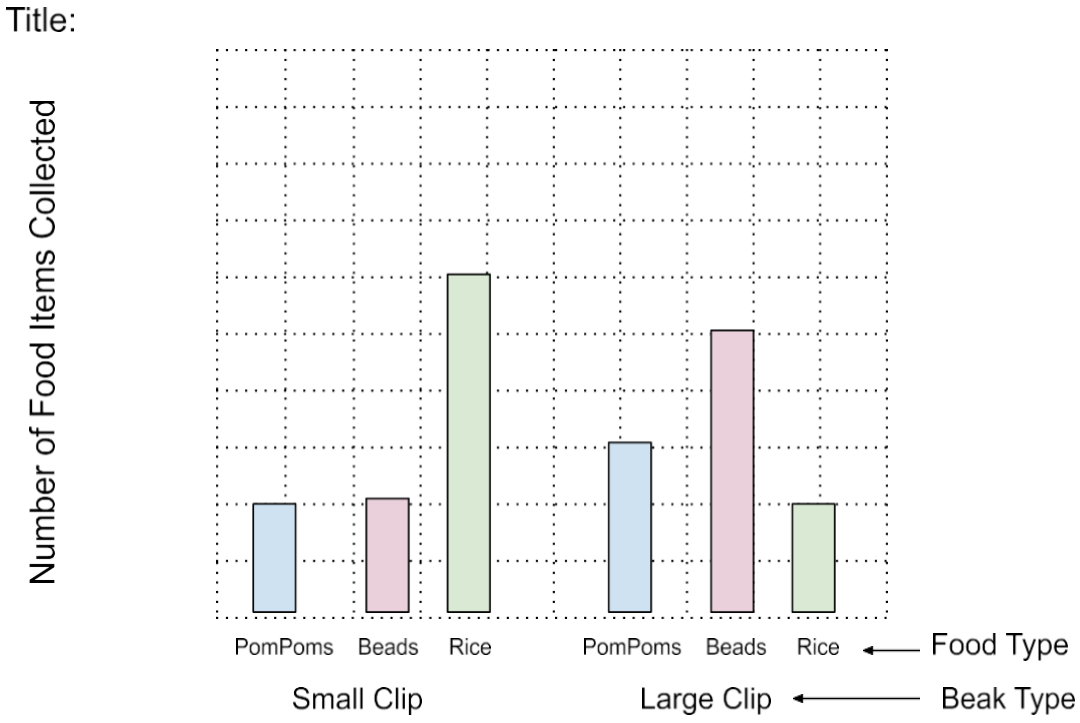
Independent Variable(s):	
Dependent Variable:	



3. Create a bar graph representing the number of each type of food you collected for each type of "beak."
    a. Your axes are already labeled, and you can begin by adding numerical values for your count of food types on the y-axis.
    b. Now you're ready to begin graphing! Create bars that go up to the amount of food you collected.

An example graph is shown below.

To graph data with two independent variables, pretend you are making two separate graphs. Start with your small clip data. Label the x-axis with the type of food and color in the bars. Repeat this process but now with data for the large clip. Write a title for your graph at the top.







4. Which type of food was the small clip best able to collect according to your data? Which type of food was the large clip best able to collect according to your data?

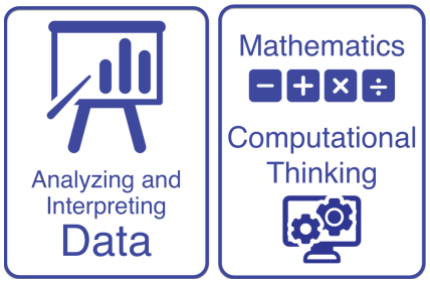
If the student has the small clip, they will likely have more rice grains. If the student has the large clip, they will likely have more beads. Both clips were able to pick up the pom poms.





5. How did the size of your "beak" impact the function? Did it make it easier or harder to pick up certain types of food? Discuss your results with your classmates.

The small clip was best able to pick up the rice grains and the pom poms. It was difficult for the small clips to pick up and put down the beads. The large clip was best able to pick up the beads and the pom poms. However, it was difficult for the large clip to pick up the rice grains relative to the small clip.



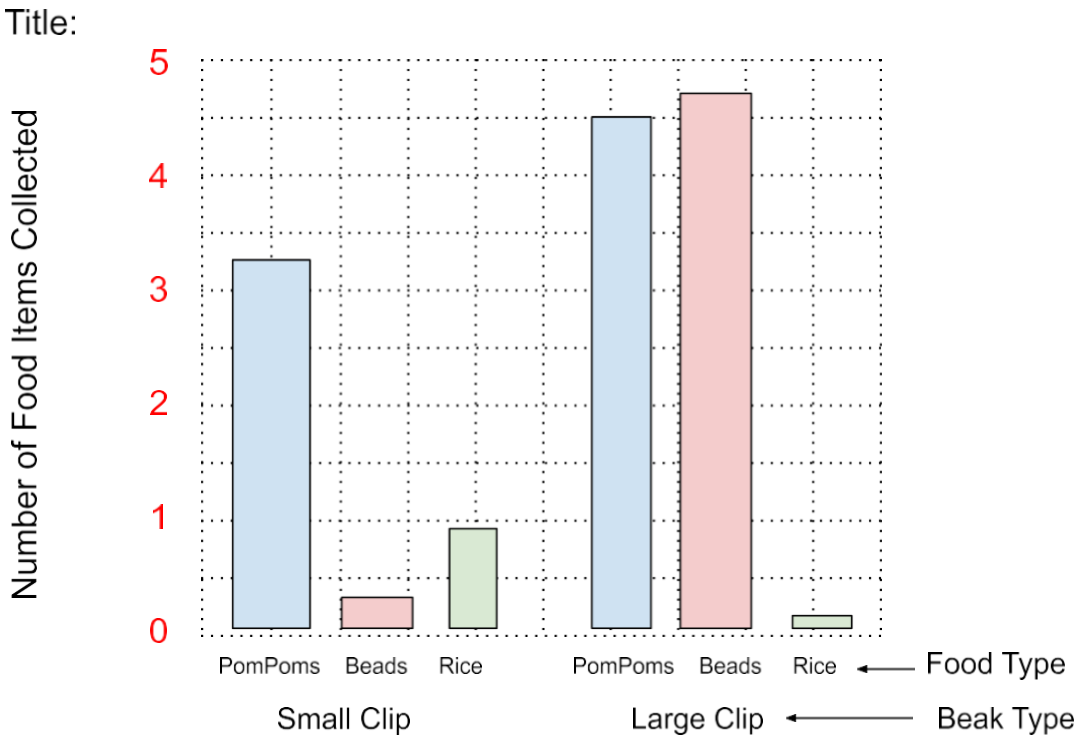
6. Now that you have some practice graphing, you will analyze the data collected by the whole class. Collect the data from each group and record the data in the table below. Calculate the average number of pom poms, beads, and rice collected by each individual for each beak type.

Class Data Table

Group	Small Binder Clips			Large Binder Clips		
	PomPoms	Beads	Rice	PomPoms	Beads	Rice
1	1	2	2	4	7	0
2	2	0	0	5	3	0
3	4	0	1	5	5	0
4	4	0	0	3	7	0
5	5	0	1	4	7	0
6	5	0	1	5	4	0
7	5	0	1	5	2	0
8	3	0	1	5	2	1
9						
10						
11						
12						
13						
14						
15						
Average	3.125	0.25	0.875	4.5	4.63	0.125

The independent and dependent variables will be the same as your individual graphs. Following the same procedure, create a graph for your class data graphing the averages.

Graph of Class Data



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7. Most scientific investigations have many repetitions to confirm the accuracy of the results. Every person conducted one repetition, and when your data is put together you have done multiple repetitions.
    a. Do you notice a pattern in the data collected across the multiple repetitions? (Hint: *What happens to the dependent variable as the independent variable changes?*)

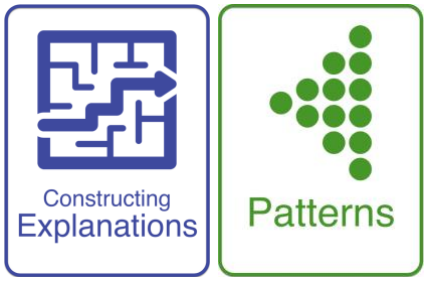
Answers will vary. An example answer is below.

A student using a small clip tends to pick up more rice than beads. A student using a large clip tends to pick up more beads than rice.

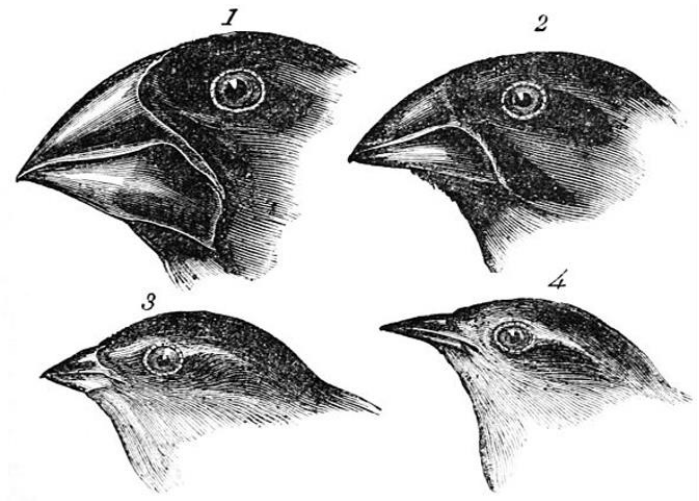
    b. Are the patterns the same from your personal data set and the class data set which contains repetitions, or did they change?

Answers will vary. An example answer is below.

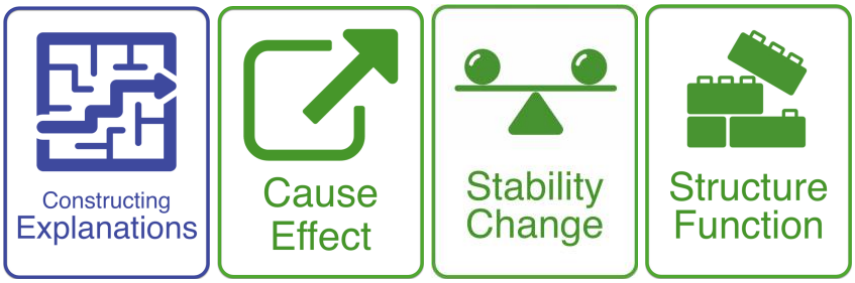
The small clip is the better "beak" for picking up the rice grains, and the large clip is the better "beak" for picking up the beads.



8. The following birds are a set of birds that live on the Galapagos Islands in South America and are called Darwin's finches after the scientist who studied them, Charles Darwin. On the islands, these birds can eat either large, hard nuts or small, soft seeds. Which of the birds below do you think are most likely to feed on the nuts and which do you think are most likely to feed on the seeds? Explain why using the patterns you observed in your data.



Birds 1 and 2 are more likely to feed on the nuts as they have larger beaks that can both fit these foods and are large enough to crush them. Birds 3 and 4 are more likely to feed on the small soft seeds, as they have beaks that are better at picking up these small objects.



9. In 2003, there was a drought in the Galapagos Islands. This low rainfall caused plants not to produce larger seeds, and the effect was that only small seeds were available to eat. When this environment changed, what do you think the effects of this would be for each of the birds in Question 8 and why? When answering 'Why' (e.g. your explanation), use your data from the experiment and be sure to address how the structure of the beak relates to the animal's ability to eat both the larger and smaller seeds.

Birds 1 and 2 are most likely to be impacted because their large beaks can't pick up the small seeds. This was simulated when the large binder clip struggled to pick up rice but the small binder clip could pick up rice.
In fact, the average beak size of all the finches became smaller due to this drought!

BIRDS AND THEIR BEAKS PART 2

Students experience first-hand how different characteristics can provide an advantage to individuals by "eating" with distinct "beaks," graph and analyze this data, and apply their results to explain the effects of adaptations on changes in the ecosystem or environment.

SOUTH CAROLINA STATE STANDARD	8-LS4-4 Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individual's probability of surviving and reproducing in a specific environment. *Clarification Statement: In a specific environment impacted by different factors, some traits provide advantages that make it more probable that an organism will be able to survive and reproduce there.* *State Assessment Boundary: Assessment is limited to using simple probability statements and proportional reasoning to construct explanations.* 8-LS4-6 Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time. *Clarification Statement: Emphasis on student explanation of trends in data using mathematical models, probability statements, and proportional reasoning to support explanations of trends of population changes.* *State Assessment Boundary: Assessment does not include Hardy Weinberg calculations.* *Birds and their Beaks Part 2 can be done without Birds and their Beaks Part 1.*
NEXT GEN STANDARD	MS-LS4-4 Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individual's probability of surviving and reproducing in a specific environment. MS-LS4-6 Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time. *Birds and their Beaks Part 2 can be done without Birds and their Beaks Part 1.*
LEARNING OBJECTIVE(S)	- Students will be able to recognize and explain the interaction between the environment and an organism's traits to produce variable amounts of fitness. - Students will be able to describe a phenotype (structure) that provides an advantage in function in a particular

	environment. - Students will be able to understand how phenotypic traits can impact survival. - Students will graph repeated class data and recognize patterns in the data. - Students will be able to apply concepts of structure and function to real-life examples.
ESTIMATED TIME	Two 45 minute class periods

WHAT YOU'LL NEED:

All of the items can be purchased from a local craft store, big box store, or online. Example products from Amazon are provided as links. The box provides the materials for 30 students, with a single bag per student containing the below:

1. 5 soft pom poms. The box includes 0.75 to 1 inch pom poms as we found this to be the most useful size (example product).
2. 15 pony beads (example product).
3. Approximately 15 rice grains (a generous pinch). *We find arborio rice to work the best* (example product). *White rice and other thin grains are not able to be picked up with binder clips.*
4. Any container ("stomach") to collect pom poms, beads, and rice. For example, this can be a lunch size paper bag (example product), plastic cup ~7oz or larger (example product), or a sandwich size reclosable bag (example product).
5. One small 0.75" binder clip (example product) and one large 1.25" binder clip (example product). *Alternatively, using fingers or clothespins may be more accessible for students with mobility limitations: mini clothespin* (example product) *and large clothespin* (example product).
6. You may want paper plates or lunch trays to help students keep their materials contained.

WHAT YOUR STUDENTS SHOULD KNOW BEFORE:

Some general knowledge of how certain characteristics serve a certain function may be helpful, but not necessary since this activity is designed for students to hypothesize and experiment with this concept.

WHAT TO DO BEFORE YOUR CLASS:

Here is an example of a student's materials including pom poms, beads, and rice, and two "beaks." Not pictured is a bag or cup.



HOW TO SET UP YOUR CLASS:

This activity can be completed by students working individually or in pairs to collect the data.

WHAT YOU NEED TO KNOW FOR YOUR SAFETY:

Small beads could be a choking hazard.
Binder clips can pinch skin.

This lesson has been designed to follow three dimensional learning, as described in NGSS standards. In this teacher version, we annotate the associated Science and Engineering Practices and Cross-Cutting Concepts using icons (from these NGSS Planning Cards) before the relevant student question and blue and green text, respectively, within the student instructions. Additionally, content and questions that specifically address the Disciplinary Core Idea is represented in orange text. Sample student responses, classroom recommendations, and other hints are in *red italicized text*. See https://scienceweb.clemson.edu/beakerbox/ for additional files such as non-annotated student versions, Spanish versions of student materials, and slides.

BIRDS AND THEIR BEAKS PART 2

Student Activity Instructions:

In this activity, you will simulate a population of finches to explore the mechanisms that drive population change. In Part 1, you kept track of the amount of food that was eaten and graphed how much food each type of "beak" was able to collect. In Part 2, you will be keeping track of how well the "birds" survive from one generation to the next.

1. Make some initial predictions about why you think some birds of the same species may survive and reproduce better than other birds with different observable traits (phenotypes).

Answers will vary.



Procedure Instructions:

1. Work in groups of 2 with your own set of materials.
   Students can be allowed to compete with their partner for one set of materials, or each student can work to select their own materials from their own set. We found the data to work out either way.
2. Look at the materials provided by your teacher. You should have the following at your station to carry out your investigation:
   a. Three types of "food" (beads, pom poms, rice)
   b. Two types of "beak" (large and small binder clips)
   c. One "stomach" (paper bag, plastic cup, or sandwich bag)
3. Put the food into a pile in the center of your table, where both partners can reach it equally.
4. Each person will have one beak
5. You will use your "beak" to collect food, one item at a time, for 20 seconds. On your teacher's cue, begin collecting food using your beak, putting what you pick up in your "stomach."
   Note: If you have a competitive class, consider reducing the time to 15 seconds. For a less competitive class, consider increasing the time to 30 seconds.
6. You can only use the "beak," black part of the binder clip to pick up the "food"

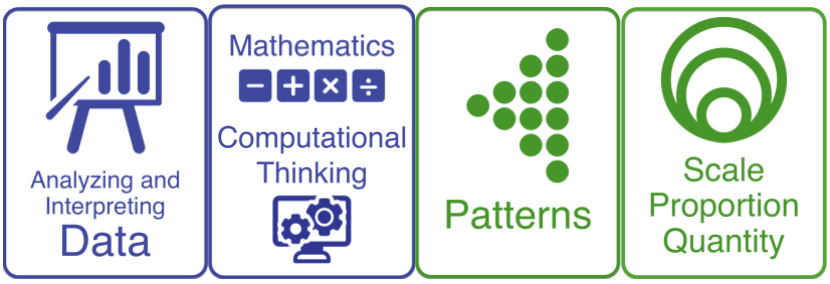
7. Once time is up, put down your "beak." Count how many of each type of food you collected and record in the data table. Circle whether or not you survived.
    a. If you were able to collect 5 or more pieces of food, you survive and reproduce. Circle Yes
    b. If you did not collect 5 or more pieces of food, you do not survive and reproduce. Circle No
8. For each round, reset the food types in the center of the table according to what is available each round
    a. Round 1: all food types available
    b. Round 2: only Beads and Rice available
    c. Round 3: only Rice available
    d. Round 4: only Beads available
9. Repeat this process (steps 3 through 7) for each round AND each type of beak to complete the data collection.
   Conduct a practice round for 20 seconds to allow students to practice using the "beaks" before timing the "official" rounds.

Data Table: Record your data here

Individual data: Type of Food Eaten and Survival

Round	Type of Beak	Pom Poms	Beads	Rice	Total	Survived?
1	Small	*2*	*0*	*3*	*5*	*Yes* No
	Large	*3*	*6*	*0*	*9*	*Yes* No
2 The environment changed and no pom poms are available	Small	0	*0*	*3*	*3*	Yes *No*
	Large	0	*9*	*0*	*9*	*Yes* No
3 The environment changed and no pom poms or beads are available	Small	0	0	*5*	*5*	*Yes* No
	Large	0	0	*6*	*6*	*Yes* No
4 The environment changed and no pom poms or rice are available	Small	0	*1*	0	*1*	Yes *No*
	Large	0	*9*	0	*9*	*Yes* No

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Class Data Table

Survival Data: Record the number of birds of each beak type that survived each round.

Calculate the percent of birds of each size that survived *each round*.

Calculating percentages:

Take the number of survivors with mini beaks and divide by the total number of survivors. Multiply this number by 100.

$$\frac{\text{\# Small beak survivors}}{\text{Total \# of survivors}} \bullet 100$$

$$\frac{\text{\# Large beak survivors}}{\text{Total \# of survivors}} \bullet 100$$

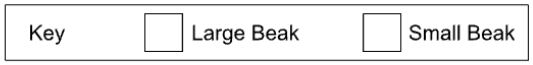
To check your work: see that the percentage of mini beak survivors + the percentage of big beak survivors = 100 for each round.

	Round 1			**Round 2**			**Round 3**			**Round 4**		
Type of Beak	Small	Large	Total	Small	Large	Total	Small	Large	Total	Small	Large	Total
Total	*15*	*15*	*30*	*6*	*15*	*21*	*14*	*15*	*29*	*2*	*15*	*17*
Percent Survival	*50%*	*50%*	100%	*29%*	*71%*	100%	*48%*	*52%*	100%	*12%*	*88%*	100%

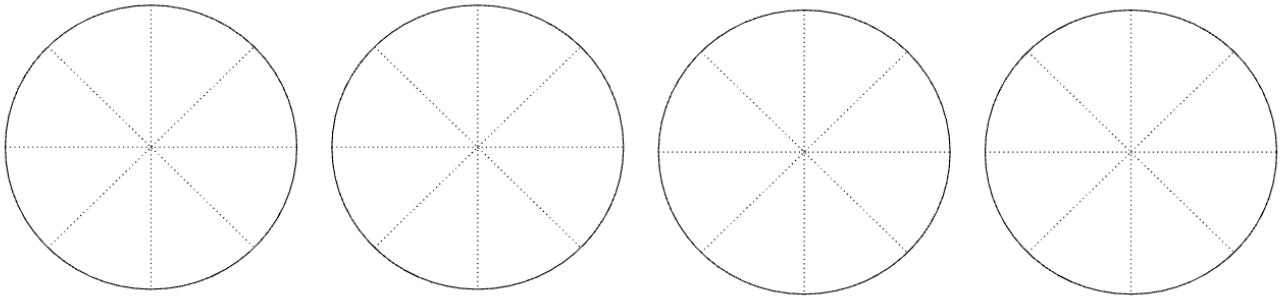
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Graph the Survival Data

In the circle graphs below, create a graph that represents the percentage of the surviving birds represented in the Class Data Table for each round. (*Hint: Use the lines provided in the circles to help you estimate the percentages*)



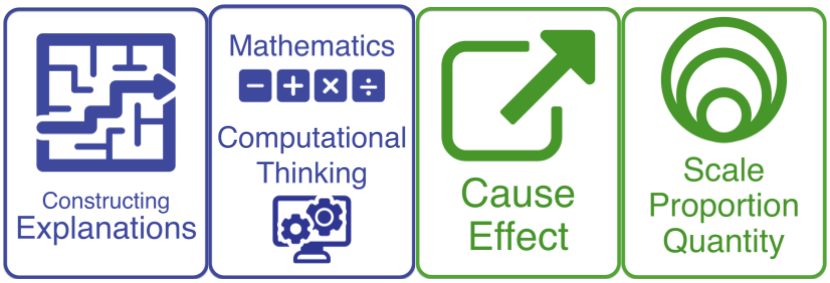
Round 1 **Round 2** **Round 3** **Round 4**





2. Describe what you notice about how the type of beak may or may not affect the survival of birds during each round?

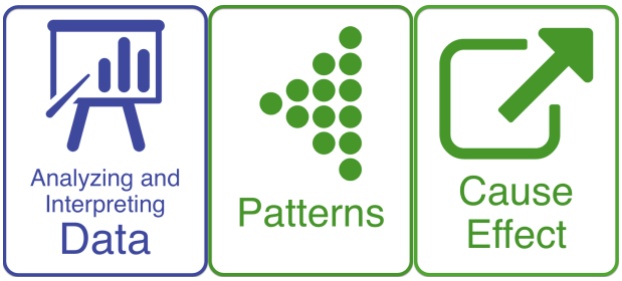
Potential outcome: During rounds 1 and 2, both types of beaks were equally able to survive. During round 3, birds with the little beaks were able to survive more than the birds with the bigger beaks. During round 4, birds with little beaks struggled to survive, but birds with big beaks survived more often.



