Adaptation and Climate Change

ND EPSCoR Lesson Plan

Lesson Title: Adaptation and Climate Change

Lesson Overview:
The lesson will introduce students to the evolutionary mechanisms underlying adaptation to climate (natural selection, gene-flow, drift, and mutation). Following this lesson students will be able to answer the question: how do organisms adapt to environmental change? and make linkages between genotypic and phenotypic variation. The lesson will include two group activities and one hands-on activity.

Lesson Objectives:

- Identify traits plants may have evolved to adapt and persist within their native environment
- Link genotype to phenotype by extracting DNA from different varieties of fruits or vegetables with varying phenotypes (ie: different types of onions)
- Quantify change in allele frequencies and associated phenotypic variation across generations in response to natural selection and genetic drift
- Relate knowledge gained to anthropogenic climate change

NSF Subject Classification: Biology

National Next Gen Standards:

- HS-LS4-2 Biological Evolution: Unity and Diversity- Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
- HS-LS4-3 Biological Evolution: Unity and Diversity- Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.
- HS-LS4-4 Biological Evolution: Unity and Diversity-Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

North Dakota Standards:

- Performance Standard HS-LS3-3 Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.
- Performance Standard HS-LS4-2 Construct an explanation based on evidence that the process of biological evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, 2 and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
- Performance Standard HS-LS4-4 Construct an explanation based on evidence for how natural selection leads to adaptation of populations.
- Performance Standard HS-LS4-5 Evaluate the evidence supporting claims that changes in environmental

conditions may result in increases in the number of individuals of some species, the emergence of new species over time, and the extinction of other species.

Grade or Grade Band: 9-12

Time Needed (estimate) 3-4 50-minute class periods (depending on introduction/extension options)

Lesson Author: Jessi Kjemhus
Teaches 7-12 science at Northwood Public School since 2015 and 9-12 science at North Border Public School prior. She graduated in 2012 with a Composite Chemistry degree from Mayville State University and then with her Master's from Valley City State University in 2015. She can be contacted at jessi.kjemhus@northwoodk12.com

Scientist/K12 Collaborator & University: Pamela Puppo & Jill Hamilton

Scientist Bio/Research:
Jill Hamilton (NDSU): The Hamilton Lab broadly focuses on understanding the mechanisms that contribute to local adaptation within natural and managed plant populations. Research in the Hamilton lab broadly aims to understand the factors influencing the distribution of genetic variation across species' ranges in both natural and managed plant populations, focusing on those mechanisms that contribute to local adaptation. We take an interdisciplinary approach to these challenges; combining population and landscape genomics with experimental quantitative and functional genomics. Our goal is to understand how genetic and environmental variation influence the expression of complex traits important to adaptation. Through this work we aim to increase our predictive power regarding the adaptive potential of populations for species management under climate change.

Pam Puppo: My name is Pam and I currently work as Assistant Professor of Botany at Marshall University in West Virginia. I used to work as a researcher at North Dakota State University in Fargo when I co-developed this Sunday Academy lesson. I am Latino, I grew up in Peru, then moved to the US to study, lived in Missouri for a couple of years, and then moved to Europe where I lived for ten years. I came back to the US a couple of years ago. I always knew I wanted to be a biologist though by the time I graduated from high-school I was torn between science and art. I decided to get a degree in Biology and keep the arts as a hobby, until I took my first Botany class at the university and fell in love with plants. I realized I could also draw the different features of plants, merging my passion for arts with science. I love looking at plants with a magnifying lens and see a world of details, colors, spots, hairs, and so many incredible things that can't be seen with the naked eye. I have traveled to many different countries for collecting and studying plants, I have lived in different continents while studying, and have learned different languages. As a Professor I teach about the fascinating things we can find in nature, I focus on plants, but I also teach Introduction to Biology, Evolution, Ecology and other classes. As to research, I study how different species of plants form in different places like the Andes of Peru and the Canary Islands in the Atlantic Ocean, I have discovered many new species of plants that were not known before, I study how genes help us to differentiate among species, and more recently I have started studying the different plants bees use for feeding their young and constructing their nests.