3. How did the interaction between the "environment" (*Hint: available food*) and the bird's beak size affect their survival? Write a claim supported by evidence and reasoning from the activity regarding the proportion of birds with different sized beaks that survived.

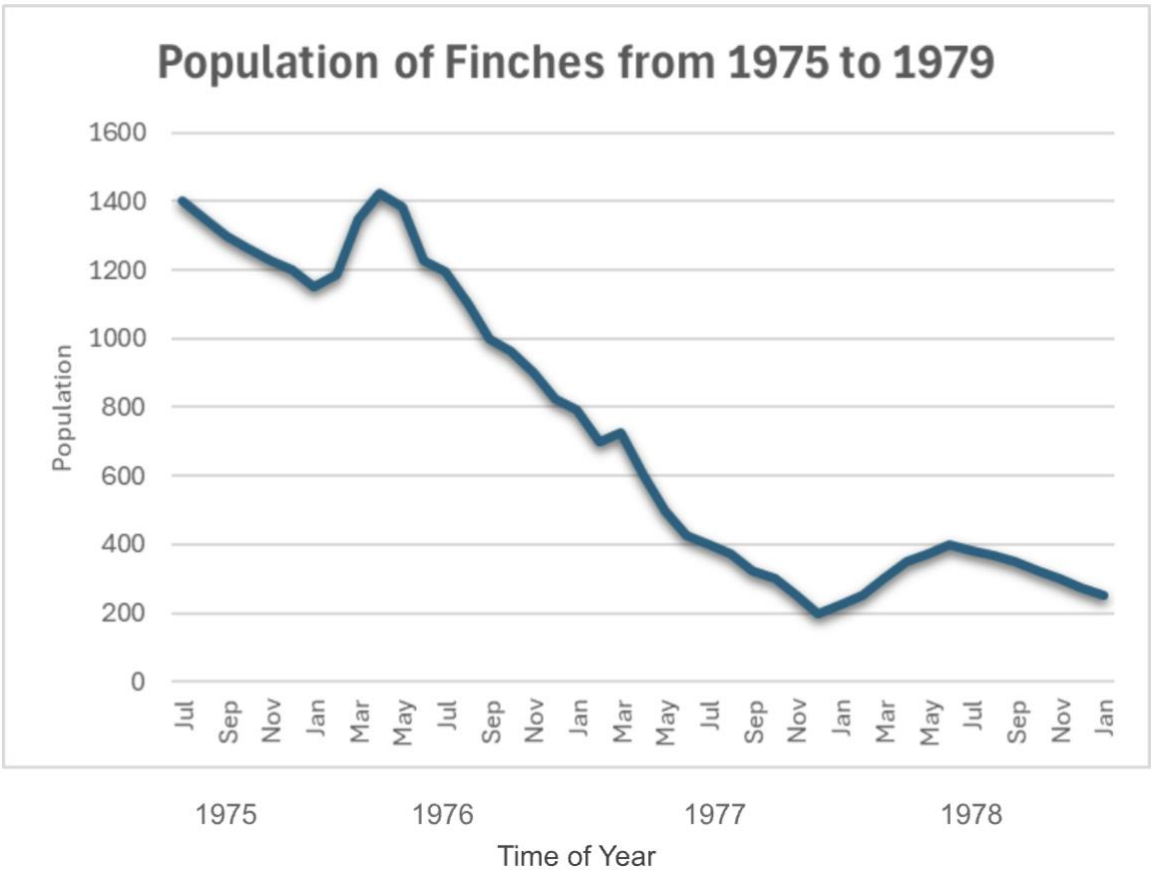
Student responses can vary:
Birds with the small beak were more likely to survive than birds with the large beak when only rice grains were available. During round 3, when only rice was available, % birds with the small beak survived while only % of birds with the large beak survived. Birds with the small beak were able to pick up the small grains of rice more efficiently than the birds with the big beak, and so when only the small food was available, they were better able to survive.

Conversely, birds with the large beak were more likely to survive than birds with the small beak when only beads were available. During round 4, when only beads were available, % birds with the large beak survived while only % of birds with the small beak survived. The birds with the small beak were less efficient at picking up the beads and could not collect enough food to survive.

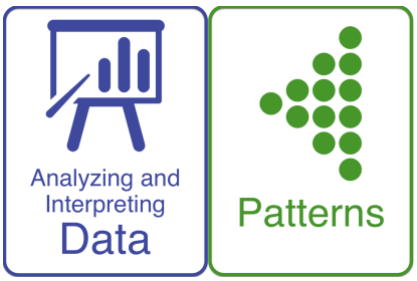


4. The graph below illustrates the finch population through the years 1975 to 1979. During this time, there was a severe drought leading to changes in the environment including the types of food available to the finches.
    a. What do you notice about the finch population from 1975-1979?
    b. What might have caused the change in the population of finches?

Graph 1

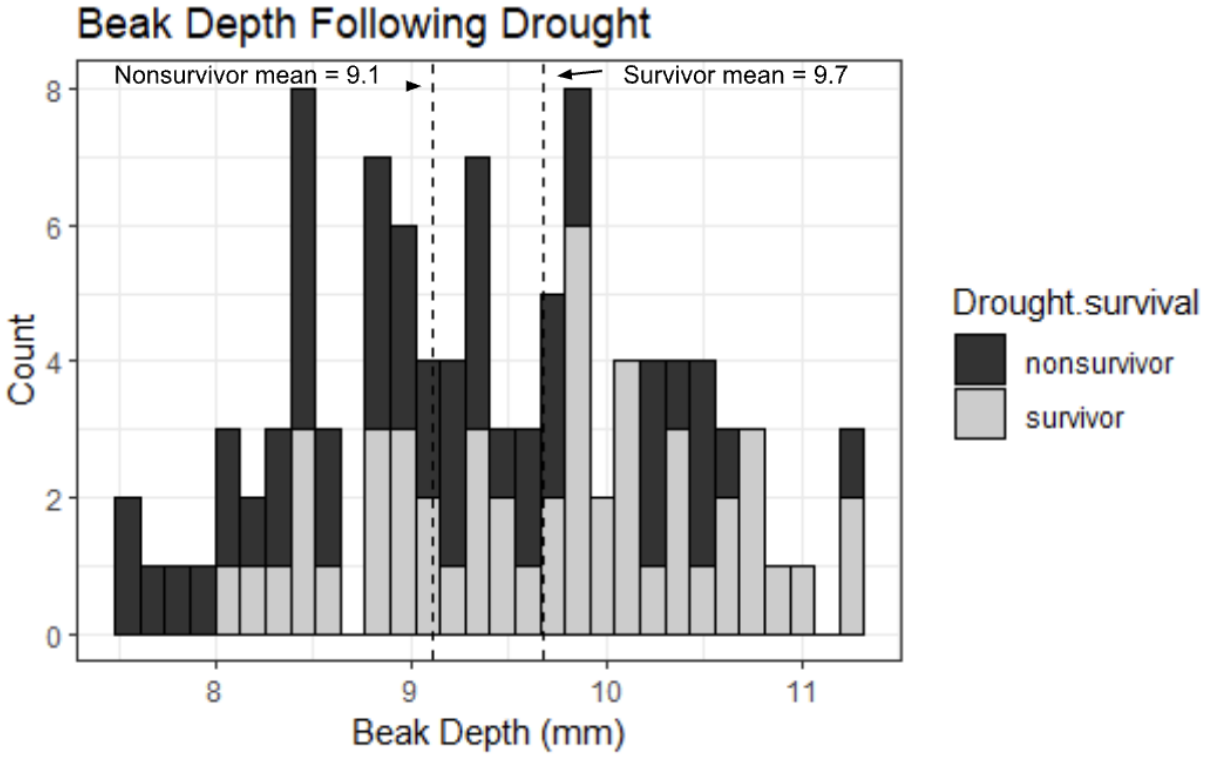


The finch population declined overall from 1975 to 1979. The entire population decreased from approximately 1400 birds in 1975 to just over 200 birds in January of 1979.

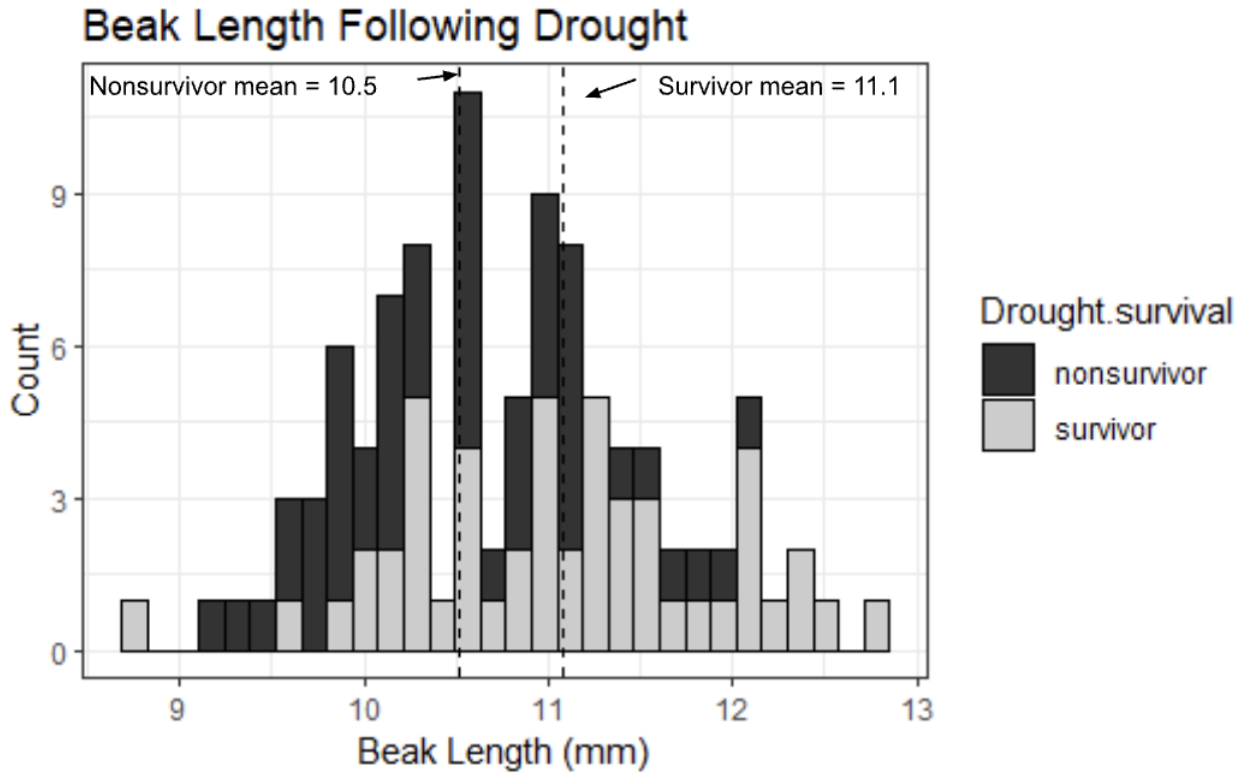


5. The following two graphs depict data collected about surviving and non-surviving finches after the severe drought in 1977. Interpret the two histograms (graphs) below and determine the pattern in beak traits (beak depth and beak length) that you notice between surviving and non-surviving finches.

Graph 2



Graph 3



It appears that birds that survived tend to have deeper, longer beaks relative to the birds that did not survive. The light gray bars are more to the right indicating a larger beak depth and a longer beak length relative to the non-surviving birds.



6. Based on the patterns in graphs 2 and 3, describe what you think the future generation of birds will look like.

Students may predict that the future generation of birds will have larger beaks, both in beak length and beak depth.



7. Construct an explanation in which you discuss how natural selection led to changes in the overall population of finches from 1975-1979. Include in your explanation how the characteristics of the surviving population of finches compared to those that did not survive citing evidence from the three graphs.

The finch population overall declined from 1975 to 1979 with hundreds of finches not surviving the change in the environment. This is evident in the pattern illustrated in the line graph and the decline in population from approximately 1400 birds in 1975 to just over 200 birds in 1979.

Examining the histograms of the beak depth and beak length, the surviving birds tend to have larger beaks than the non-surviving birds. This suggests that birds with smaller beaks were not able to survive.

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SELECTION

Students explore and discuss how different events affect a population, using graphs and their results to explain the effects of selection.

SOUTH CAROLINA STATE STANDARD	8-LS4-4 Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individual's probability of surviving and reproducing in a specific environment. *Clarification Statement: In a specific environment impacted by different factors, some traits provide advantages that make it more probable that an organism will be able to survive and reproduce there.* *State Assessment Boundary: Assessment is limited to using simple probability statements and proportional reasoning to construct explanations.* 8-LS4-6. Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time. *Clarification Statement: Emphasis on student explanation of trends in data using mathematical models, probability statements, and proportional reasoning to support explanations of trends of population changes.* *State Assessment Boundary: Assessment does not include Hardy Weinberg calculations.* 7-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. *Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).* *Note: Including 7-ESS3-3 is an opportunity to reinforce standards from last year*
NEXT GEN STANDARD	MS-LS4-4 Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. MS-LS4-6. Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

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	MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
LEARNING OBJECTIVE(S)	- Students will create visualizations of their data to better identify patterns, share their visualizations, and compare strengths and weaknesses of evidence resulting from visualized data. - Students will use computational thinking to generate explanations using their population data to explain changes in genetic variation after a series of events. - Students will recognize the impact of environmental events, including those influenced by human activity, on the frequency of phenotypes. - Students will identify cause and effect relationships for the beetles that survived and did not survive specific events and provide evidence for these relationships.
ESTIMATED TIME	**Two 45 minute class periods**

WHAT YOU'LL NEED:

This activity requires a set of selection event cards and counters per student group. Within the box, we provide four sets of laminated cards (24 cards each) and four sets of counters (28 for each of pink, green, blue, and yellow). We suggest that a set of event cards and counters be used by 4 students or pairs of students.

A number of options are available for the counters, including those listed below. Example products from Amazon are provided as links:

1. Bingo chips or similar plastic counter. We find the 0.75" size to be the best size (example product)
2. Colored squares of paper. We find laminated cardstock to be the most sturdy and a 1.5" square to be the best size (example product)
3. We also provide drawings of beetles in the appendix. These can be printed out in color and cut so a single beetle illustration is on each piece of paper.

WHAT YOUR STUDENTS SHOULD KNOW BEFORE:

Some general knowledge of evolution and natural selection may be helpful, but not necessary since this activity is designed for students to hypothesize and explore how selection impacts a population.

Students will calculate percentages and utilize various forms of graphing. How familiar students are with these practices will impact how long the activity lasts. Teachers may need to provide mathematics and graphing support for students.

This lesson can be used to reinforce concepts within the 7th grade South Carolina standards relating to monitoring and minimizing the human impact on the environment.

WHAT TO DO BEFORE YOUR CLASS:

None

HOW TO SET UP YOUR CLASS:

Students will work in groups. We suggest groups of 3-4 students or student pairs.

WHAT YOU NEED TO KNOW FOR YOUR SAFETY:

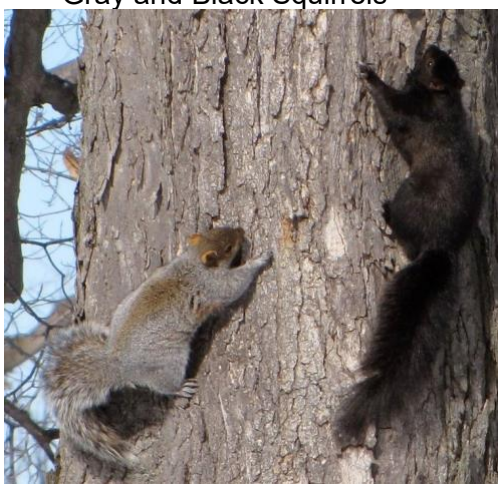
None

This lesson has been designed to follow three dimensional learning, as described in NGSS standards. In this teacher version, we annotate the associated Science and Engineering Practices and Cross-Cutting Concepts using icons (from these NGSS Planning Cards) before the relevant student question and blue and green text, respectively, within the student instructions. Additionally, content and questions that specifically address the Disciplinary Core Idea is represented in orange text. Sample student responses, classroom recommendations, and other hints are in *red italicized text*. See https://scienceweb.clemson.edu/beakerbox/ for additional files such as non-annotated student versions, Spanish versions of student materials, and slides.

SELECTION

Phenomenon: Think of a time when you saw a squirrel. What color was it? Do you remember where you saw it? Have you ever seen a squirrel whose appearance surprised you? How well adapted are the squirrels that you saw to the environment they live in? How well do you think they might survive in their current environment? What do you think might cause the squirrels to look different? Why don't you think we see more of the black morph or blonde morph of the squirrels?

Gray and Black Squirrels



Blonde Squirrel



White Squirrel



Image: White Squirrel Research Institute (CC BY-SA 2.0 DEED) https://www.squirrelmapper.org/the-squirrels

Student activity instructions:

The frequency of organisms with a certain trait (phenotype) can be influenced by a variety of events, both naturally occurring and those influenced by human activity. Through a process called selection, traits can either increase or decrease within a population. For this activity the driving question is: How will different selective forces affect a population?

MATERIALS NEEDED

- 24 Selection Event Cards
- 20 pink "beetles"
- 20 yellow "beetles"
- 20 green "beetles"
- 20 blue "beetles"
- Scorecards (see page 2)
- Optional: gameboard (see next page)
- Optional: calculator

NUMBER OF PARTICIPANTS

1 to 4

ADAPTATION: Selection *TEACHER*

GOAL

For this activity, you'll each be in charge of monitoring an isolated population of beetles that are affected by different events. See Figure 1 for a sample game set-up

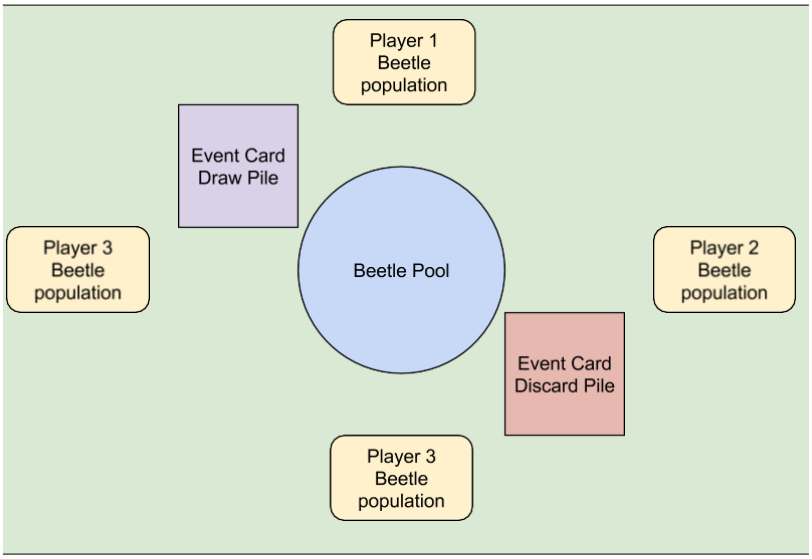
SETUP

- Shuffle the EVENT CARDS and place them face down in the middle of your group where everyone can reach them.
- Place all of the "beetles" in the center of the table where everyone can reach them (Beetle Pool).
- Each player draws 5 pink, 5 yellow, 5 green, and 5 blue counters ("beetles") from the pile and places them in front of you. This is your starting population.
- Record the number of beetles of each color following the example of the starting population line on your SCORECARD.

GAMEPLAY

- Rock-paper-scissors to decide who goes first.
- The first player draws an event card and follows the instructions on the card. Record the event card and effect on your SCORECARD. At the end of your play, record your beetle numbers in the Round 1 Row on your SCORECARD.
    - When an event card tells you to ***draw beetles at random***, you can close your eyes or look away to draw the indicated number of beetles from the beetle pool.
- After the first player plays, gameplay proceeds to the left.
- The next player draws an event card and follows the instructions on the card, recording their beetles in Round 1. Continue through all four players.
- When play returns to the first player, Round 2 begins.
- Play through 5 Rounds.
- If you run out of beetles, play with the beetles you have. For example, if you only have 1 green beetle and the instructions on the card tell you to lose 2 green beetles, just play your 1 green beetle.

Figure 1: Beetle Selection Game Set-up



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POST GAME ANALYSIS

Using your data in your scorecard, calculate the percentage that you have of each color in your starting population by dividing the number of beetles of that color by the total number of beetles in the population. Record the percentages in the data table.

SCORE CARD: BEETLE POPULATION

Round	Pink		Yellow		Green		Blue		Total	
	#	%	#	%	#	%	#	%	#	%
Starting Population	5	25%	5	25%	5	25%	5	25%	20	100%
1	5	31.25%	5	31.25%	1	6.25%	5	31.25%	16	100%
2	5	38.5%	3	23%	0	0%	5	38.5%	13	100%
3	4	40%	3	30%	0	0%	3	30%	10	100%
4	4	40%	3	30%	0	0%	3	30%	10	100%
5 Ending Population	0	0%	3	50%	0	0%	3	50%	6	100%

TRACKING YOUR EVENTS

Round Number	Card Title	Card Description	Effect on population
Example	Resource	All beetles can eat	+ 3 random
1	Pollution	Pink beetles stand out	-4 pink
2	Disease	Virus infects green & yellow	-2 yellow -2 green
3	Invasive Species	A new species competes with beetles	-3 random
4	Deforestation	The population moves	no change
5	Hunting	Humans capture pink beetles	-4 pink

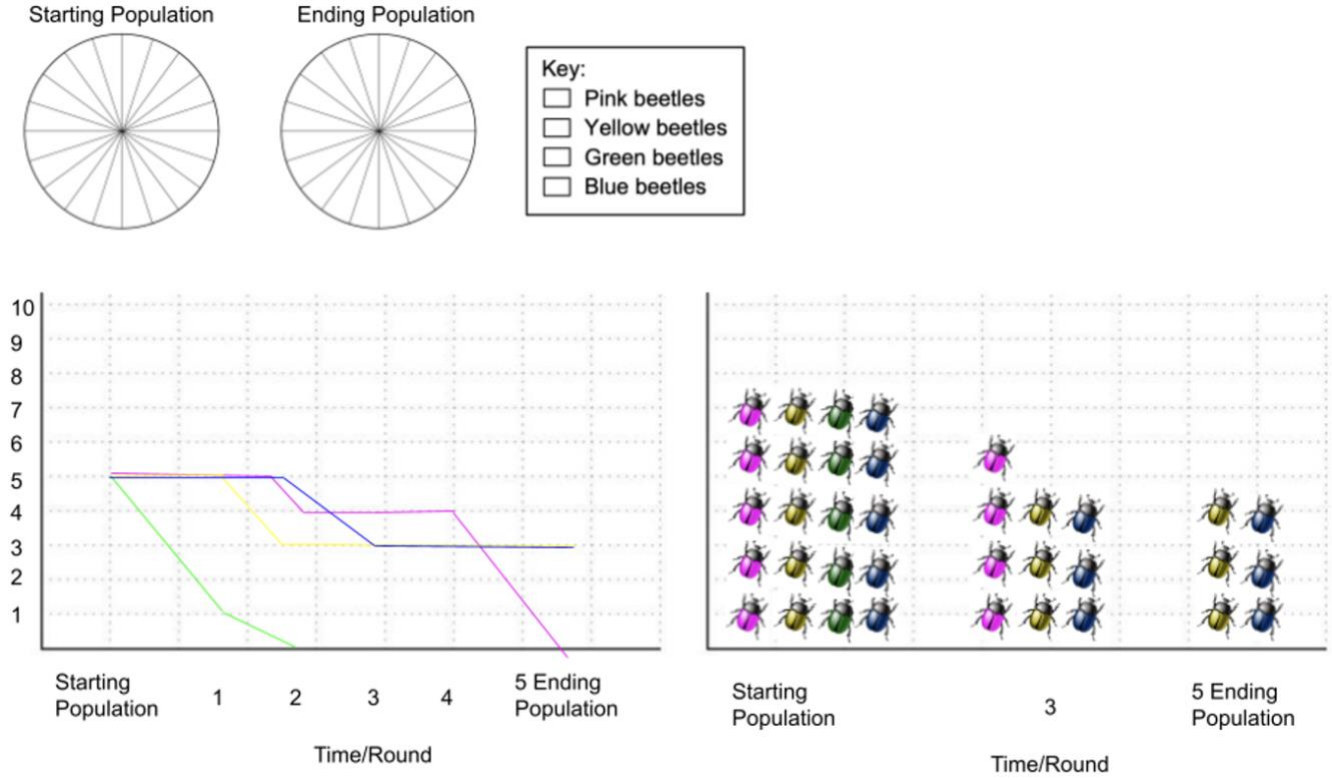
ADAPTATION: Selection *TEACHER*





1. Data tables do not lend themselves to seeing patterns compared to other visual representations. To more fully analyze your results, use your data in the SCORECARD to create a visual representation of your data. Consider your independent variable and dependent variables and the key outcome you want to be able to visualize.

Options for students to display their data include pie charts, pictographs, bar charts, histograms, and line graphs.



If you prefer a bit more scaffolding for your students, this could be an opportunity to talk about some different types of data visualization.

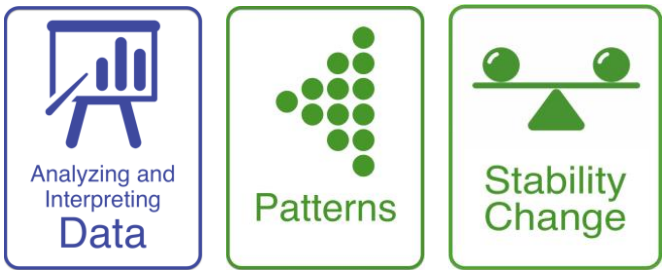
You could also assign certain visualization options to portions of your class to give this question more structure while still enabling the gallery walk and comparison in question 3



1. Explain why you chose this particular visualization (in question 1) to represent your data.

Answers will vary.

Students should consider their independent and dependent variables and the outcome they are wanting to visualize.



2. Compare your data about your starting population to the ending population. Using your visual from question 1, what patterns do you notice? What stayed the same and what changed in terms of the numbers or percentages of each color of beetle?

Answers will vary depending on the set of events that happened. It is highly likely that the ending population will not have an even distribution of colors (as compared to equal representation in the starting population), that students will not end with 20 total beetles that that started with, and maybe that they are completely missing a certain color (i.e. that beetle went extinct).

This question is meant to get students thinking about the trends in their data to assist with the next question where they will compare types of graphs.



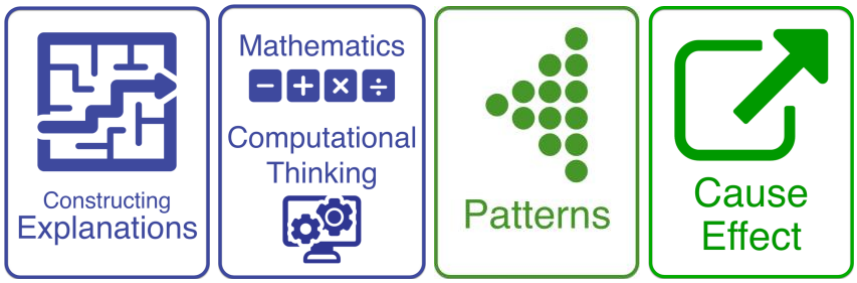
3. Do a gallery walk of other visual representations. Compare and contrast at least two visual representations of the data and consider the patterns you were able to identify (Look for patterns across data; what data are included or excluded).
    a. Which visualization do you think best represents data and why? Consider the following:
        i. What information is included or excluded in each type of graph?
        ii. What are the benefits of including or excluding certain data?

This might be a good class discussion after students think about visual representations of data.

There isn't a correct answer here, but this is to get students thinking about how the same data can be analyzed and presented in different ways. For example, students may note that in the bar graph the total number of beetles is represented, while the pie chart does not accurately show whether they had a lot or very few beetles. Some graphs might show all 5 rounds and some might only represent the ending round.

Research supports the explicit teaching of Nature of Science. Discussing the difference between data and evidence is important for students as outlined in the article below:

- *Scientific data are not the same as scientific evidence.*
    - *"Data and evidence serve different purposes in a scientific investigation. Data are observations gathered by the scientist during the course of the investigation, and they can take various forms (e.g. numbers, descriptions, photographs, audio, physical samples, etc.). Evidence, in contrast, is a product of data analysis procedures and subsequent interpretation, and is directly tied to a specific question and a related claim" (Lederman et al., 2019, p. 491)*
- *Lederman, J., Lederman, N., Bartels, S., & Jimenez, J. (2019). An international collaborative investigation of beginning seventh grade students' understandings of scientific inquiry: Establishing a baseline. Journal of Research in Science Teaching, 56(4), 486-515.*



4. Talk with your group members and discuss the following:
   a. The patterns you notice in the traits (color) of beetles that survived and those that did not survive across all your data (use your visual representations and percentages).

   Note: Students are examining across populations. The populations all started out the same, but each student drew different event cards.

   Answers will vary
   Students may indicate that pink beetles tend to die out faster than the other types of beetles or that blue beetles survive better.

   b. Spread the event cards out and determine if certain beetle colors are more affected by events.

   Answers will vary
   Students may notice that more events decrease the number of pink beetles and fewer events decrease the number of blue beetles. Students may notice that many events randomly target certain phenotypes.

   c. Using the evidence from (a) and (b) write an explanation about which of your beetle populations are more likely to survive or not.

   Answers will vary
   Possible patterns: Pink are least likely to survive because they are specifically targeted to be negatively affected by pollution, disease, hunting. Blue are more likely to survive because one of the predator and one of the resource events add to blue and there are no cards that specifically negatively target blue.

   Students should use their percentages or trends in their graphs to support their explanations and the above pattern may not be noticed due to random chance. Students should discuss if other beetles survived more because of these random chance cards.

5. Pollution, hunting, and disease disproportionately affect the pink beetles.
   a. Are these events driven by humans? Why or why not?

   Pollution is driven by humans; Hunting is driven by humans; Disease can be argued to be human and not human driven

b. What is our ethical obligation, if any, to try and prevent the loss of the pink beetle phenotype?

Ethical obligation answers will vary and there is no one correct answer. Students can consider if this phenotype has any impact on the larger population, if it might impact an economic niche (pink beetle hunting for their color), if it might impact other animals who feed on the beetles who have a harder or easier time seeing those remaining, etc.

c. Propose one method for monitoring or minimizing a human impact.

Answers will vary.
Possible Responses:

- *Companies must measure pollution*
- *Government regulates amount of waste disposed of and where*
- *Hunting licenses*
- *Limits to number of beetles per year per person*
- *Disease is monitored by ecologists*
- *Captive breeding and release*
- *Antibiotic application to kill bacterial infections in beetles*

Appendix: Selection event cards

POLLUTION!

An oil spill at a nearby factory cause the pink beetles to stand out more to predators.

– 4 pink



FLOOD!

A flood has severely damaged your beetles' habitat and wiped away some of your beetle population.

– 5 random



A new plant species has been introduced into your ecosystem. The pink beetles like to feed on the new plant.



+ 4 pink

RESOURCE!

The amount of resources in the ecosystem cause population sizes to stay steady.

Do not add or remove any beetles.



RESOURCE!

A new plant species has been introduced into your ecosystem causing the population to grow.



+ 5 random

RESOURCE!

DISEASE!

A disease has infected all of your beetles.



– 4 random

ADAPTATION: Selection *TEACHER*

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DISEASE!



Your beetles were exposed to bacteria, but only the pink beetles were susceptible to infection.

– 2 pink

DISEASE!



A virus has affected the yellow and green beetles.

– 2 yellow and
– 2 green

MUTATION!



A DNA mutation in some of the yellow beetles allow them to reproduce better.

double the number of yellows you have

PREDATOR!

A predator is unable to see the blue beetles when it hunts at night.



– 6 non-blue and
+ 3 blue

DEFORESTATION!

Removal of trees from the forest has led to the beetles having to move habitats. The beetle population is not harmed but does not grow.

Do not add or remove beetles.



INVASIVE SPECIES!



A new invasive species in the ecosystem feeds on the same food as the beetles, reducing their resources.

– 3 random

BeakerBox
CLEMSON® SCIENCE OUTREACH

The amount of resources in the ecosystem cause population sizes to increase.

+ 3 random



RESOURCE!

Some of the plants the beetles feed on are struggling due to rising temperatures. This forces the beetles to find a new food source and decreases the population.

– 3 random



CLIMATE CHANGE!

A new plant that grows at the top of the trees has been introduced into your ecosystem. Only the green beetles can reach this food without being spotted by predators.



+ 3 green

RESOURCE!



A predator of the beetles increases in number, leading to more beetles being eaten.

– 4 random

PREDATOR!

HUMANS!

The city sprayed pesticides to reduce mosquitoes, but the pesticide also reduced the beetle population.

– 4 random



HUMANS!

The city sprayed pesticides to reduce mosquitoes. The green beetles weren't affected, but the other beetles were.

– 4 non-green

+ 3 green



ADAPTATION: Selection *TEACHER*

BeakerBox
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The amount of resources in the ecosystem cause population sizes to increase.

+ 2 random



RESOURCE!

The amount of resources in the ecosystem cause population sizes to increase.

+ 1 random



RESOURCE!

HUNTING!

Humans have taken an interest in the coloring of the pink beetles.



– 4 pink

INVASIVE SPECIES!

An invasive species has been introduced into the ecosystem. This species preys on the beetles.



– 3 random

MIGRATION!

Some beetles from your population have migrated to a new ecosystem, causing your population to decrease.

Have each player randomly select 1 of your beetles and add it to their population.



MIGRATION!

Some beetles have migrated to your population from another ecosystem, causing your population to increase.

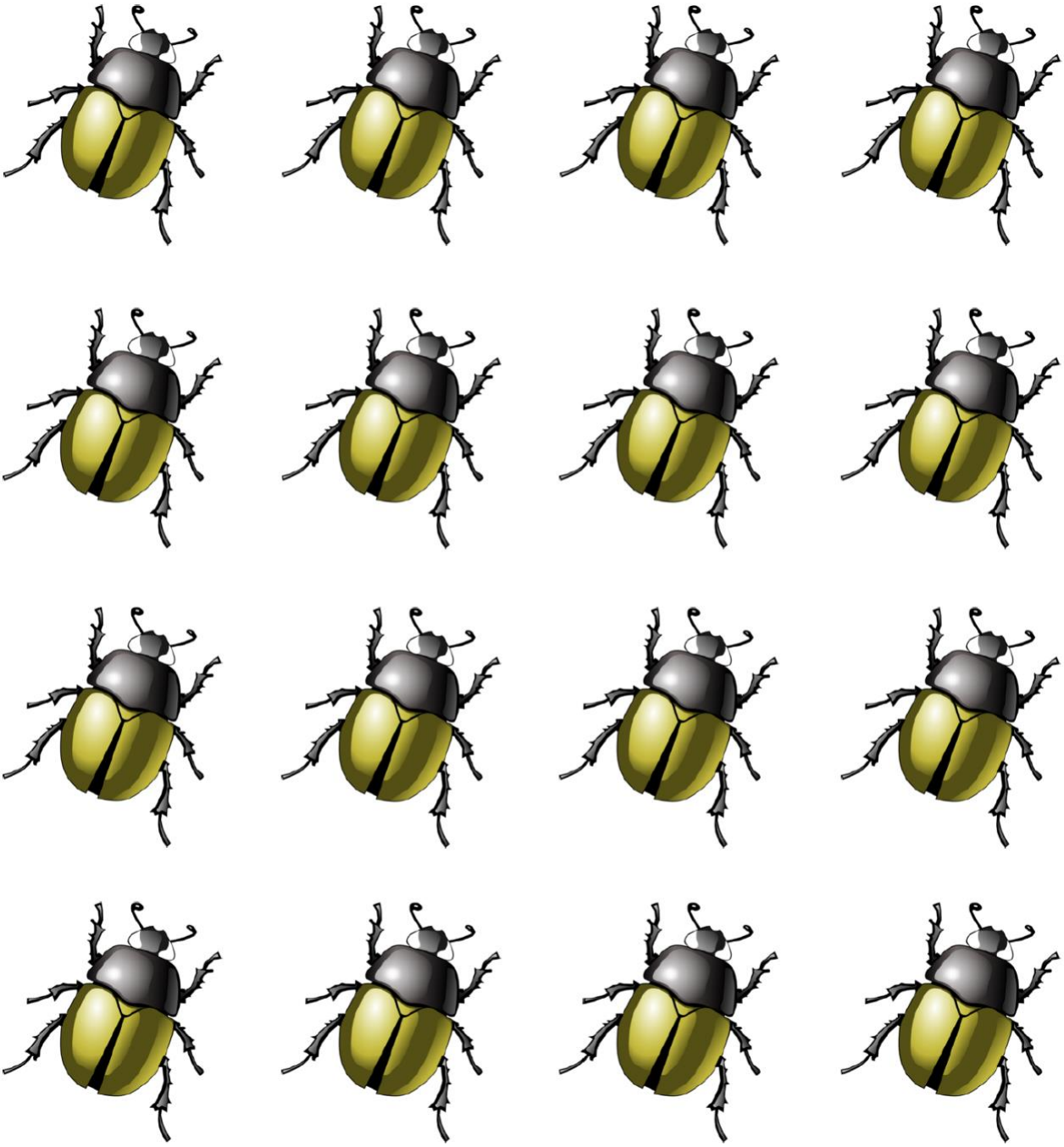


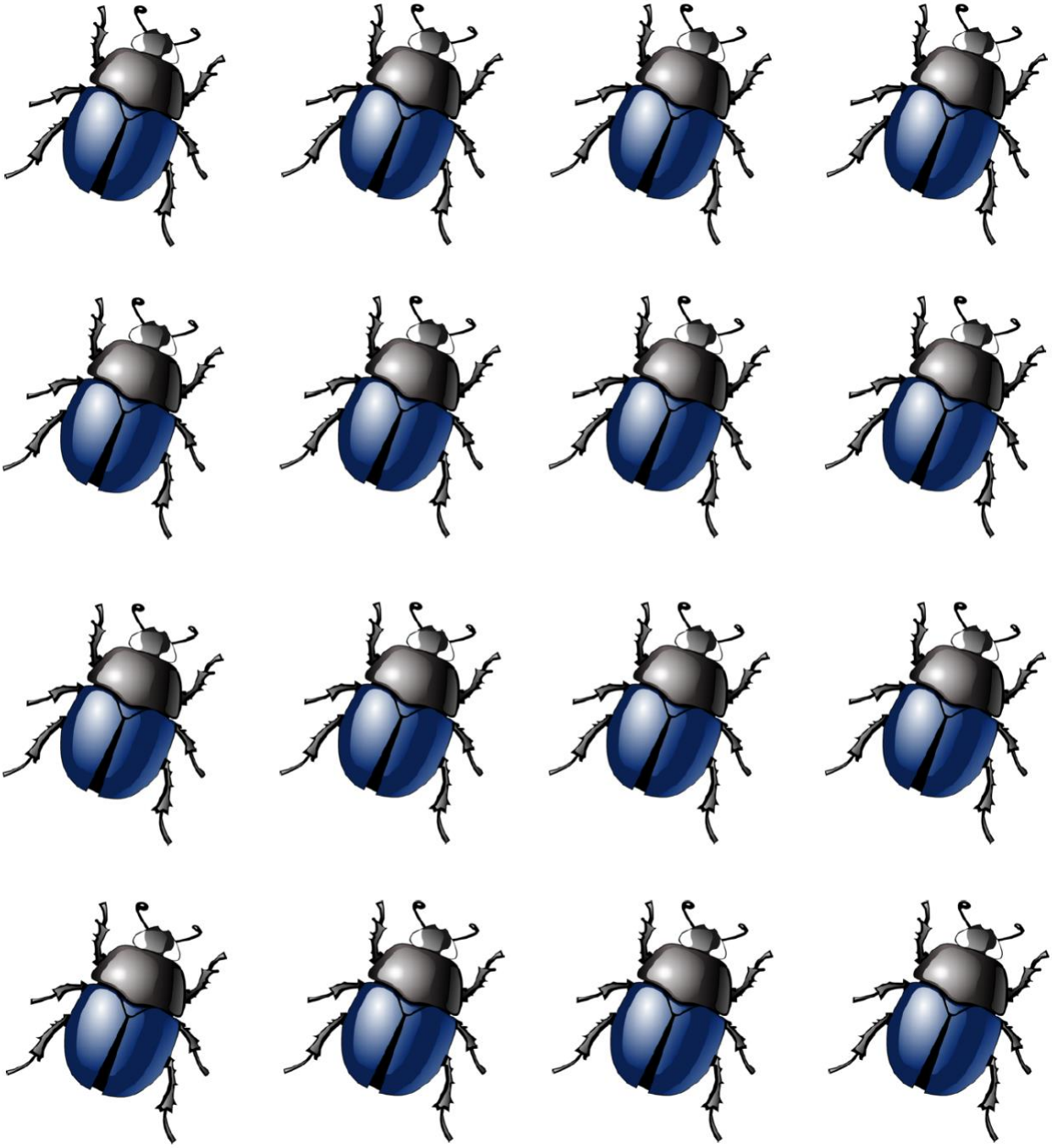
Select 1 random beetle from all the other populations and add it to your beetles.

ADAPTATION: Selection *TEACHER*

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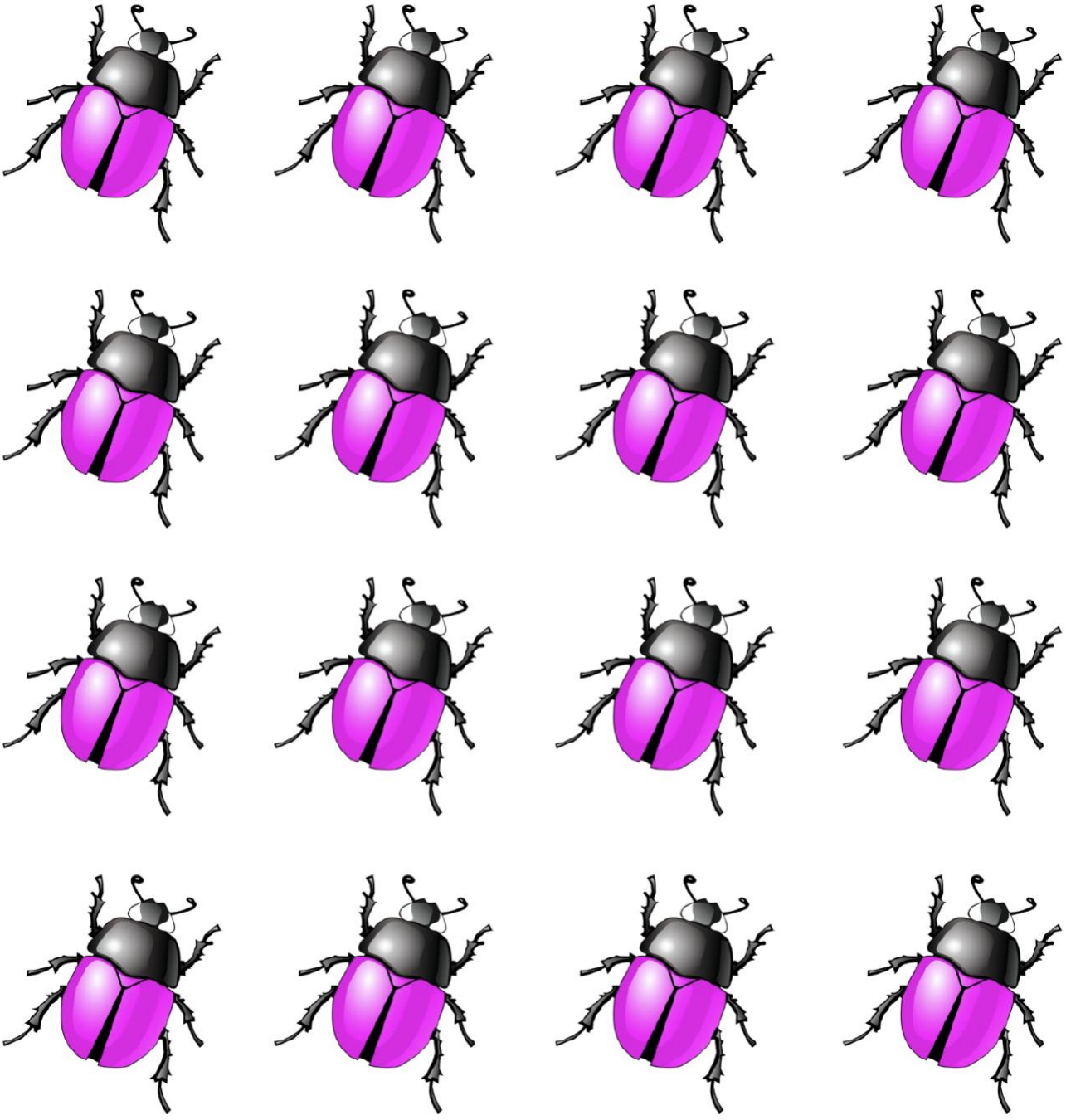
Appendix: Beetle pictures (for optional use as counters)