Preparation/Materials

Background knowledge students must have to be successful

- Students need to know the difference between weather and climate with weather is from day to day/ hour to hour and climate is the overall average weather patterns for an area.
- Students need to know that different climates have different species that live there.
- Students need to know that DNA is the backbone of life containing all of its information changes in it can possibly lead to changes in organisms both good and bad. Accumulation of these changes can lead to evolution and creation of new species.
- Students need to know climate can play a role in which animals have the traits to survive and which ones do not.

Essential Terminology

- Traits- genetically determined characteristics
- Mutation- change in base order of DNA
- Genotype- genetic makeup of an organism
- Phenotype- observable characteristics of an individual resulting from the interaction of its genotype with the environment.
- Adaptation- the process by which a species becomes fit for its environment. Occurs due to natural selection's influencing heritable genetics over several generations.
- Allele- variant of a gene
- Natural Selection- organism with desirable traits for an environment will survive passing down those traits

Resources

- Optional: Explore Learning- Gizmo- has a couple great natural selection due to environment lab simulations. Could be done to introduce the topic, extension, or even a modification for students as the lab can be modified
- Pepper moth case study and game

Websites:

- https://www.explorelearning.com/
- https://askabiologist.asu.edu/peppered-moths-game/natural-selection.html
- https://courses.lumenlearning.com/boundless-biology/chapter/population-genetics/
- https://www.ndepscor.ndus.edu/ndep/nature/sunday-academy/stem-module-topics/

Materials needed:

Lesson 1

- Computer
- Activity cards on index cards
- PowerPoint projector

Lesson 2

- M&Ms or similar colored candy
- Ziploc bags

Lesson 3

- Immersion blender
- Knives
- Plastic Cup
- Paper towels
- Paper clip
- Spoon
- Ice
- ½ onion
- 2 tbsp. dish detergent
- 1 tsp. salt
- ½ cup of water
- 1 coffee filter
- ¼ cup Ice-cold alcohol

PowerPoint – found as separate attachment

Procedure/Activities

Lesson 1:

- Optional Natural Selection Gizmo or Evolution: Mutation and Selection Gizmo or Rainfall and Bird Beaks to introduce the topic but can also be used as an extension activity or even modified to students who need extra practice or support on the topic. Another option is pepper moth case study and game
    - **https://www.explorelearning.com/**
    - **https://askabiologist.asu.edu/peppered-moths-game/natural-selection.html**
- PowerPoint Slides 1 and 2
    - Adaptation is a characteristic that makes a population able to live in a particular environment
- Slide 3
    - Different plants have developed a set of characteristics that allow them to live in different environments. For example, go to slide 4
- Slides 4 and 5
    - Cactus have spines instead of leaves, open the stomata at night (to avoid losing too much water), accumulate water in the stems, stems have ridges to expand, etc
- Go over slide 6, hand out worksheet, and activity cards/index cards
- Give about 20 minutes to work
    - Depending on where stand on time, can either present at the end of the hour or next day

Lesson 2:

- Review vocab adaptation
- Slide 7
- Go over natural selection vocab
- Slides 8 and 9
    - The genes responsible for the particular characteristic are passed along the next generation, making the new generation better adapted to the environment
- Slides 10 and 11
    - Importance of diversity for natural selection
    - https://courses.lumenlearning.com/boundless-biology/chapter/population-genetics/
- Slides 12-15
    - Movement of an individual (and the genetic material they carry) from one population to the other
    - If different genes are transported, it can be a source of genetic variation
- Slides 17-19
- Slide 20
- Go over mutation vocab

- Slide 21
    - All DNA is made with only four “building blocks” called nucleotides: ACGT: adenine, cytosine, guanine, and thymine
    - Mutation is a change in DNA and are random
- Slide 22
- Go over allele, traits, phenotype, and genotype vocab
- Slides 23-25
- Slide 26, go over Activity 2 and hand out sheet. Teacher key to go with activity discussion.
    - Let’s see how genes change their frequency with a game. Imagine we have a morphological trait (color) associated with a given genotype
    - Same phenotype (red) but different genotype!
- Slide 27 compile information, answers may vary based on student outcomes
- Slide 28

Lesson 3:

- Review vocab from previous day
- Review what DNA is
    - Make the point that DNA is where mutations occur and it is what leads to changes in organisms thus adaptations/evolution
- Slides 29-30, hand out activity 3 worksheet
    - Go over steps and items they will need
- Clean up lab, Discuss lab and wrap up question
- Slide 31
- Slide 32
    - We have all heard about climate change, but what is it? Climate has been changing for millions of years (explain graph)
- Slide 33
    - However, since the industrial revolution (around 1950), when humans started burning fuels and producing in mass, the climate has changed faster than ever before
- How does this all tie into the vocab word: natural selection?
- Slide 34- reflect on activity one about the plants they research, discuss hypothesis question: In a rapidly changing environment what type of stresses might this plant experience?
- Slides 35 and 36

Extensions for above average students:

- Natural Selection Gizmo or Evolution: Mutation and Selection Gizmo or Rainfall and Bird Beaks - must have an account already
- Pepper Moth Case Study and game
- Find examples of animals who have succeeded or are on the decline due to climate change

Mediation/Support for students that need it:

- Natural Selection Gizmo or Evolution: Mutation and Selection Gizmo or Rainfall and Bird Beaks
- Provide websites to look up tree information from
- Step by step instruction for activities
- Frequent check-ins

Lesson Outline (for research-based lessons)

1) Observe Phenomena
2) What questions should we be able to answer?
3) Write a Hypothesis
4) Come up with a Research Plan
5) Carry out investigation
6) Revisit the Background Research
7) Construct Explanations. (TASKS-Publish/Communicate Findings)

Standards Alignment

ND Science Standard(s):

- Performance Standard HS-LS3-3 Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.
- Performance Standard HS-LS4-2 Construct an explanation based on evidence that the process of biological evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, 2 and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
- Performance Standard HS-LS4-4 Construct an explanation based on evidence for how natural selection leads to adaptation of populations.
- Performance Standard HS-LS4-5 Evaluate the evidence supporting claims that changes in environmental conditions may result in increases in the number of individuals of some species, the emergence of new species over time, and the extinction of other species.

Disciplinary Core Idea: e.g. Biology- environment can shift who is best suited and lead to natural selection

North Dakota DPI Standards:

ND ELA

W.7 Conduct short as well as more sustained research projects to answer questions (including self-generated questions) or solve problems.

a. Develop a research question.

b. Narrow or broaden the inquiry when appropriate.

c. Synthesize multiple source

ND Technology Standards

Standard 8: Attributes of Design: Explore the attributes of design.

- 7.1.4 Organize research information
- 7.1.5 Present research findings, including information and evidence from a variety of sources
- 7.4.3 Incorporate research into presentations

ND Business Standards

Strand 3 Career Development

Standard 1: Relate the importance of career readiness skills to career development.

- 3.3d.1.8 Create presentations for a specific purpose and audience

Strand 4. Standard 1: Listen actively, use the communication process, read and research information, and integrate technology to enhance communication effectiveness.

- 4.1d.1.5 Use basic applications (word processing, spreadsheets, presentations, and graphics)
- 4.1d.1.34 Create and deliver virtual conferences and presentations

Strand 4. Topic 4: Spoken Communication 4b. Presentations Standard 1: Demonstrate professional speaking techniques and strategies.
Strand 7 Information Technology-Topic 2: Information Literacy Standard 1: Gather, evaluate, use, cite, and disseminate information from technology sources.

- 7.2.1.14 Present analyzed information in a meaningful format

Next Gen Standards:

- HS-LS4-2 Biological Evolution: Unity and Diversity- Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
- HS-LS4-3 Biological Evolution: Unity and Diversity- Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.
- HS-LS4-4 Biological Evolution: Unity and Diversity-Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

Science and Engineering Practices

- Developing and Using Models

Cross Cutting Concepts

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Unit Objectives

- Students will be able to relate knowledge about how adaptations occur to anthropogenic climate change

Assessment

- Students will examine, using information they learned about mutations and genetics, how adaptations occur to survive in changing environments through class discussion

Daily Plans and Assessments

Learning Target for each day/activity

- Lesson 1/Day 1- Students will become familiar with a plant to see what environments it is native to and its uses to humans

- Lesson 2/Day 2- Students will carry out an activity to see how random allele combinations and the phenotypes they result in.