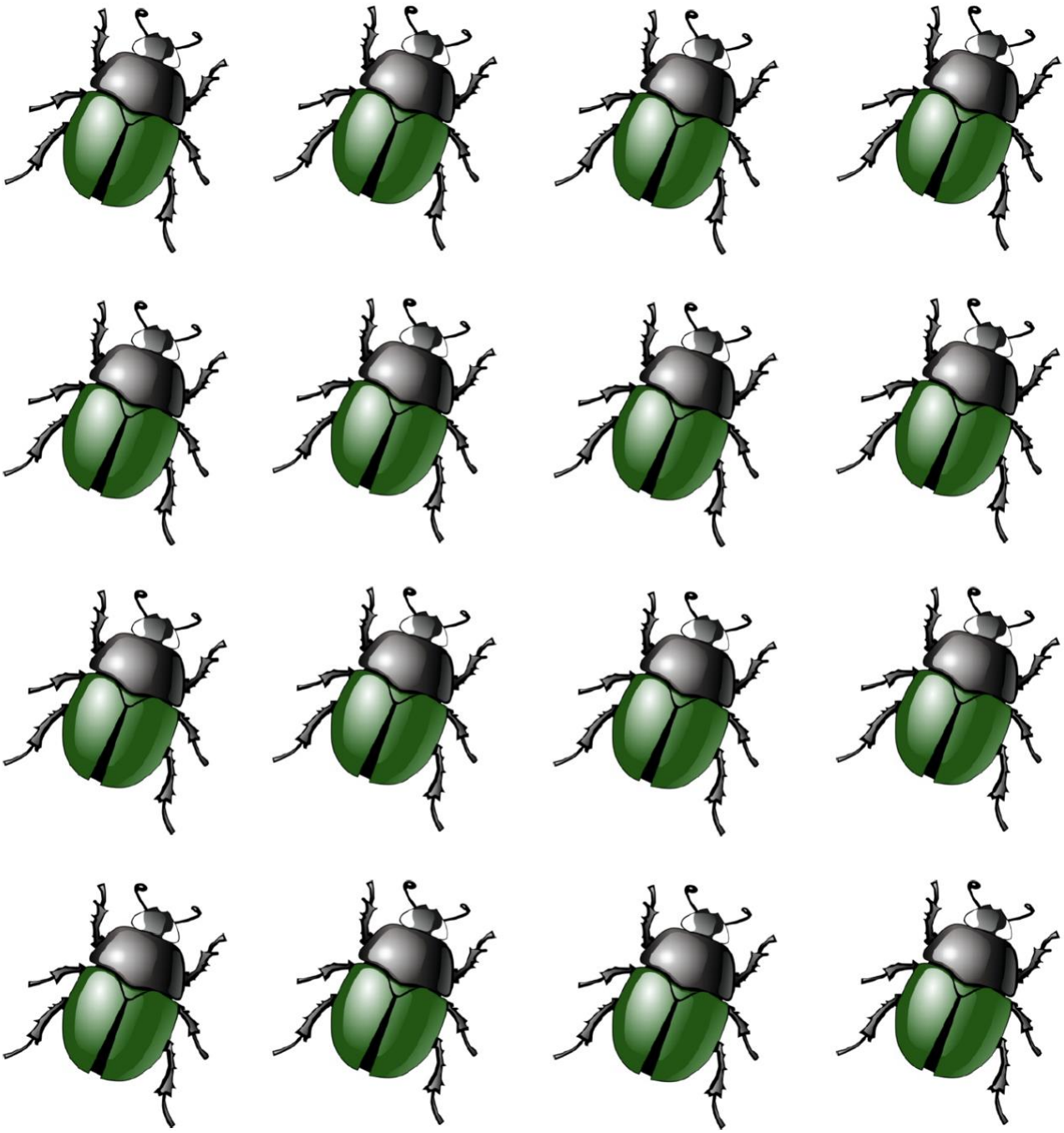
ADAPTATION: Selection *TEACHER*

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ADAPTATION: Selection *TEACHER*

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ADAPTATION: Selection *TEACHER*

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PLANTS AND HUMANS

Students use a card game to explore types of adaptations that plants have evolved to survive environmental challenges, apply this knowledge to technologies humans have used in agriculturally and medicinally important plants, and evaluate infographics to explore how scientific information is communicated.

SOUTH CAROLINA STATE STANDARD	8-LS4-2. Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer their ancestral relationships. *Clarification Statement: Emphasis is on explanations of the ancestral relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.* *State Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures.* 8-LS4-5. Gather and synthesize information about technologies that have changed the way humans influence the inheritance of desired traits in organisms. *Clarification Statement: Emphasis is on synthesizing information from reliable sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, gene therapy); and on the impacts these technologies have on society and scientific discoveries.* *State Assessment Boundary: Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.*
NEXT GEN STANDARD	MS-LS4-2. Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer their ancestral relationships. MS-LS4-5. Gather and synthesize information about technologies that have changed the way humans influence the inheritance of desired traits in organisms.
LEARNING OBJECTIVE(S)	- Students will make starting inferences regarding how plant adaptations support survival in some challenging conditions while not lending benefit in others - Students will encounter examples of how humans have influenced the inheritance of desired traits in some organisms of agricultural importance and how humans have used some plants for medicinal and therapeutic purposes - Students will explore how scientific information is communicated by evaluating infographics further

	developing their scientific literacy skills - Students will engage in argumentation regarding how humans use technologies to influence the inheritance of desired traits in organisms Optional Extension Activity - Students will evaluate the technologies humans use to influence the inheritance of traits in plants and will develop an argument regarding how they may or may not help address challenges of climate change.
ESTIMATED TIME	Part I: 30-45 minutes plus an additional 10-15 minutes per round if you add extra rounds Part II: 45-60 minutes Part III: 45-60 minutes

WHAT YOU'LL NEED:

For Part I: This activity requires 20 Plant Adaptation Cards and 8 Plant Challenge Cards per group. Both are available in the Appendix, with the Plant Adaptation Cards over 5 pages and the Plant Challenge Cards over 2 pages. Four sets of laminated cards are provided with each box and PowerPoint slides of the Plant Challenge Cards are available on the BeakerBox website.

For Part II: This activity requires 6 Ancestral Plant Comparison Cards and 6 Modern Plant Comparison Cards, both in the Appendix. Four sets of laminated Plant Comparison Cards are provided with each box, and PowerPoint slides of Plant Comparison Cards are available on the BeakerBox website.

For Part III: This activity requires Genetic Modification Infographics 1 through 5 and the Infographic Vocabulary Glossary. One set of laminated Infographics and Glossary is provided with each box. Note that students also have the Infographic Vocabulary Glossary within their materials.

For optional extension activity: This optional activity requires Climate Infographics 1 through 5 and uses the same Infographic Vocabulary Glossary used in Part III. One set of laminated infographics is provided with each box.

WHAT YOUR STUDENTS SHOULD KNOW BEFORE:

Some general knowledge of adaptation may be helpful, but not necessary since this activity is designed for students to predict and learn about the effects adaptation may have on plants.

WHAT TO DO BEFORE YOUR CLASS:

Make sure you have the appropriate cards and infographics for each part of the activity you are implementing (See WHAT YOU'LL NEED above). Plan for how you will group students to complete each part of the activity. For example, grouping to play the card game in Part I, grouping to complete the card sort and discussion in Part II, and how students will access the infographics in Part III.

HOW SET UP YOUR CLASS:

Students will work in groups. Group size may depend on how you decide to play the card game in Part I and how you plan to have students complete Part III (station rotations or small groups). We recommend groups of no larger than 3-4 students.

For Part I: There are 3 options to play this game: Team vs Nature, Team vs. Team, everyone for themselves

1. Team vs Nature: Students work as a small group to pick the best cards to play for each challenge card. Each plant card that survives the challenge card goes to the team. Each plant that dies from the challenge card goes to nature. Either nature wins or the team wins- this is a good option for a non-competitive/ cooperative group.
2. Team vs. Team. Seat students in groups of four with two two-person teams within each group. Divide the cards randomly between the two groups (10 each). Each team will play a plant card. Each plant that survives the challenge card, the team keeps, each plant that dies goes to the nature pile. The team at the end with the most cards wins. This is a good option for students who like group competition.
3. Everyone for themselves: seat 4 students to a group. Divide the cards evenly among the 4 students (5 each). Each person will place a plant card for each challenge card. Students keep the plant cards that survive and give the plant cards that die to the nature pile. Once all cards are played, the student with the most cards at the end wins. This is a good option for students who enjoy individual competition.

WHAT YOU NEED TO KNOW FOR YOUR SAFETY:

None

This lesson has been designed to follow three dimensional learning, as described in NGSS standards. In this teacher version, we annotate the associated Science and Engineering Practices and Cross-Cutting Concepts using icons (from these NGSS Planning Cards) before the relevant student question and blue and green text, respectively, within the student instructions. Additionally, content and questions that specifically address the Disciplinary Core Idea is represented in orange text. Sample student responses, classroom recommendations, and other hints are in *red italicized text*. See https://scienceweb.clemson.edu/beakerbox/ for additional files such as non-annotated student versions, Spanish versions of student materials, and slides.

PLANTS AND HUMANS

PART I: What adaptations do plants have that help them survive in their environments?

Phenomenon: Consider the environments plants grow in such as a yard, around the school, the medians of highways, cracks in the sidewalk, forests, and so on. Examine the pictures of different environments and think about various challenges plants might face in each environment that could impact their survival.

 **Swamp**	 **Tidal Creek**	 **Grass Field**
 **Golf course**	 **Beach Dunes**	 **Scrub**
 **Virginia Creeper (Native to South Carolina)**	 **Spanish Moss growing in a tree**	 **Urban forest**

1. Thinking back to the pictures or other environments that plants grow in, what are some adaptations that plants have to help them survive in their environments?

Answers will vary:
Possibilities include deep roots (e.g. dune grass), ability to absorb water from the air (e.g. Spanish moss), appendages for climbing trees (e.g. Virginia creeper), "knees" for exchanging oxygen and CO2 in the swamp (e.g. cypress trees), sprawling root systems (e.g. grasses in an urban forest), adaptations to survive in various environments like high salinity and low light

2. How do you think humans can/do use plant adaptations to support human society?

Answers will vary:
Medicine
Agriculture
Entertainment, Golf
Keep soil/ sand from eroding (e.g., beach dunes)
Selecting plants adapted to drought to grow in more dry areas
Selecting plants for aesthetic beauty in gardens and plantings
Grasses for parks and golf courses – soft to play on
Planting trees and shrubs to serve as windbreaks, slowing down wind
Planting trees in urban areas to cool areas in the summer
Planting trees along roadways to slow people down

PLAYING THE PLANT ADAPTATION GAME

Plants face a lot of different challenges from their environments. In this game, you will explore some changes or events in the environment that impact plants and that some plants have adapted to survive.

- Read through all of the plant cards to get a sense of the adaptations for each of the plants. You may notice the icons in the bottom left corner of some plant cards, the meanings of which are described in the table below.

Item	Icon	Description
Fork		Is eaten by humans
Tractor		Selectively adapted by humans
Medicine bottle/pill capsule		Used in traditional medicine (the use of natural products to treat illness, prevent disease, and maintain health)
State of South Carolina		Native to the state of South Carolina

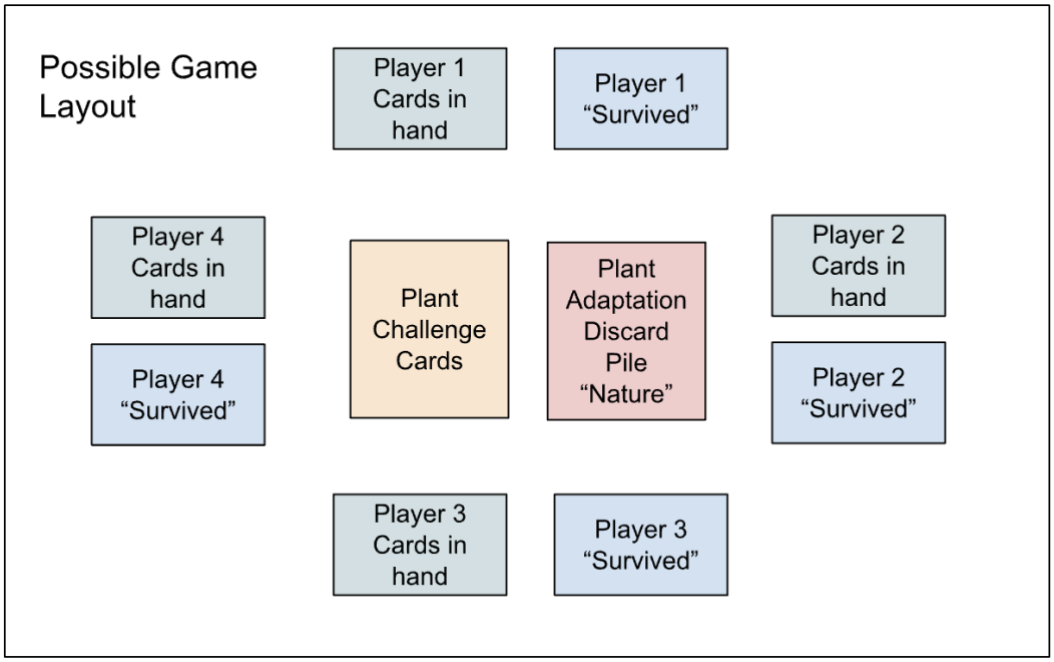
3. Now that you have looked through the cards, for what purposes do humans use and/ or adapt plants? (Challenge: come up with some additional responses compared to question 2.)

Answers will vary:
Humans modify plants for food
Humans use plants for medicine, food, and products
Humans modify food plants to survive and grow in different environments
Humans modify plants to be pest resistant or harvest oils to create pesticides

GOAL
In this activity, your aim is to keep as many plant cards as possible from the beginning of the game to the end.

SETUP

- With instructions from your teacher, decide on the version of the game you will play:
  a. Team vs. Nature (Group of students playing cooperatively)
  b. Team vs. Team (Group of students playing in teams against each other)
  c. Everyone for Themselves (Individual students playing against each other)
  Note: Teachers may dictate the type of game play or allow each group of students to choose their game play. Collaborative game play might result in more discussion among team members whereas individual game play may decrease conversation due to its competitive nature.
- Shuffle the PLANT ADAPTATION CARDS and then divide them so each team/player has the same number of cards. If there is an uneven number of cards remaining, leave the extras out of the game. ***Each player may read the cards in their hand.***
- Shuffle the PLANT CHALLENGE CARDS and then place them in the center. You'll want to put the side with a thick black border and the name of the challenge facing up.
- *Alternatively, teachers can hold the plant challenge cards and display them by holding them up or using the slides provided on the BeakerBox website.*



GAMEPLAY

- For each round, the top challenge card represents the event for that round. (Alternatively, the teacher or one player could play the challenge cards at random)
- Each team plays one plant "against" the challenge.
- Once all teams/players have played a card, turn the challenge card over to see which plants survived and which plants were killed by the challenge.
- If your plant survived, you should put that next to you in your "survived" pile. ***You may NOT play this card again***, but this will help you keep track of how many of your plants survived.
- If your plant was killed, place it in the "nature" pile indicating these plants were returned to nature. These cards will not be played again.
- Repeat this until all plant adaptation cards have been played.
- After all the plant adaptation cards have been played, count the number of plant cards in the "survived" pile and record each team's/player's score in the data table.
- The team/player with the most "survived" cards wins!
- Play multiple rounds as you wish.

There are 8 different challenges that your plants may face, so you should take a minute to look through your cards and think about whether each plant in your hand would survive or die given that challenge.

Your plants may be challenged by:

1. Herbivores
2. Low Light
3. Extreme Cold
4. Fire
5. A Bulldozer
6. Drought
7. High Water
8. Pests

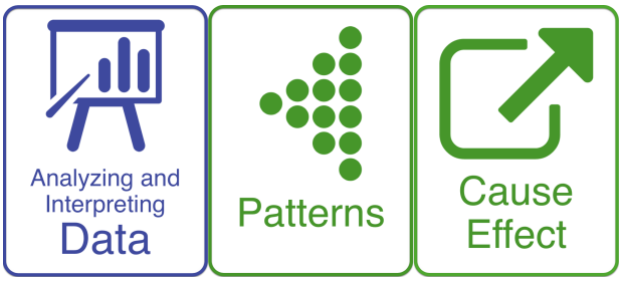
Team/ Player	**Round 1**	**Round 2 (Optional)**
1		
2		
3		
4		

POST GAME ANALYSIS



4. Take a look at the Pests Plant Challenge Card. Pull the Plant Adaptation Cards for all plants that can survive pests. Read the descriptions of the plants' characteristics and adaptations. What characteristics do you notice that allow different plants to survive pests?

Nearly all plants resists pests because of a bioengineered, chemical, or structural defense.
--Bioengineered/modified by humans: corn, rice, and sugarcane
--Naturally produce a chemical like an oil or sap: cypress, eucalyptus, milkweed, mint, and poison ivy
--Structural protection like strong stalks (bamboo), thick bark (redwood), and leathery leaves (fern)



5. Specifically look at the Plant Adaptation Cards for corn, rice, and sugarcane.
   a. What do these plants have in common about their ability to survive pests?

Corn, rice and sugarcane have been modified by humans to survive pests.

   b. What icons do these Plant Adaptation Cards have in common?

Fork and tractor

   c. Why are some plants modified by humans for society and others are not?

Some plants are less useful to humans because they cannot be used for food, medicine, building houses, stabilizing runoff, aesthetically unpleasing, deterring pests, and supporting soil health.

PART II: How have humans influenced the desired traits of organisms?



6. Brainstorm ways humans have influenced the desired traits of organisms.

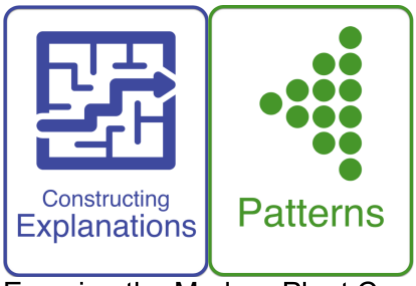
What I Know: *Answers will vary. Accept student thinking but be aware of incomplete knowledge or common, yet incorrect ideas.*
We influence plants for larger size, color, taste, growing period, etc.

What I Wonder: *Answers will vary. Accept all questions that are on topic. Consider placing questions that are more broad or a little removed from the topic in a "parking lot" to be answered later.*
How do people decide what to modify?

7. **Card Sort:** Examine the Ancestral Plant Comparison cards labeled A-F with an orange border displaying early forms of modern day foods from plants. What fruit or vegetable do you think are shown on each of these cards?

Students will predict using prior knowledge. All predictions that are plant based are acceptable. (e.g. pomegranate, papaya, asparagus, melon, ginger, peach, cherry)

- *Alternatively, teachers can display these images using the slides provided on the BeakerBox website and have the class guess as a group.*



8. Examine the Modern Plant Comparison cards labeled G-L with a purple border displaying modern day food from plants. Determine which image from the A-F Plant Comparison cards matches with Plant Comparison cards labeled G-L. You should form 6 pairs of cards.
    a. Check your Plant Comparison Card pairs with your teacher before moving on to the next step. Teacher Signature: _____

Key for Plant Comparison Cards:
A&G are watermelon, B&I are banana, C&K are carrots, D&H are corn, E&L are eggplant, and F&J are apples

b. What anatomical similarities and differences do you notice?

Seeds, skin/rind, color, size, shape - answers will vary regarding similarities and differences students notice relative to these anatomical features; students may also recognize other features such as where the plants grow (e.g., on a tree, underground, etc.)

c. Write a scientific explanation, which includes a claim, evidence, and reasoning, of how you connected the ancestral plant with the modern plant.

Through the use of anatomical similarities and differences (evidence), a plant's ancestral relationship can be inferred (claim) because they are related/ genetically related/ share similar DNA/inherited traits (reasoning).

Answer structure may vary and students may use different vocabulary when providing reasoning depending on prior knowledge.

Note: This is a great place to use sentence stems if students are struggling. Plant _____ is ancestral to plant _____.The data shows they are related because _____. The science of inheritance supports this claim because _____.

Possible answer with this structure: Plant A is ancestral to Plant G. The data shows they are related because they have a similar shape, seeds, and rinds. The science of inheritance supports this claim because traits are passed down and therefore they share similar DNA.



9. **How** do you think the ancestral plant became the modern day plant? Generate two mechanistic ideas with your classmates.
Mechanisms are processes that cause something to happen.

There are no wrong answers. Acknowledge every student's ideas.
Keep an eye out for any commonly held incorrect ideas - like plants "choosing" to adapt in certain ways.

Potential responses:
Pollinator extinction, domestication, ecosystem disruption, changes in herbivory, traits selected over time, bioengineering, artificial selection, natural selection, etc.



10. As a class, generate questions about how humans have modified plants to support the survival of humans. Reference question 5 when generating questions. You may also look back at the Plant Adaptation Cards you examined for question 5.

Answers will vary. Please accept all questions. If students struggle asking scientific questions, use some of the potential questions below to "prime the pump" and model questioning. It may open students up to asking more questions.

Potential questions:
What time of year are the plants grown?
How were the seeds planted?
How would farmers adjust to new pests/challenges to provide the success of crops?
How do humans breed plants?
How long does it take to modify plants? What does it mean to modify plants? What kinds of plants are modified?
When plants are bred for one characteristic, does it affect other characteristics?
How do humans breed a plant for one particular characteristic?
What does it mean to be genetically modified?
How do humans genetically modify plants?
Can humans change one characteristic without changing other characteristics?
Do changes in plants cause changes in other organisms?
What are the goals humans have for modifying plants?
Why do plants need to be modified?
Why do humans want certain plant structures?
Why were corn and rice chosen to be modified?
How do environmental conditions impact traits that are modified?
Are the modification techniques different for each plant?
Why do we change the foods we eat?

Part III: How has technology changed the way humans have influenced the desired traits of organisms?

Information about Scientific Communication

Science communication can be defined as a way of delivering information from the scientific community to a more general audience like non-scientists. Science communication can include delivering a speech/presentation, having a conversation, writing an article, blogging, posting on social media, or creating a piece of artwork. Great science communication can be very tricky to accomplish and is a skill that needs to be practiced.

Infographics are one way scientists can communicate information to the general public. Consider the following characteristics of science communication as you look at the infographics in the following activity. This will potentially help you answer the strengths and weaknesses column in question 11.

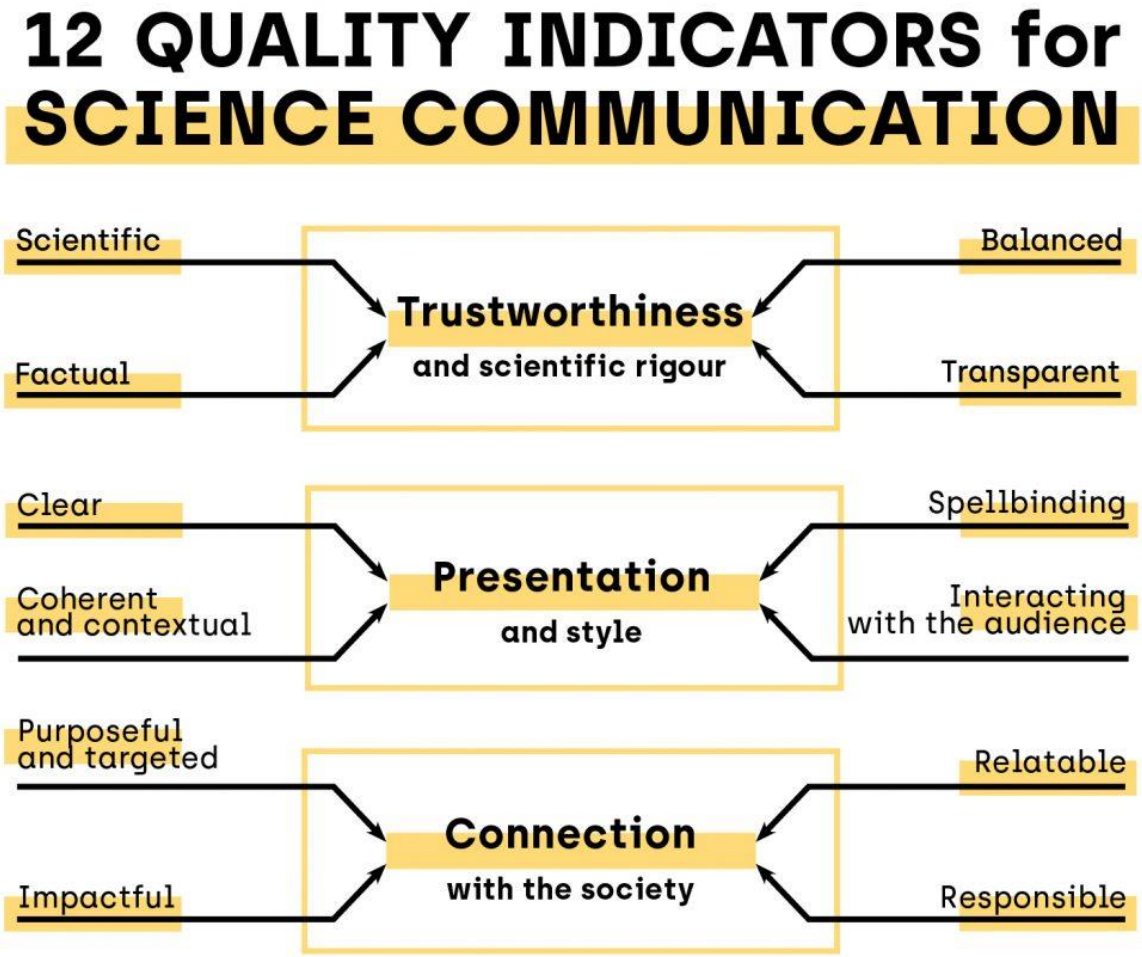


Figure 1: Image from: https://questproject.eu/12-quality-indicators-for-science-communication/



12. Explore the provided resources to learn more about how humans have influenced the desired traits of organisms.
    Note: The Genetic Modification Infographics for this question are included in the appendix if you need additional copies. Also in the appendix is a glossary of terms in the infographics that students may not be familiar with; this glossary is also included in the student copy.
    a. Examine each of the five infographics to explore how humans work to modify organisms.
       Note: Teachers can determine the best way to have students access the information in the provided materials. For example, students could engage in station rotations and look at every resource, students could access the information through a jigsaw activity and bring information back to home groups, or you can project each infographic.
    b. Write down at least one thing you learn and one question you have in the chart below.
    c. Utilize the *12 Quality Indicators for Science Communication* to evaluate each infographic, identifying at least one strength and one weakness.

Info-graphic #	What you Learned	What questions do you have about ways humans have influenced the inheritance of traits?	Identify one strength and one weakness of each infographic
1			Strength: Weakness:
2			Strength: Weakness:

3			Strength: Weakness:
4			Strength: Weakness:
5			Strength: Weakness:

d. Share what you learned from the infographics. Share what questions the infographics raised for you. Discuss strengths and weaknesses of the infographics.
Note: Teachers facilitate a class discussion examining the information students recorded in the station rotation table. Students could share out questions on sticky notes, index cards, or a virtual tool (e.g. Padlet) to create a driving question board. Finally, a discussion about the strengths and weaknesses of infographics serving as a means of science communication and how they may contribute to or help combat misinformation will conclude the activity. Being able to judge quality science documents contributes to students' scientific literacy.

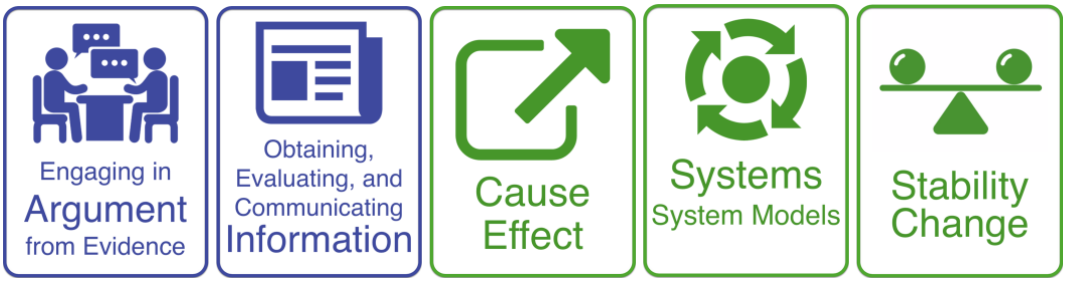
Scientific literacy defined:

- *is "an evolving combination of the science related attitudes, skills, and knowledge students need to develop inquiry, problem solving, and decision making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them" (Council of Ministers of Education, Canada, [CMEC], 1997, as cited in Lederman & Abell, 2014, p. 548).*
- *incorporates personal and societal issues*
- *"illuminates how science permeates and interacts with many areas of human endeavor and life situations…sometimes called science for citizenship" (Lederman & Abell, 2014, p. 546)*

13. Lesson Wrap up: Reflect on what you learned about while exploring the infographics. Fill out the chart below regarding your thinking about how humans have influenced traits and used technology to create genetically modified organisms (GMOs).
Students could complete this on their sheet, on a sticky note, or an exit ticket.

3 Things I Learned today:
2 Things I found interesting:
1 Thing I still have questions about:

OPTIONAL EXTENSION ACTIVITY



Philosophical Chairs Prompt: Is it worthwhile that humans are working to produce plants that can withstand the effects of climate change? Why or why not?

a. Examine the infographics with information about how the climate worldwide is currently changing.
b. Compare the information you have gathered about how humans influence the inherited traits of plants (pay attention to the research and development time on climate infographic 5).
c. Construct an argument using evidence from the provided information to prepare to engage in a philosophical chairs discussion. Use the prompt above and the questions below to help guide your thinking.

Some other questions to think about while crafting your argument:

- Who will be most affected by climate change? Why?
- Whose responsibility is it to help those affected by climate change? Why?
- What are the repercussions if humans are unable to produce plants that can withstand climate change?

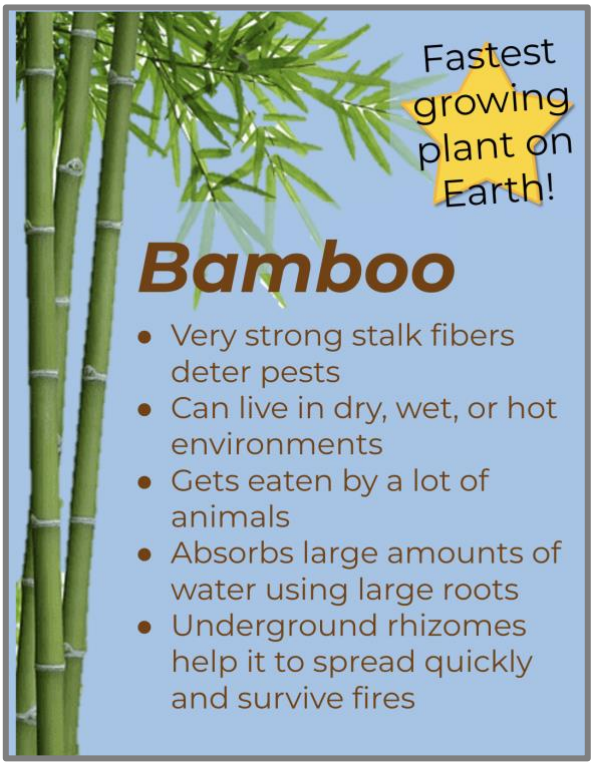
Note: This extension activity could become a multidisciplinary unit. There may be opportunities to collaborate with social studies teachers incorporating concepts of human geography, map reading, cultural impacts, resource sharing, treaties, economics, etc. Additionally, you may partner with ELA instructors to consider perspective taking and reading different mediums. Partnering with math teachers may provide additional opportunities for analyzing and interpreting graphical representations of climate change data (percentages, rates, probability, etc).

Additional resources for this philosophical chairs extension activity:
Communications by Design - Philosophical Chairs Graphic Organizer
https://cbdconsulting.com/free-resources/articles/an-engaging-critical-thinking-activity-philosophical-chairs/

NWESD - Philosophical Chairs Scaffolded Protocol
https://files.nwesd.org/jlongchamps/ELL/Mar%2028/GraphicOrganizerforDebate-Version2.pdf

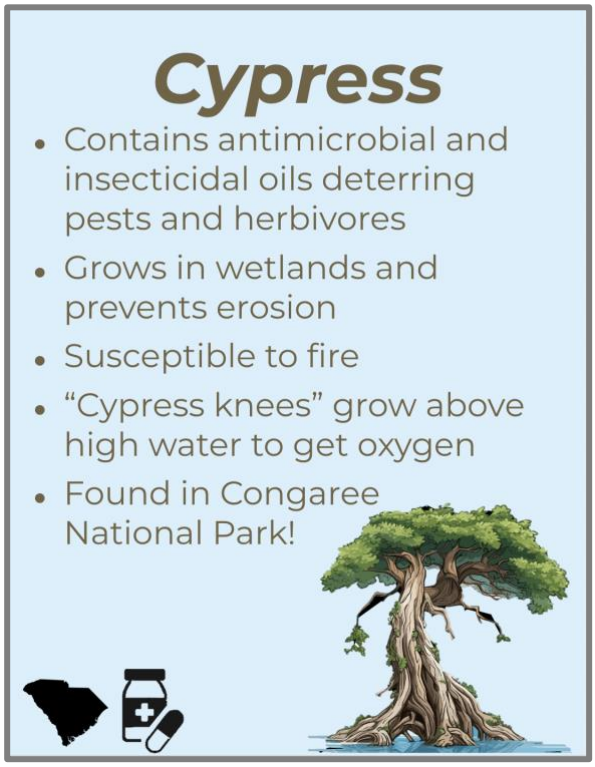
AVID - Philosophical Chairs Information and Graphic Organizers
https://www.osceolaschools.net/site/handlers/filedownload.ashx?moduleinstanceid=2280&dataid=26434&FileName=AVID_Philosophical%20Chairs%20Instructions.pdf

Appendix: Plant Adaptation Cards

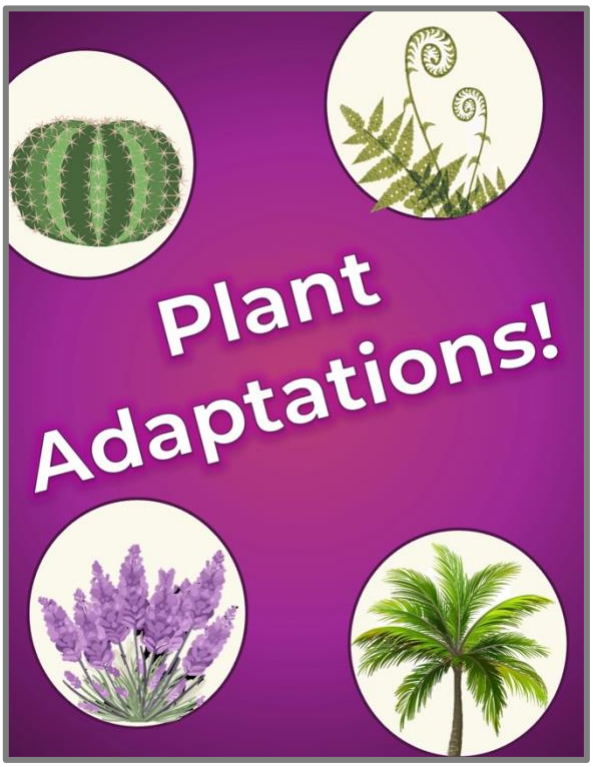


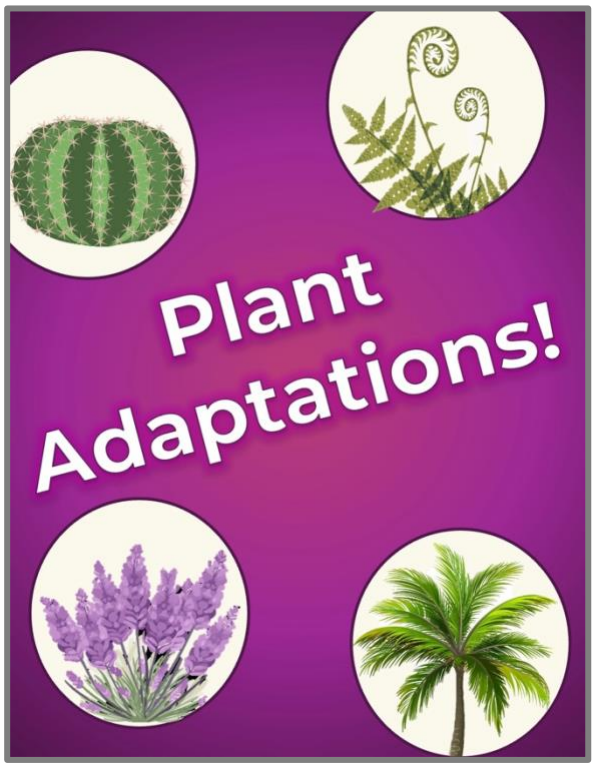


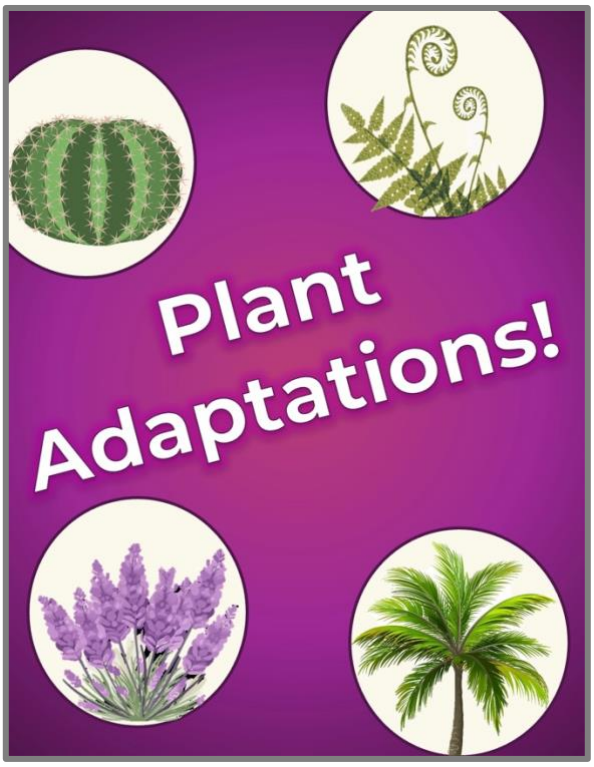


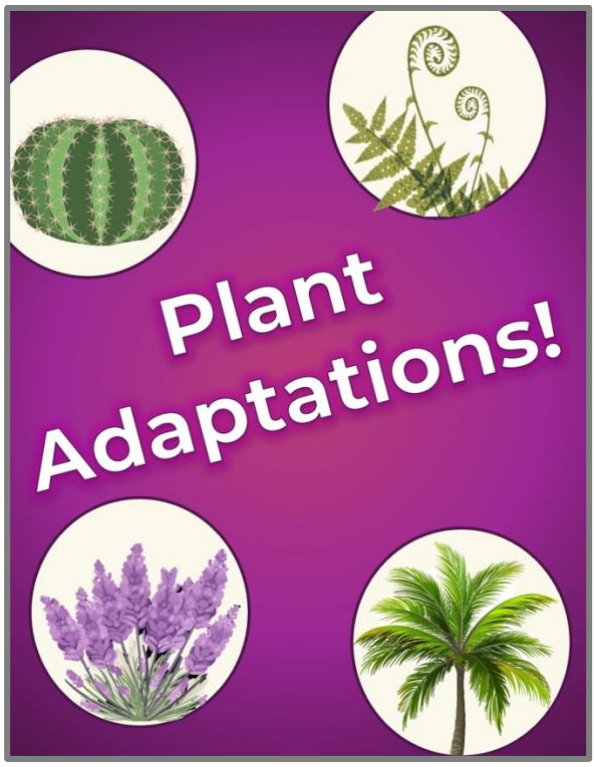


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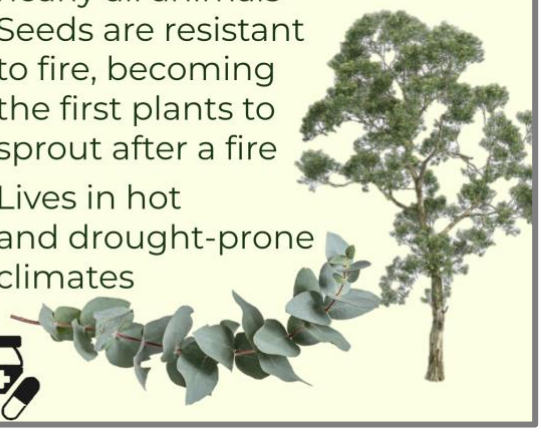
Elderberry

- Traditional medicine used to treat colds and flu, and to boost immunity
- Often found by lakes, ponds, or roadsides
- Seeds contain a toxin to prevent mammals from eating them
- Berries are enjoyed by lots of birds and ***when cooked*** can be used in pies and jellies



Eucalyptus

- Oils repel insects
- Traditional medicine used to treat coughs and colds
- Poisonous when eaten for nearly all animals
- Seeds are resistant to fire, becoming the first plants to sprout after a fire
- Lives in hot and drought-prone climates



Fern

Resilient!

- Underground rhizomes protect from fire
- Leathery leaves deter insects and animals
- Traditional medicine used to treat lung and digestive problems
- Grows in the shade
- Survives mild droughts, cold, and flooding

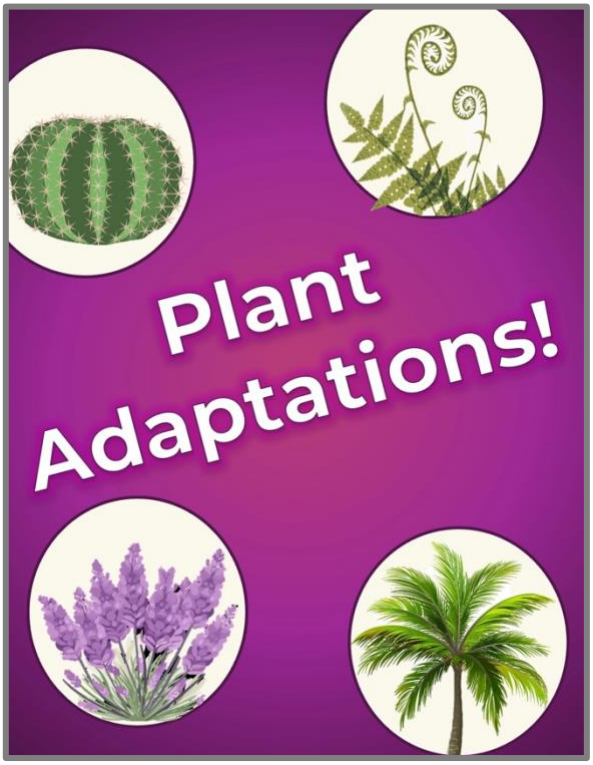


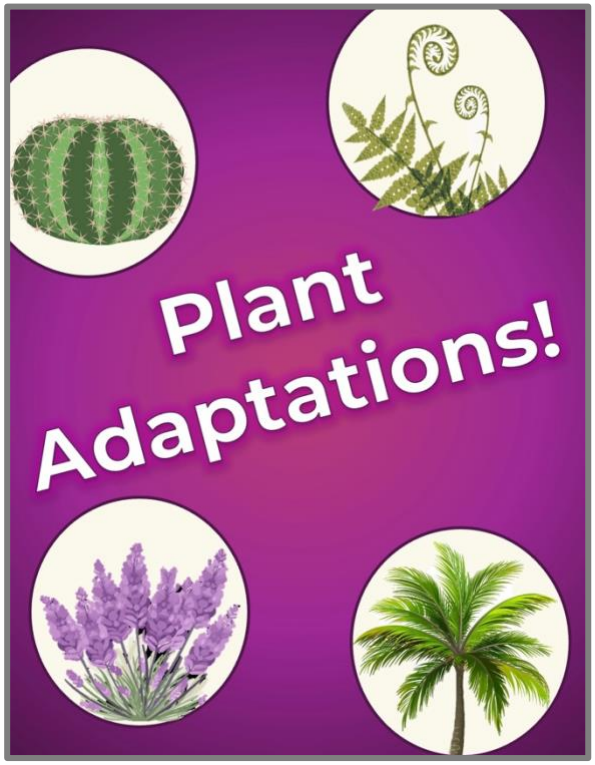
Hibiscus

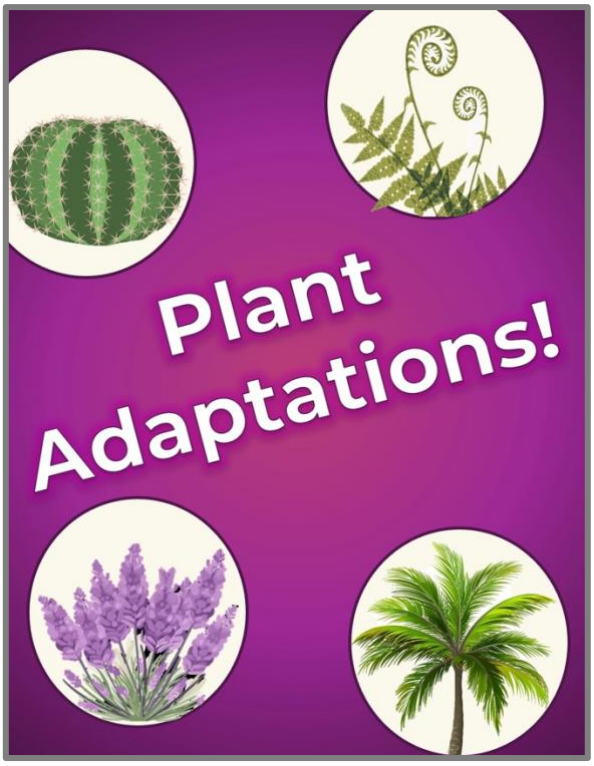
- Grows best in sunny, warm, humid, tropical environments
- Bright colors and nectar attract pollinators like hummingbirds and butterflies
- Flowers are edible
- Traditional medicine used for heart health