- Lesson 3/ Day 3- Students will use lab techniques to extract onion DNA and examine it

Criteria for Success/Assessment for each activity

- Lesson 1- Students research necessary information and synthesize it to share with the class

- Lesson 2- Students will identify genotypes and phenotypes in a series of scenarios

- Lesson 3- Students will successfully extract DNA and tie together genetics, adaptations, environment and species success or decline

Additional Lesson Resources / Materials

References:

Puppo, P. and Hamilton, J. “Adaptation and Climate Change”. Web. 16 July 2020.
https://www.ndepscor.ndus.edu/ndep/nature/sunday-academy/stem-module-topics/

Websites for purchasing materials

If need general supplies:

Nasco
https://www.enasco.com/c/Education-Supplies/Science

Flinn
https://www.flinnsci.com/

Carolina
https://www.carolina.com/lab-supplies-and-equipment/science-lab-supplies/science-lab-classroom-supplies/10300.ct

School Specialty
https://www.schoolspecialty.com/science-supplies-and-products

Amazon
www.amazon.com

Activity 1 – Phenotype to Environment

With this activity you will investigate traits a plant has evolved to survive and persist in its native environment and make predictions for how a changing environment might affect the plant's survival. Make a power point with your answers (maximum of three slides per group).

Materials:

- Computer
- Activity Cards

You are each assigned a plant – tell us a little bit about that plant:

- Find a picture!
- Does this plant have a 'common name'?
- Is this plant used by Native American communities? How?
- Is it an herb, bush, tree? How does it reproduce?
- What is its distribution and habitat preferences?

Make a hypothesis: In a rapidly changing environment what type of stresses might this plant experience?

Teachers Answers to Activity 1

- Acer negundo
    - Common names: box elder, boxelder maple, ash-leaved maple, maple ash
    - Uses: sap is used as sweetener or as beverage, leaves are used to relieve dry mouth, etc.
    - Tree, sexual reproduction (by seed)
    - Native to North America but it is an invasive species in Europe, China and Australia
    - This species grows well in disturbed areas and is well adapted to different climates, in face of climate change, it will probably do well. Apparently, it is susceptible to drought so it might suffer from drought stress in dry areas.

- Amelanchier alnifolia
    - Common names: saskatoon, Pacific serviceberry, western serviceberry, alder-leaf shadbush, dwarf shadbush, chuckley pear, western juneberry
    - Uses: stems used for arrows, leaves boiled for tea, fruits eaten fresh or dried, etc.
    - Shrub, sexual reproduction (by seed)
    - Native to North America, from Alaska to western and north-central US, also in western Canada.
    - Grows from sea level up to 8,500 ft in California and up to 11,200 ft in the Rocky Mountains. It is common in the understory of forests.
    - Since it grows in temperate regions, it might get affected if temperature raises. Since it grows in forest understory, cutting down the forests might also impact it.

- Artemisia cana
    - Common names: silver sagebrush, sticky sagebrush, silver wormwood, hoary sagebrush, dwarf sagebrush
    - Uses: leaves and stems are burned as insect repellant
    - Shrub, sexual reproduction (produces fruits)
    - Native to central and western North America, distributed in the US and Canada.
    - It is tolerant to flooding but the seedlings are sensitive to drought so in case of severe drought, the new plants will not probably germinate.

- Betula papyrifera
    - Common names: Paper birch, white birch, canoe birch
    - Uses: bark is used for making torches and also as a container for

collecting sap
    - Tree, sexual reproduction (by seed)
    - Native to northern North America, distributed along north US and Canada
    - It is susceptible to high temperatures and humidity so it will be affected by a rise in temperature and abundant rain or floodings.

- Cucurbita foetidissima
    - Common names: buffalo gourd, coyote gourd, fetid gourd, fetid wild pumpkin, Missouri gourd, stinking gourd
    - Uses: root used to treat all sorts of body ailments, fruit is used as soap, infusion made with the seeds is used to kill intestinal worms
    - Herb or vine, sexual (by seed) reproduction and asexual reproduction by nodal roots
    - Distributed in central and southern US and north of Mexico.
    - This species needs warm temperatures, growing in arid or semi-arid areas with little water. This plant might be susceptible to flooding and a decrease in temperature.