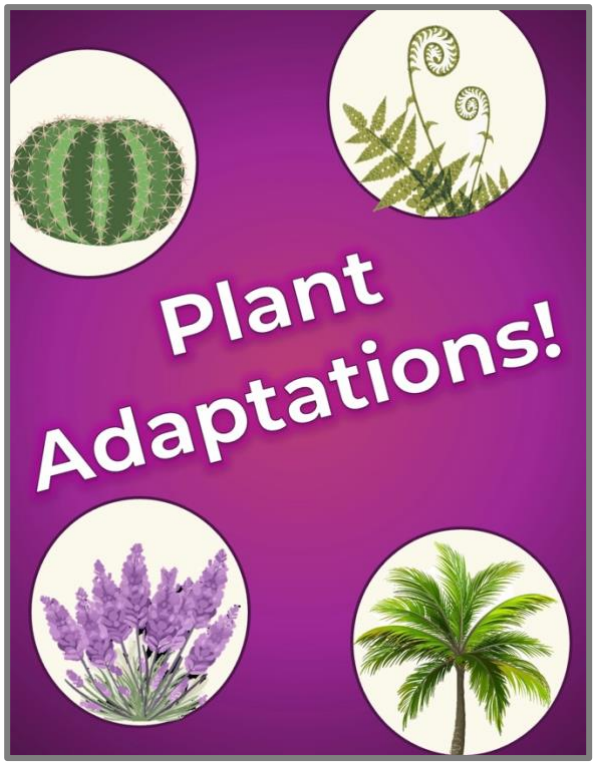


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Magnolia

- Bark has fire resistant cork layer
- Deep tap root keeps them standing during hurricane winds
- Traditional medicine used to treat anxiety and prevent malaria
- Tough leaves deter insects and animals



Milkweed

- Grows in lots of soil types including rocky, clay, sandy, or soil with very little moisture
- Produces a sticky white sap with a chemical that is poisonous to most insects and animals
- The only place a monarch butterfly can lay eggs



Mint

- Produces an oil with a strong scent that deters insects
- Traditional medicine used to treat stomach issues like nausea
- Used in teas and as flavoring
- Produces menthol molecules that cause a cooling sensation

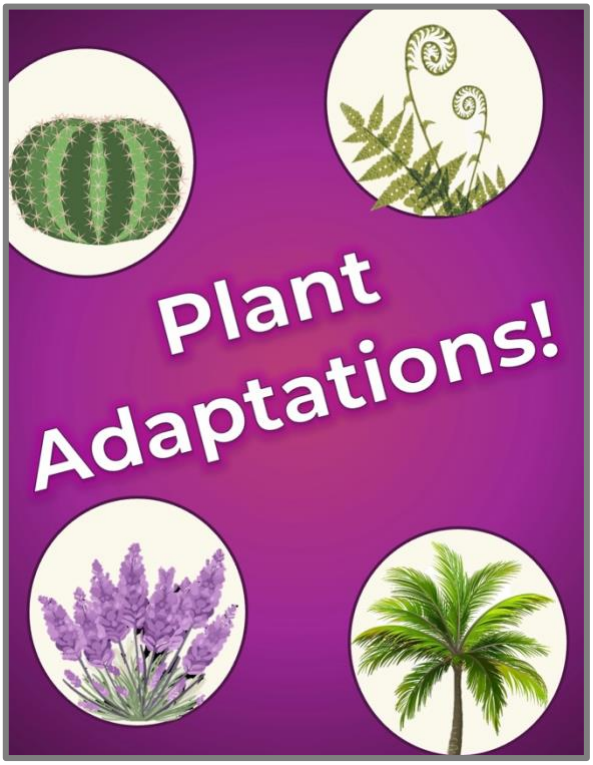


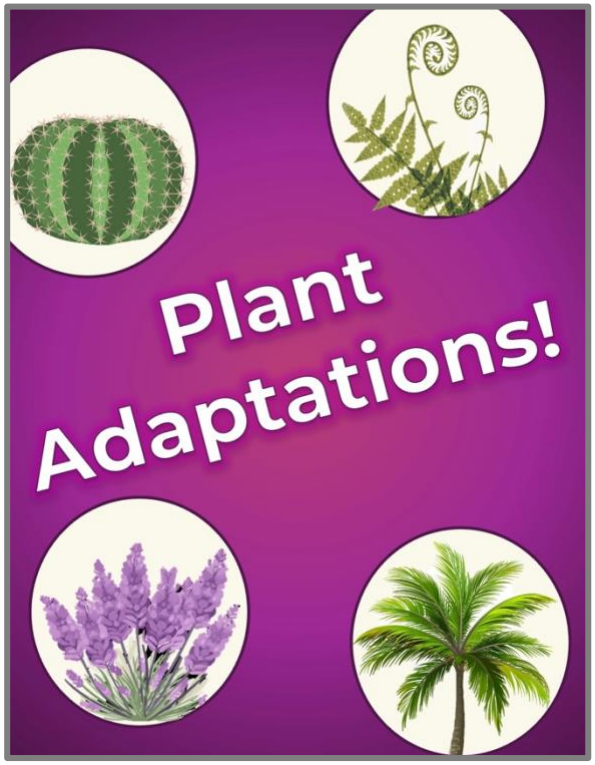
Moss

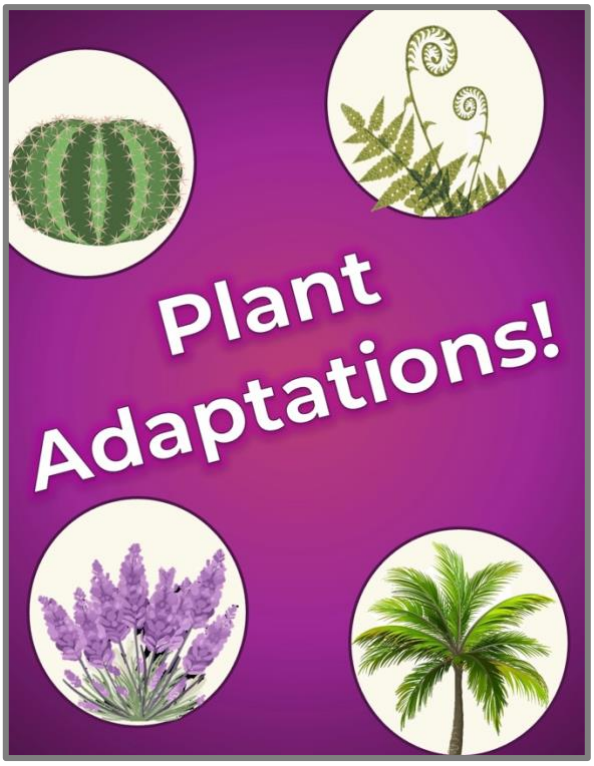
- Lives anywhere with water– even on rocks!
- Incredibly resilient, able to grow in the shade, survives drying out, and produces "anti-freeze"
- Cherokee tribe used moss as an antibiotic and anti-inflammatory

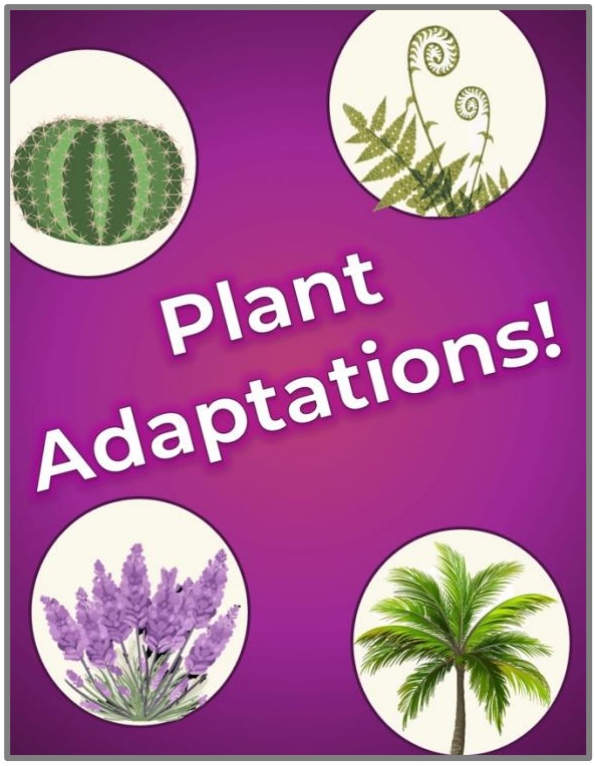


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Pitcher Plant

- Lives in warm environments and wetlands
- Carnivorous: traps and digests insects for nitrogen
- Trichomes ("trapping hairs") in the pitcher prevent insects from climbing out
- Fires are key to restore their habitats



Poison Ivy

Toxic!

- Produces a chemical irritant to repel insects and animals
- "Leaves of three, let it be"
- Can grow in very dry soil



Potato

- Tubers adapted for starch storage help the plant survive harsh winters and fires
- Tubers grow underground
- Vulnerable to disease and lack of water
- Artificially selected to be BIG!



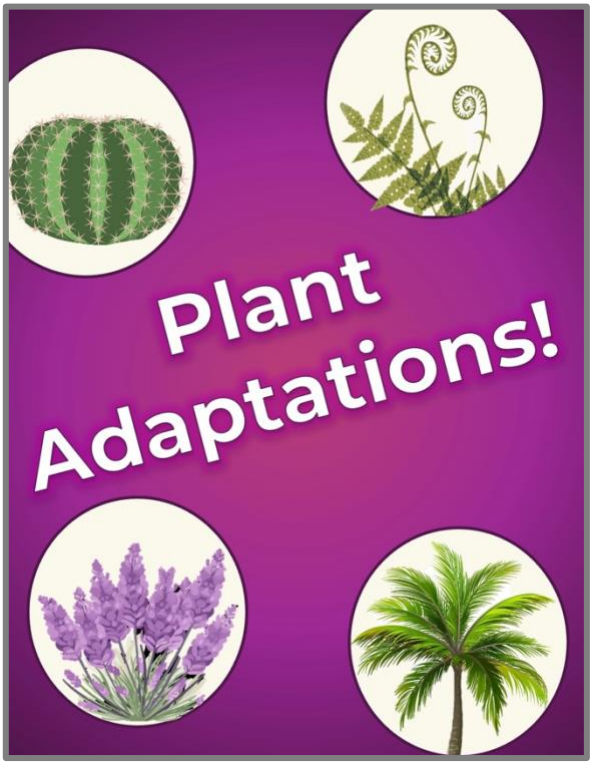


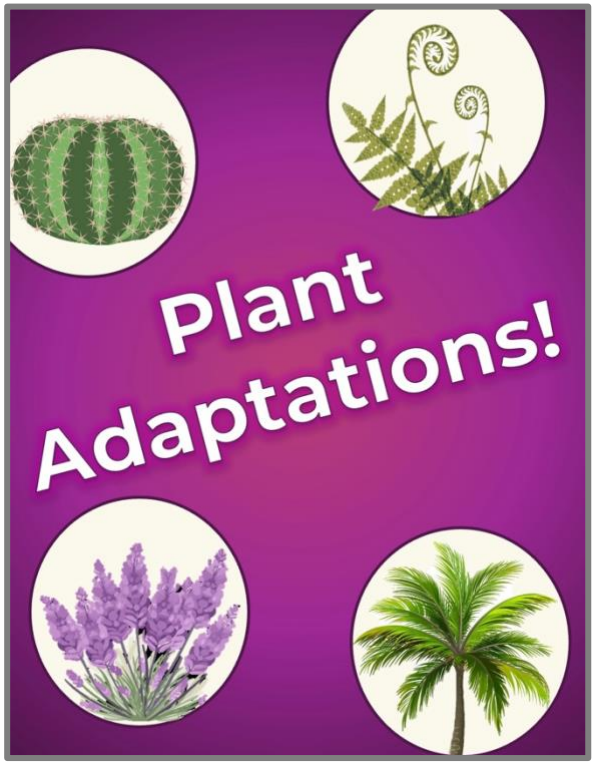
Prickly Pear Cactus

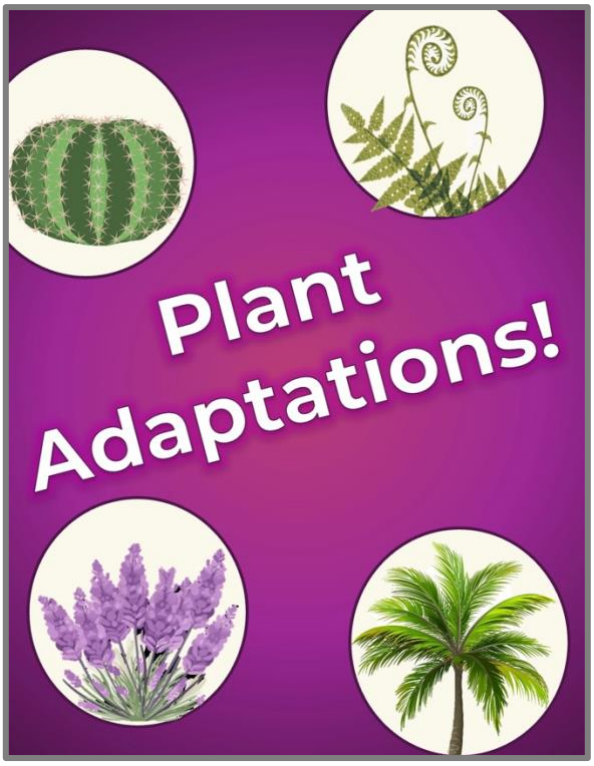
- Opens stomata at night to preserve water in hot and dry climates
- Leaves adapted to be spines to deter herbivores and prevent evaporation of water
- Traditional medicine used for >100 ailments like burns, ulcers, and diabetes
- Vulnerable to pests

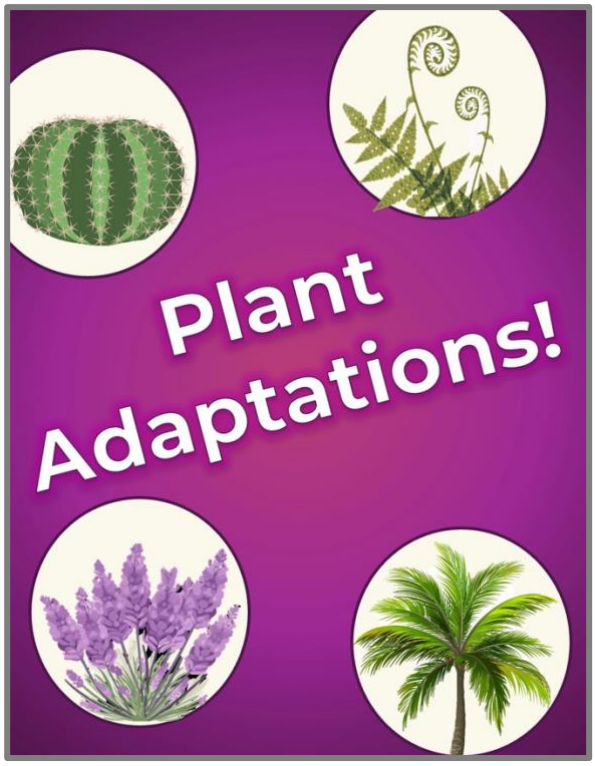


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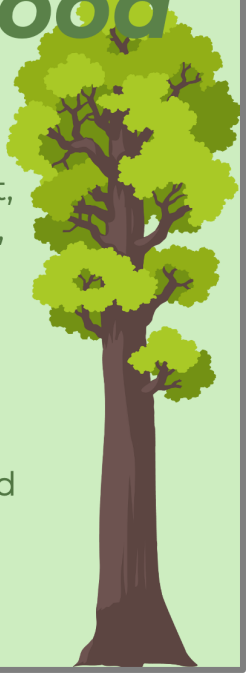




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Redwood

- Thick bark and tannin-rich wood are resistant to rot, insects, predation, and even fire!
- Requires lots of sunlight to grow
- Only grows in the Northern Pacific Coast as they need moisture from coastal fog



Rice

Most valuable crop in the world!

- Domesticated and bred for pest resistance by humans
- Adapted to being submerged in water, such as developing tissue with air pockets



Sugarcane

- Stalks can withstand fire and flooding
- Genetically modified to resist the sugarcane borer insect
- Grows best in tropical environments with lots of water
- Spreads quickly using underground rhizomes

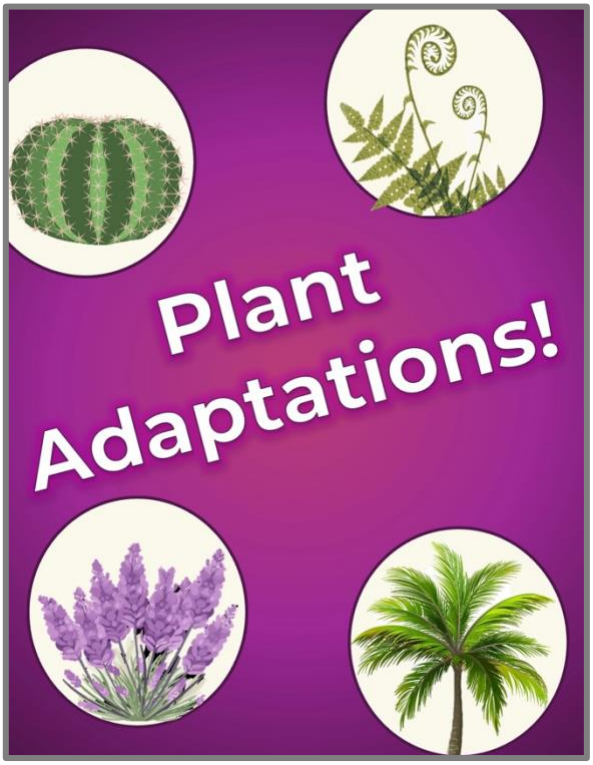


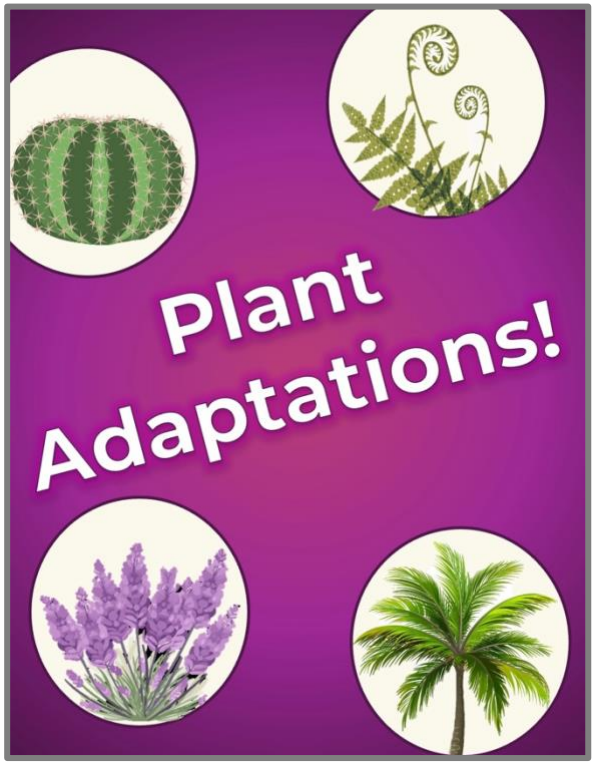
Water Lily

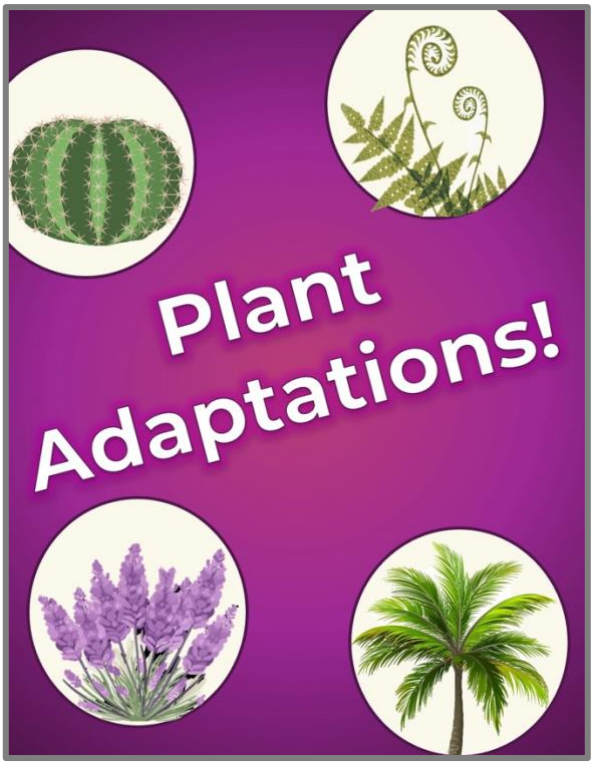
- Lives in water
- Large, broad leaves with air spaces enable it to float and get sunlight
- Specialized air canals to allow oxygen to reach the roots
- Preyed on by insects

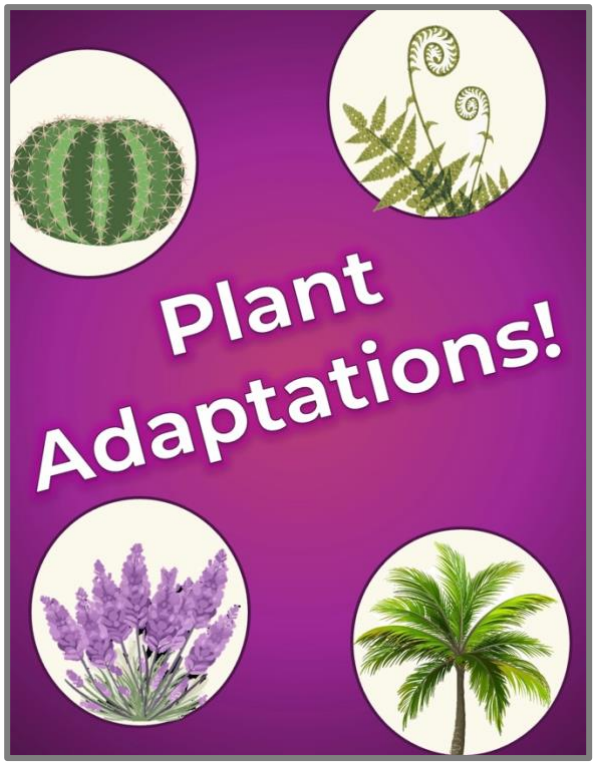


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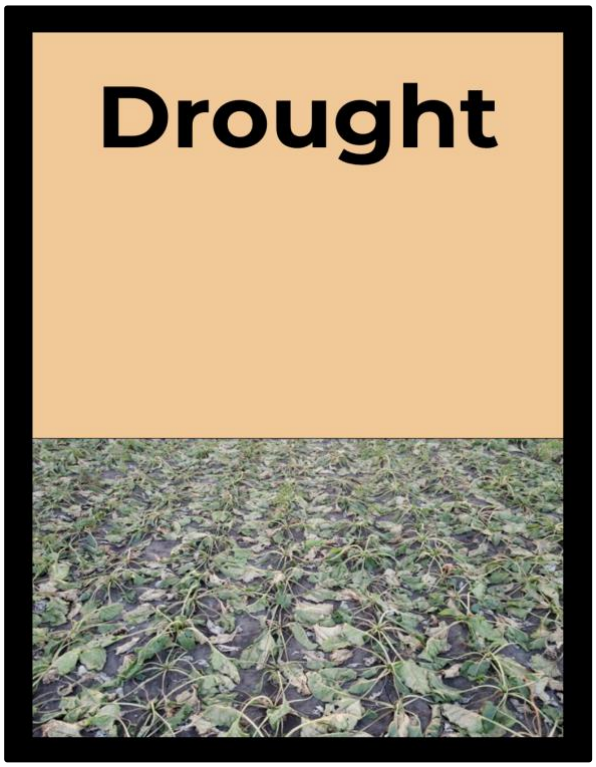




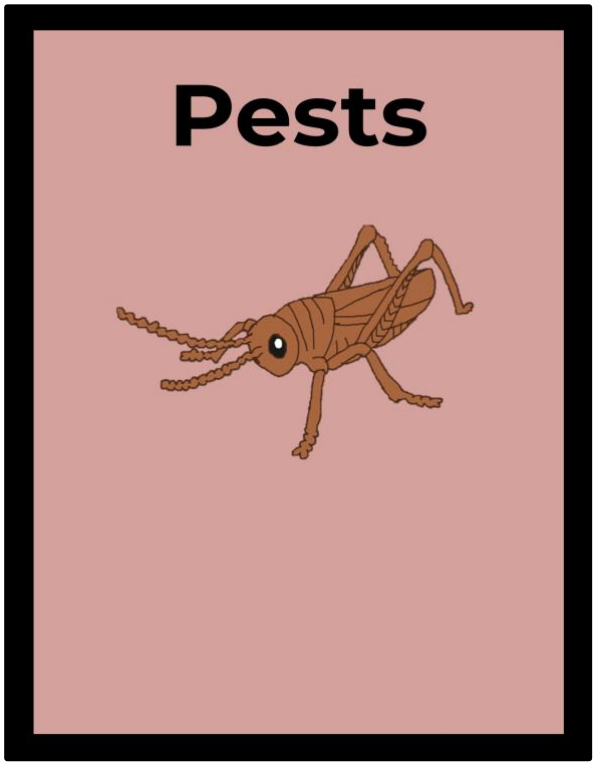
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Appendix: Plant Challenge Cards









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Dies:	Survives:
• Carrot • Cypress • Elderberry • Hibiscus • Magnolia • Mint • Pitcher Plant • Potato • Redwood • Rice • Sugarcane • Water Lily	• Bamboo • Corn • Eucalyptus • Fern • Milkweed • Moss • Poison Ivy • Prickly Pear Cactus

Dies:

- all plants

Dies:	Survives:
• Carrot • Elderberry • Hibiscus • Moss • Potato • Prickly Pear Cactus • Water Lily	• Bamboo • Corn • Cypress • Eucalyptus • Fern • Magnolia • Milkweed • Mint • Pitcher Plant • Poison Ivy • Redwood • Rice • Sugarcane

Dies:	Survives:
• Carrot • Corn • Eucalyptus • Hibiscus • Magnolia • Milkweed • Mint • Poison Ivy • Potato • Prickly Pear Cactus • Redwood	• Bamboo • Cypress • Elderberry • Fern • Moss • Pitcher Plant • Rice • Sugarcane • Water Lily

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Fire



Extreme cold



Herbivores



Low Light



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Dies:

- all but carrot, fern, moss, and potato

Dies:	Survives:
• Carrot • Corn • Cypress • Elderberry • Hibiscus • Milkweed • Mint • Moss • Poison Ivy • Prickly Pear Cactus • Rice • Water Lily	• Bamboo • Eucalyptus • Fern • Magnolia • Pitcher Plant • Potato • Redwood • Sugarcane

Dies:

- all but fern and moss

Dies:	Survives:
• Bamboo • Carrot • Corn • Hibiscus • Mint • Moss • Pitcher Plant • Potato • Rice • Sugarcane • Water lily	• Cypress • Elderberry • Eucalyptus • Fern • Magnolia • Milkweed • Poison Ivy • Prickly Pear Cactus • Redwood

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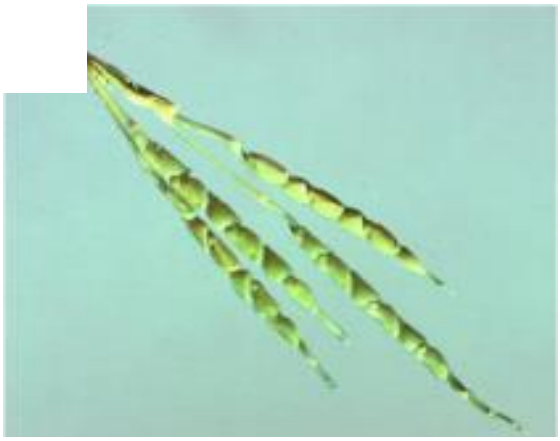
Appendix: Ancestral Plant Comparison Cards

A













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Appendix: Modern Plant Comparison Cards

G



I



K



H



L



J



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Genetic Modification Infographic 1

Crop Modification Techniques

BIOLOGY FORTIFIED

Cross Breeding

Combining two sexually compatible species to create a variety with the desired traits of the parents



The Honeycrisp Apple gets its famous texture and flavor by blending the traits of its parents.

Mutagenesis

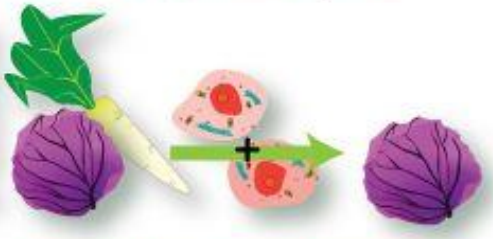
Use of mutagens such as radioactivity to induce random mutations, creating the desired trait



Radiation was used to produce a deeper color in the red grapefruit.

Protoplast Fusion

Fusion of cells or cell components to transfer traits between species



Male sterility is transferred from radishes to red cabbage by fusing their cells. Male sterility helps plant breeders make hybrid crops.

Polyploidy

Multiplication of the number of chromosomes in a crop to impact its fertility



Seedless watermelons are created by crossing a plant with 2 sets of chromosomes with another that has 4 sets. The seedless fruit has 3 sets.

Genome Editing

Use of an enzyme system to modify DNA directly within the cell



Genome editing was used to develop herbicide resistant canola to help farmers control weeds.

Transgenesis

Addition of genes from any species to create a new variety with desired traits

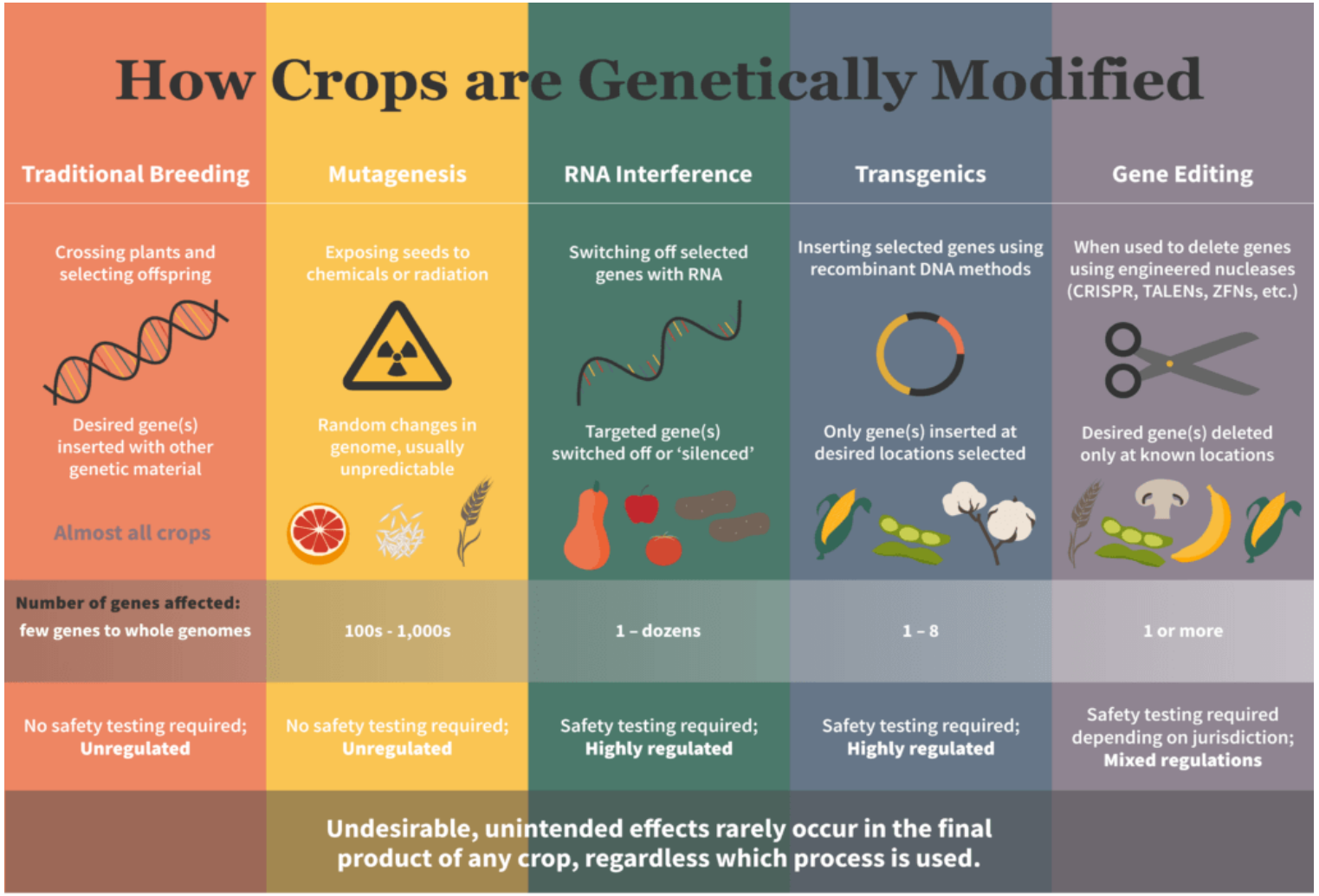


The Rainbow Papaya is modified with a gene that gives it resistance to the Papaya Ringspot Virus.

www.biofortified.org

Follow us on Twitter (@franknfoode) or join our Facebook Page
By Layla Katiraee (@BiochicaGMO) in collaboration with Karl Haro von Mogel (@kjhvm)
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Genetic Modification Infographic 2



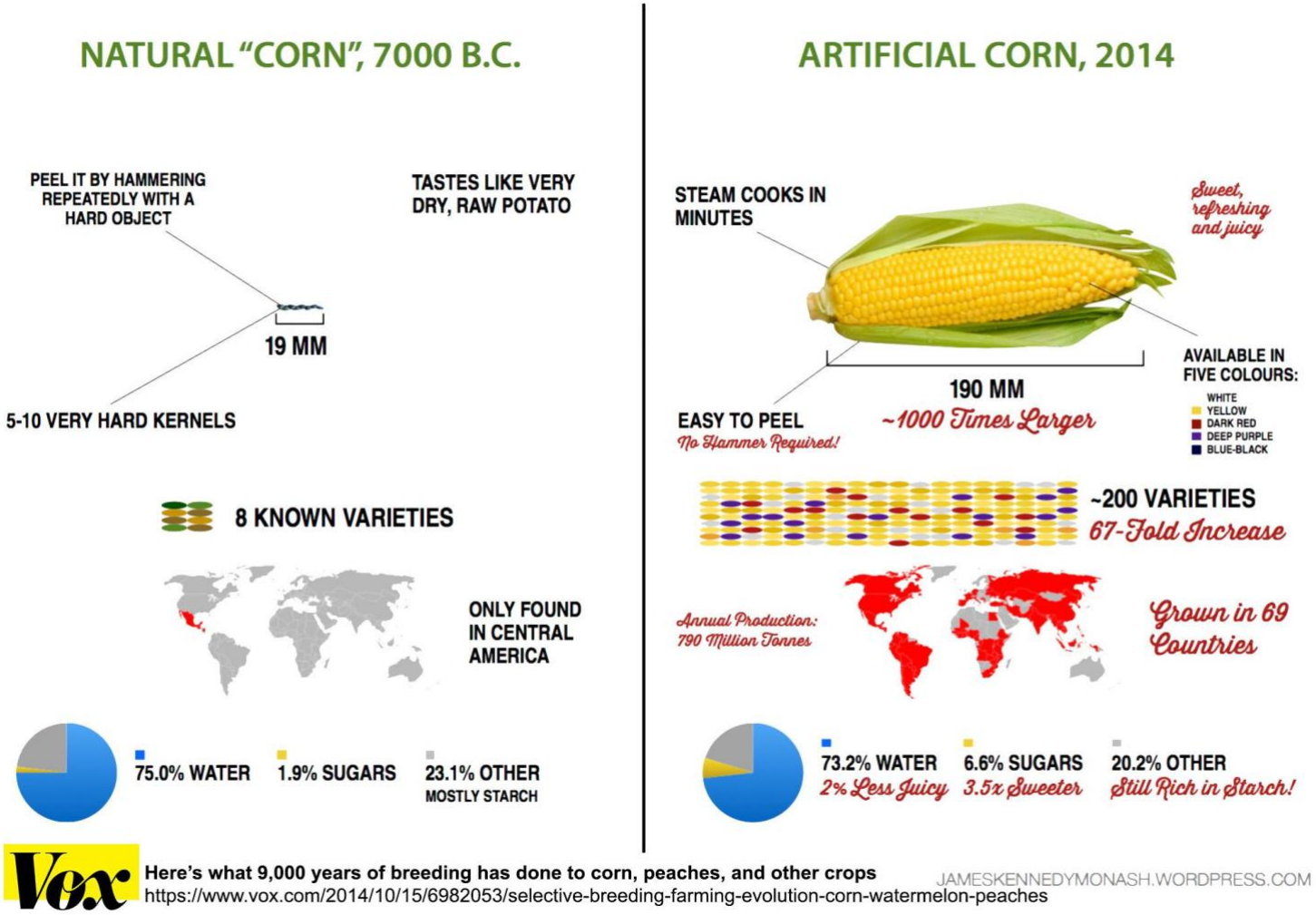
Genetic Literacy Project
SCIENCE NOT IDEOLOGY

Sources: Biotechnology Provides New Tools for Plant Breeding, University of California Davis Publication 8043; Plant Breeding: Induced Mutation Technology for Crop Improvement, F.J. Novak, H. Brunner, International Atomic Energy Agency, 1992; Atomic Gardens: Public Perceptions and Public Policy, B. Dick, M. Jones, Life Sciences Foundation Magazine: RNAi for Crop Improvement, International Service for the Acquisition of Agri-Biotech Applications Pocket K No. 34. **Infographic by Kayleen Schreiber, PhD; advisor: Wayne Parrott, PhD.**

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Genetic Modification Infographic 3

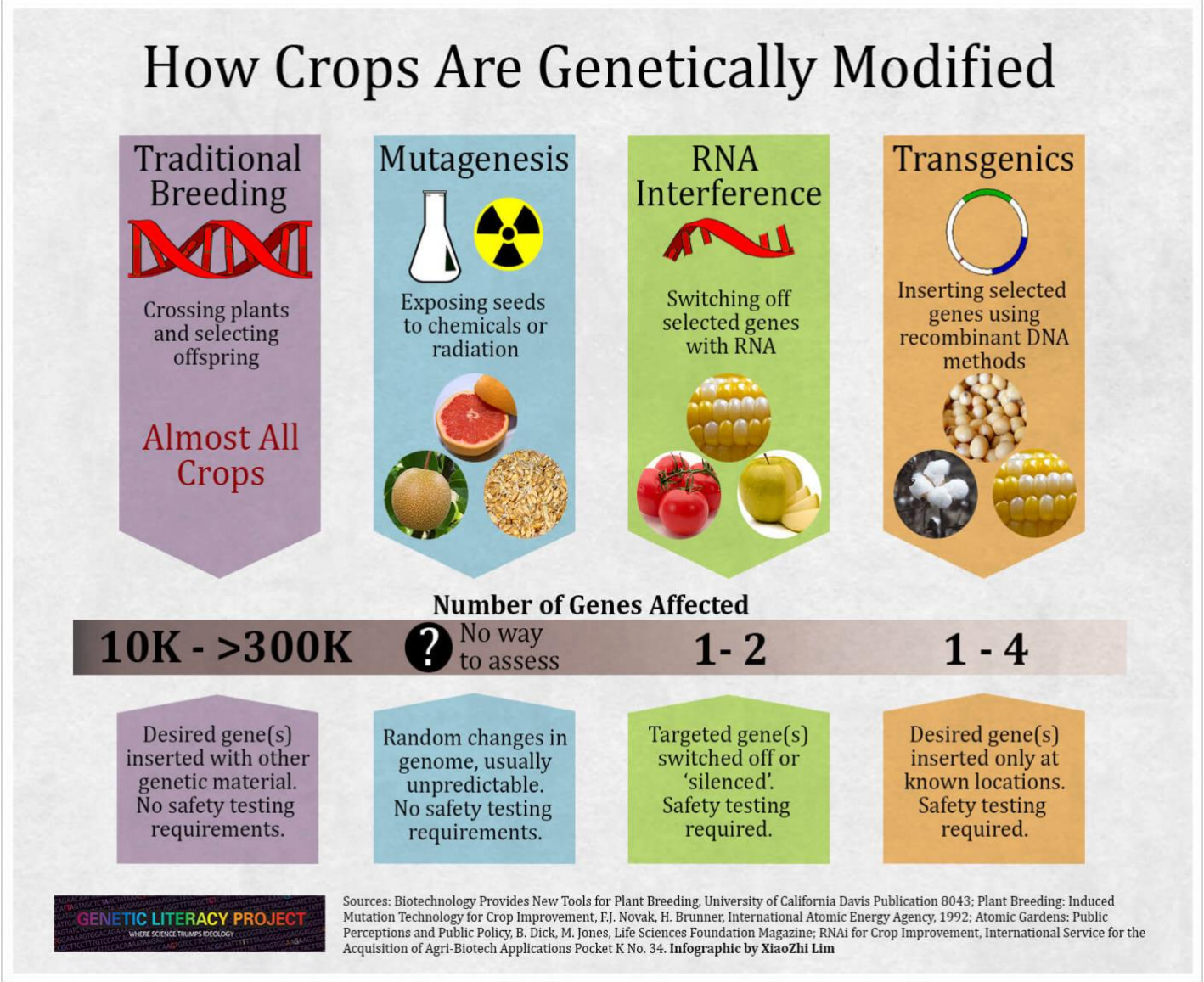


This infographic provides examples of how traditional plant breeding has been used to modify agricultural crops. Traditional plant breeding and selection of the best offspring (artificial selection) was used to develop modern corn and additional modifications have been made through various biotechnological processes.

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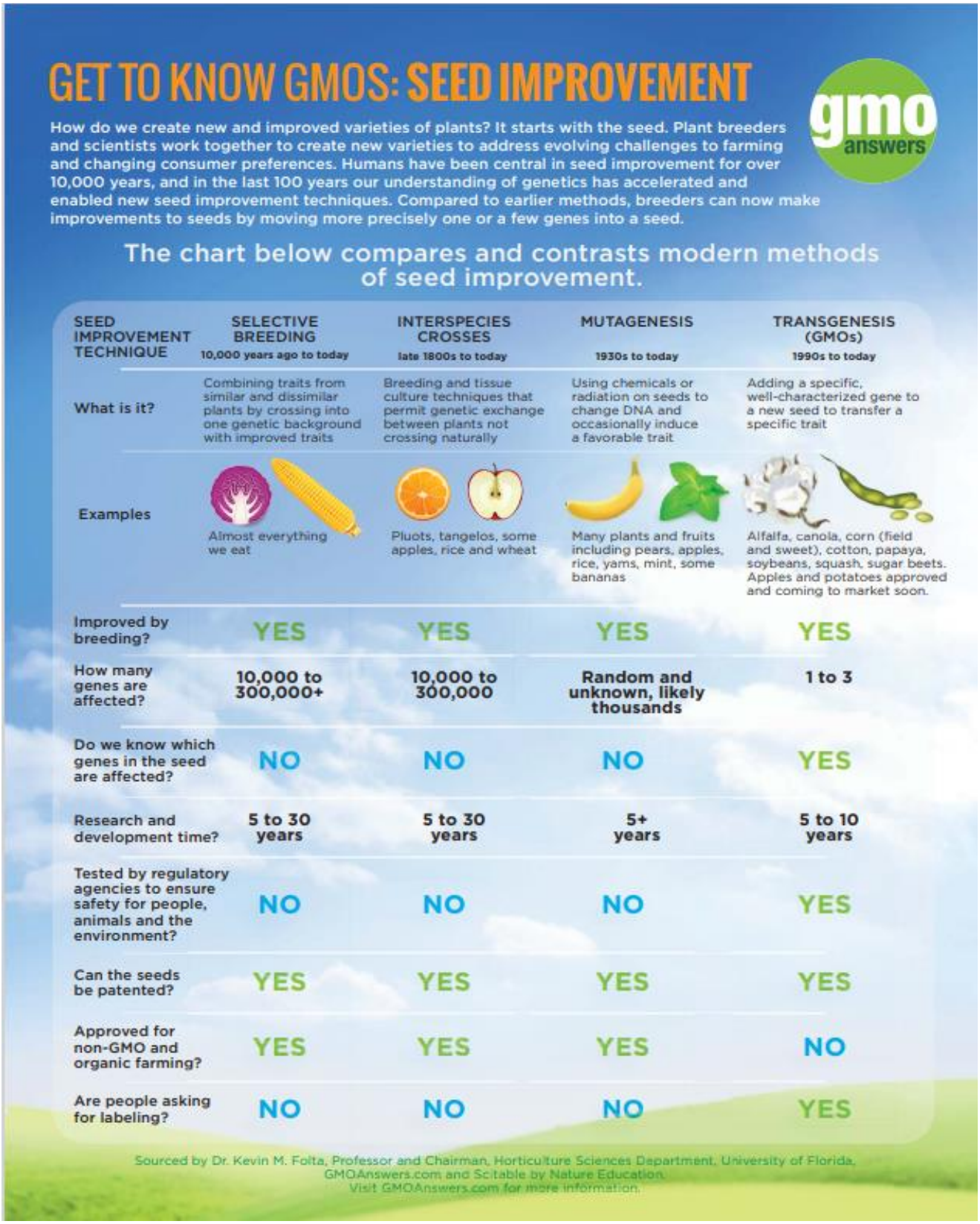
Genetic Modification Infographic 4



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Genetic Modification Infographic 5



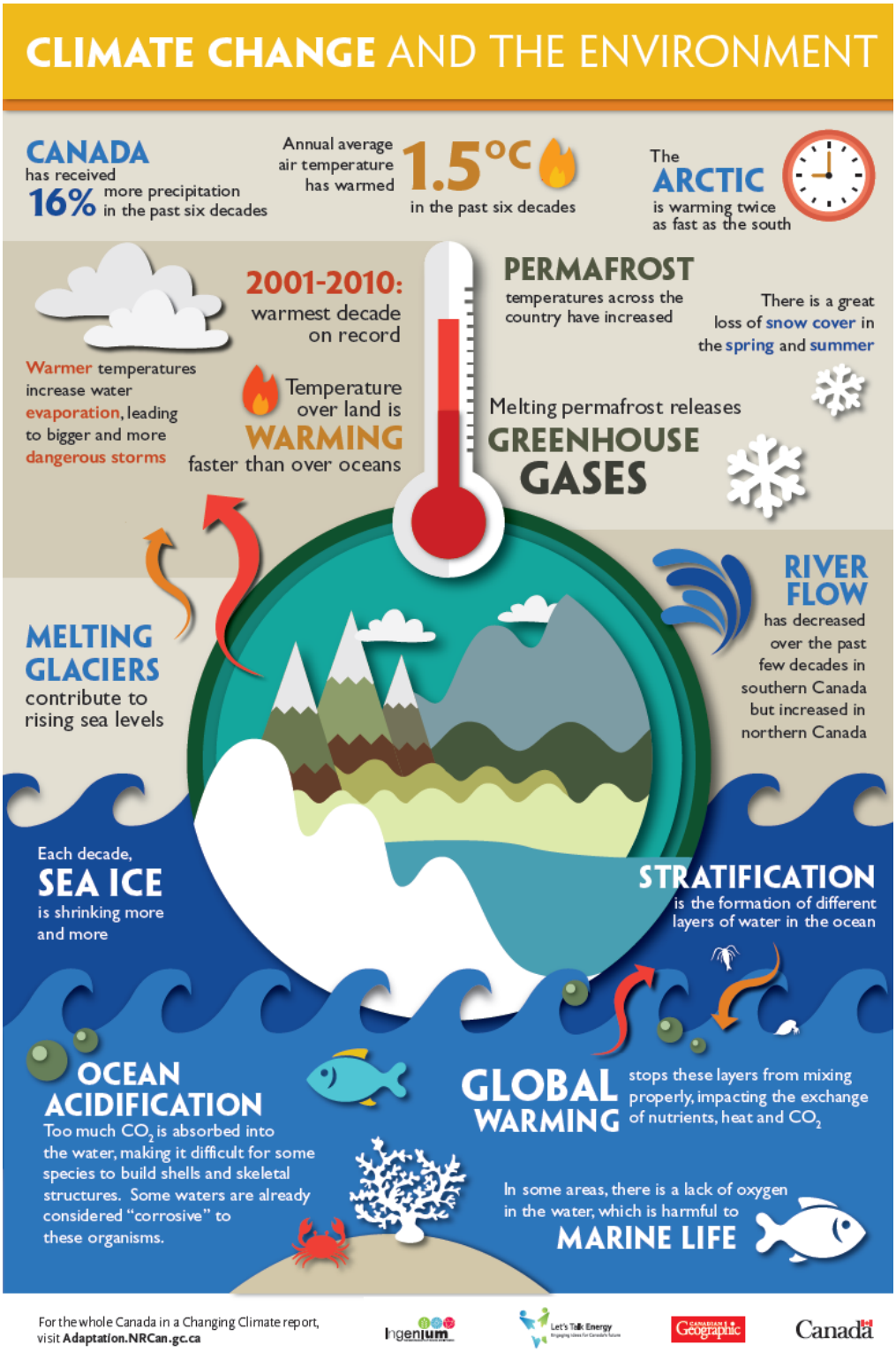
ADAPTATION: Plants and humans

Infographic Vocabulary Glossary

Artificial	Not naturally occurring, occurring through human selection
Balanced	Taking everything into account; fairly judged or presented
Chromosome	A threadlike structure found in the nucleus of most living cells that carries the genetic information
Clear	Explained well, in an understandable manner
Coherent	Logical and consistent explanation or argument
Contextual	Relating to a particular setting or circumstance
Corrosive	Having the quality of corroding or eating away, erosive, harmful, or destructive
DNA	Deoxyribonucleic Acid: a molecule found in living cells that contains the genetic information for an organism's development and function. Consists of a double strand of nucleotides.
Enzyme	A protein molecule that helps speed up chemical reactions in the body
Factual	Concerned with what is actually the case rather than interpretations of or reactions to it. Actually occurring.
Fusion	The process resulting in the joining of two or more things together
Gene	A segment of DNA that contains information for making proteins; the basic unit of heredity that is passed from parent to child; A sequence of DNA found on a chromosome.
Impactful	Having great power or force or potency or effect
Mutagens	A physical or chemical agent that changes an organism's DNA causing a mutation
Nucleases	An enzyme (see above) that breaks nucleic acids (like DNA and RNA) by cutting the bonds that link them together
Oceania	A geographical region in the Pacific Ocean that includes Australasia, Melanesia, Micronesia, and Polynesia
Offspring	The young or children of a parent; the descendants of a person, animal, or plant

Permafrost	Any ground that remains completely frozen at 32°F (0°C) or colder for at least two years straight. Common in regions with high mountains and in higher latitudes.
Pluots	A hybrid fruit created through the cross between a plum and an apricot
Purposeful	Intentional; having or showing a purpose
Recombinant DNA	Combining different pieces of DNA
Relatable	Enabling a person to feel that they can relate to someone or something
Responsible	Capable of being trusted
Rhizome	A horizontal underground stem that grows in plants
RNA	Ribonucleic Acid; a molecule found in living cells and some viruses that is essential for most biological functions. Consists of a single strand of nucleotides.
Scientific	Related to or exhibiting the methods or principles of science. Practicing or using thorough or systematic methods.
Spellbinding	Holding one's attention completely as though by magic; fascinating
Tangelos	A citrus fruit hybrid, a cross between an orange or tangerine and a pomelo or grapefruit.
Targeted	Directed at a particular audience
Tissue culture	A technique that involves growing cells or tissues from an organism in a controlled environment
Traits	Genetically determined characteristic; A distinguishing quality or characteristic
Transparent	Easy to perceive or detect

Climate Infographic 1

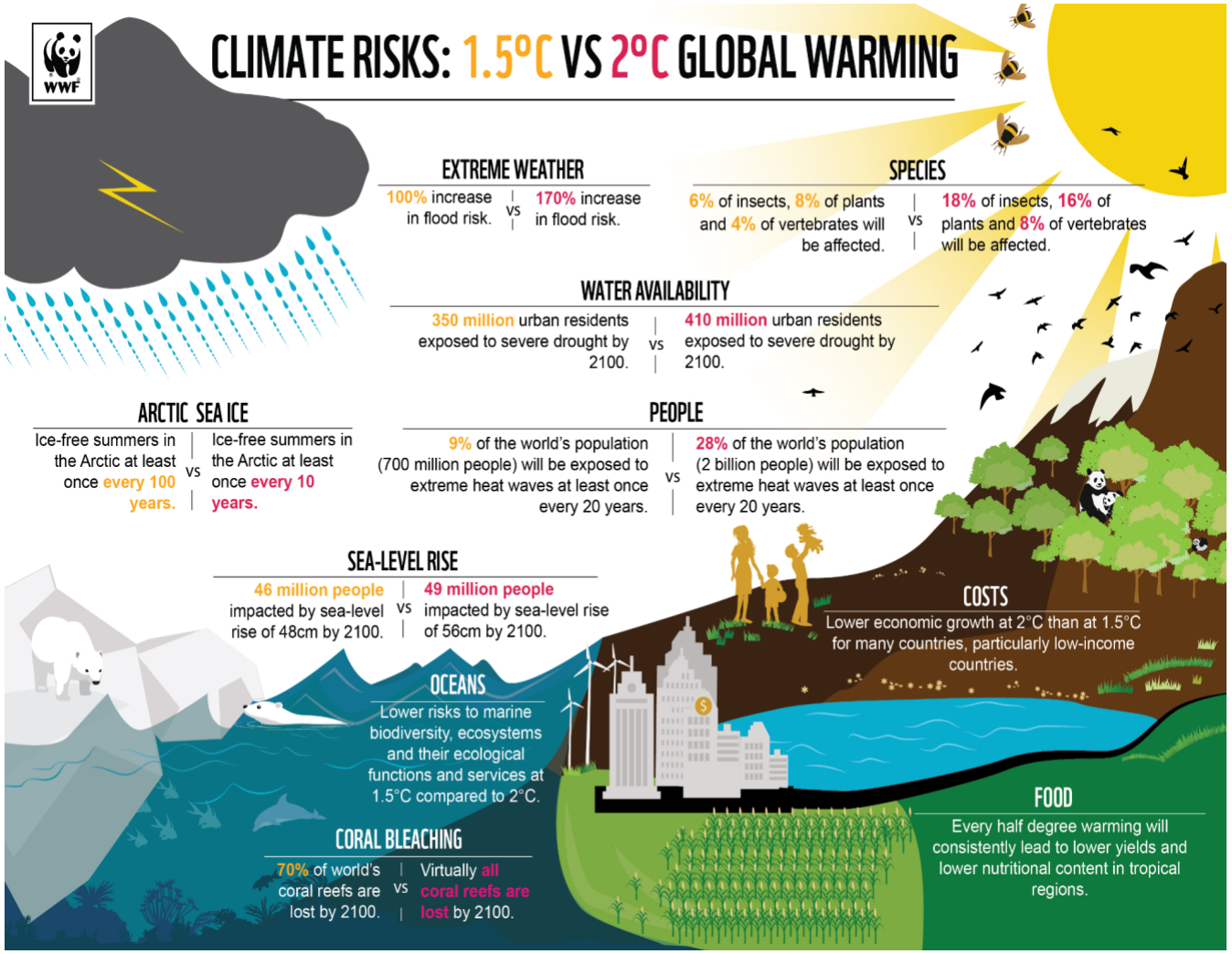


This infographic explains the environmental effects of the 1.5°C (2.7°F) increase in average temperatures that have occurred in the past 60 years (since about 1960).

Infographic from: https://www.cakex.org/tools/educational-climate-adaptation-lesson-plans-and-infographics

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Climate Infographic 2



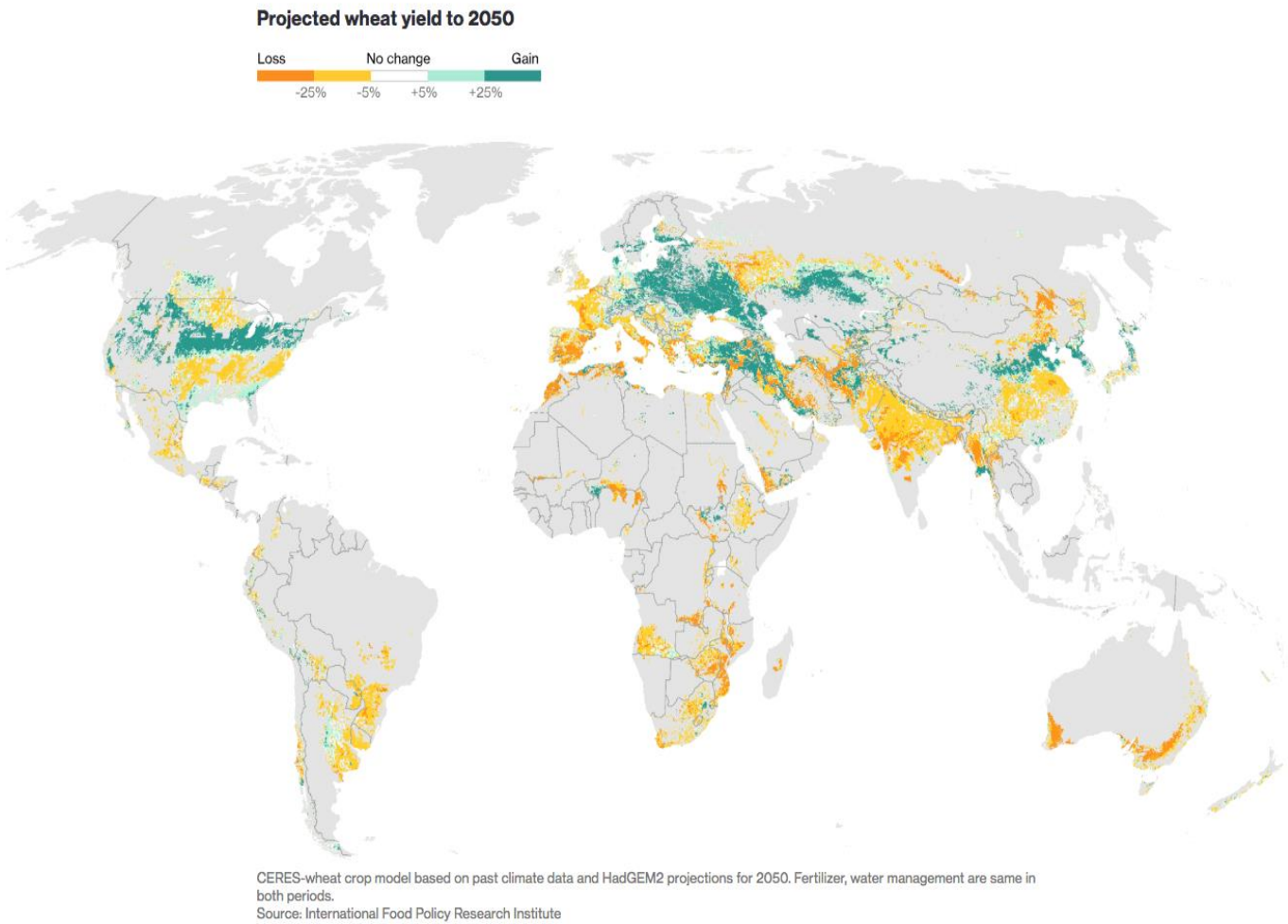
This infographic explains the impact an extra 0.5°C (0.9°F) increase in average global temperature can have on weather, species, sea level, food production, and habitats such as coral reefs and the arctic.

Infographic from: https://visme.co/blog/climate-change-facts/

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Climate Infographic 3



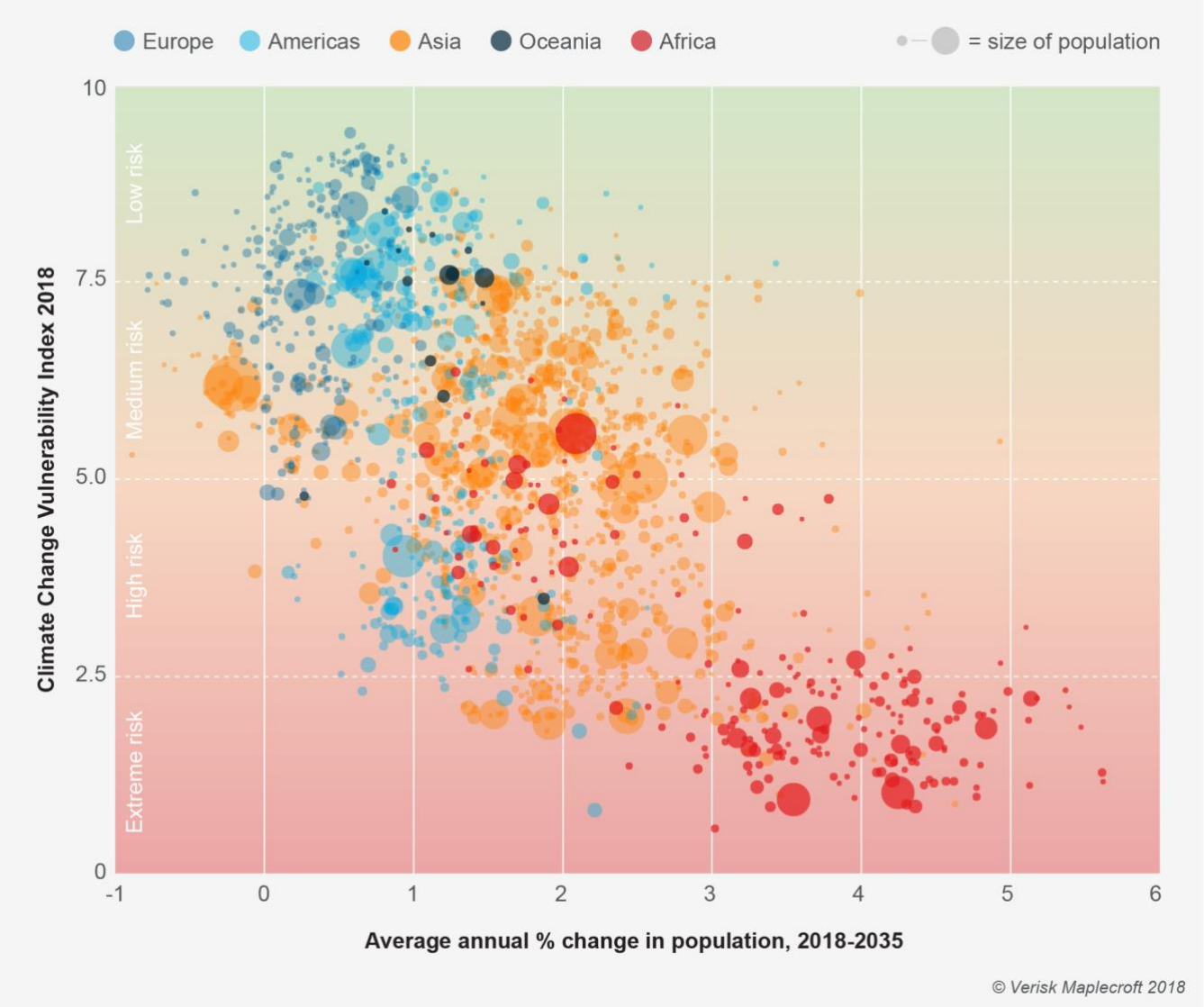
This infographic displays the shift in predicted wheat harvested in different regions of the world by 2050. Dark green indicates a gain (increase) in wheat production and orange represents a decrease (loss) of wheat produced. Wheat is a major food source both for humans and livestock and therefore is a resource to nations.

Infographic from: https://visme.co/blog/climate-change-facts/

ADAPTATION: Plants and humans

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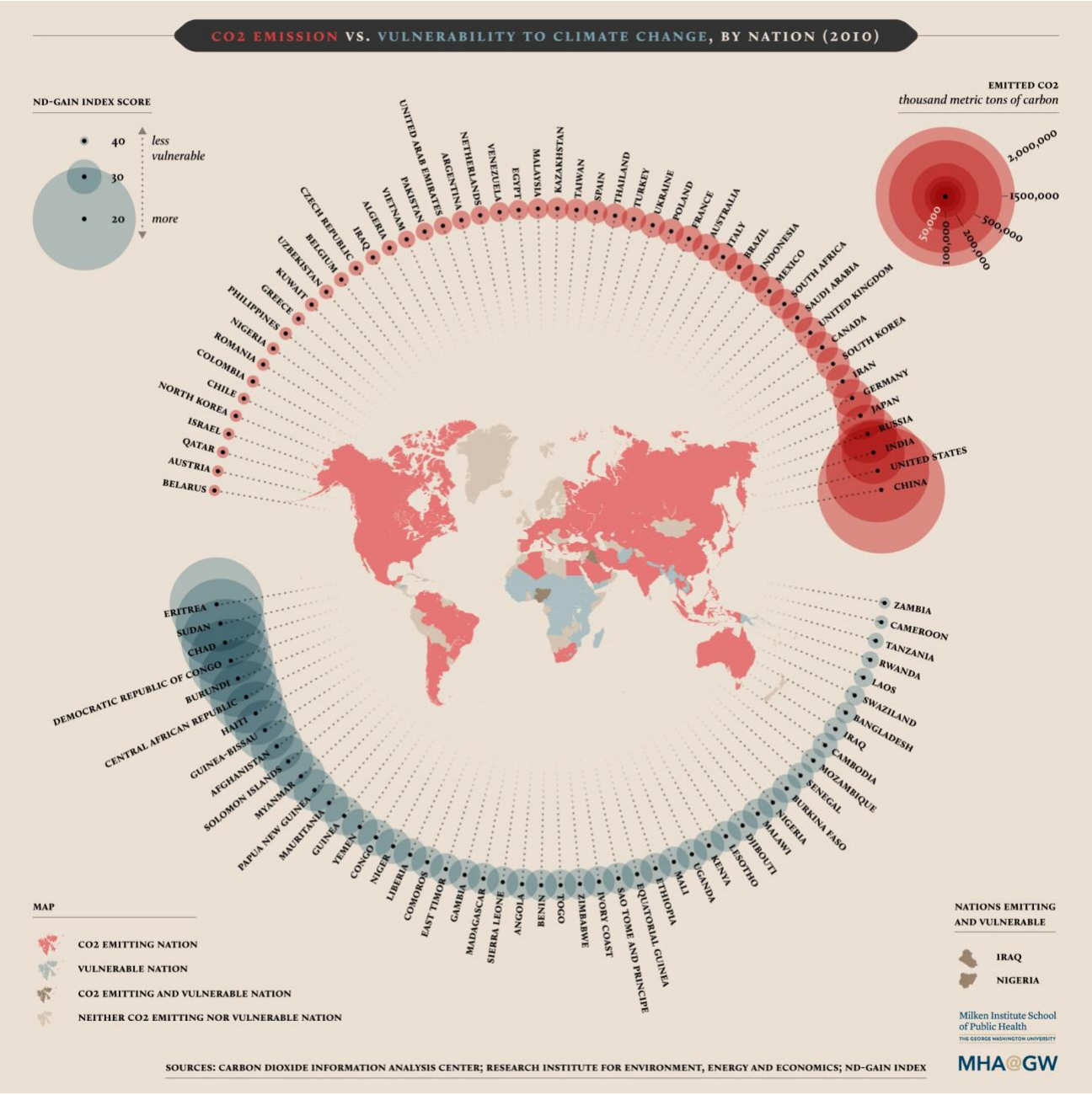
Climate Infographic 4



This infographic compares a United Nations prediction of population growth in cities from 2018 to 2035 (x axis) to a measure of how vulnerable each city is to the effects of climate change (y axis). Note that the y-axis places “extreme risk” closer to the bottom and “low risk” closer to the top. As indicated in the legend, larger circles represent a larger number of people living in each city, and the color represents the continent on which the city is located. A dot placed farther right means the city has experienced a greater change in population and a dot placed closer to the y-axis indicates that the city has not changed as much in population.

Infographic from: https://visme.co/blog/climate-change-facts/

Climate Infographic 5



The Milken Institute School of Public Health created this graphic in 2015 as a comparison between two data groups. In this visualization, the red circles represent countries which emit the most carbon dioxide. The blue circles represent the countries which are the most vulnerable due to carbon dioxide emission.

Infographic from: https://visme.co/blog/climate-change-facts/

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