- Dalea purpurea:
    - Common names: purple prairie clover
    - Uses: roots are chewed because of their sweetness, infusion of the leaves to treat diarrhea, poultice of crushed leaves used for curing wounds, etc
    - Perennial herb, sexual reproduction (by seed)
    - Native to central North America, distributed in central Canada and southeast and southwest US, abundant in the great plains.
    - It is adapted to areas with periodical fires since it likes open areas, grows in well-drained areas so it might be subject to stress if periodic flooding occur. Also, lack of pollinators might impact its propagation

- Echinaceae angustifolia:
    - Common names: echinacea, purple coneflower, blackroot
    - Uses: the root is used for wounds, swelling, snake bites, seed heads chewed to relieve toothache and other ailments
    - Perennial herb, sexual reproduction (by seeds), also it is possible to propagate using root or stem cuttings
    - Native to North America, grows in central US and Canada, abundant in the Great Plains
    - Grows in dry prairies so it might be sensitive to floodings

- Fragaria vesca:

    - Common names: wild strawberry
    - Uses: fruits eaten fresh or dry
    - Perennial herb reproduces mostly asexually by lateral shoots though it can also be propagated by seed
    - Distributed throughout the Northern Hemisphere
    - It tolerates well wet or dry conditions, but it is sensitive to extreme drought or flooding. It can also survive mild fires

- Fraxinus pennsylvanica:
    - Common names: green ash, red ash
    - Uses: wood used for bows, tipi pins and pegs, firewood, etc
    - Tree, sexual reproduction (by seed) - Native to central and eastern North America but has become naturalized in Europe
    - This tree grows fast and is well adapted to urban areas, so it might do well in disturbed environments. It is highly sensitive to beetle infestation so if climate change favors beetle reproduction, this might significantly impact green ash populations

- Galium aparine:
    - Common names: cleavers, bedstraw, goosegrass, catchweed, etc
    - Uses: roasted seeds are used as a coffee substitution, plant used for skin irritations
    - Annual herb, sexual reproduction (by seed), the fruits are hairy and attach to the hair of animals
    - It is considered to be native to North America by some, but it is widespread across the world.
    - Though this plant would probably be successfully adapted to changing environments, it generally prefers moist soils which could make it sensitive to extreme drought

- Juglans nigra:
    - Common names: black walnut –
    - Uses: walnuts are edible, bark is used for black dye, leaves are used for skin ailments, etc
    - Tree, sexual reproduction (by seed) 6
    - Native to eastern North America, it has been introduced in Europe and is also cultivated in Hawaii
    - This species prefers open habitats so if climate changes favoring herb coverage the young trees might suffer from lack of exposure to the sun. Likewise, this species is highly susceptible to beetle infestation so if beetle population increases, it can severely affect black walnuts population

- Lepidum densiflorum:
    - Common names: common pepperweed, prairie peppergrass
    - Uses: tea made with the plant is used for the kidneys, leaves are consumed in salads, seeds are used as condiment, etc
    - Annual herb, sexual reproduction (by seed)
    - Widespread across North America, common in Canada and the US
    - It grows throughout a variety of environments, it can be invasive. It is probable that in a changing climate, this plant will be able to successfully adapt

- Maianthemum racemosum:
    - Common names: star-flowered, false Solomon's seal
    - Uses: berries have a laxative effect, root is used for wounds
    - Perennial herb, asexual reproduction by lateral roots (rhizomes) and sexual reproduction (by seeds)
    - Native to North America it grows in the US, Canada and Mexico
    - This plant prefers shaded areas with deep, moist soils. In a climate change scenario, this plant might be stressed by drought and by deforestation

- Nelumbo lutea:
    - Common names: yellow lotus, American lotus, water chinquapin, etc
    - Uses: seeds and tubers are eaten (cooked), leaves can also be eaten, it is considered to have some sort of mystical powers
    - Aquatic herb
    - Native to North America, it grows in the US and some countries in central America and the Caribbean
    - This plant is adapted to lakes and swamps and grows in flooded areas. The species would probably not survive long periods of drought

- Prunus virginiana:
    - Common names: chokecherry, bitter-berry, Virginia bird berry
    - Uses:
    - Shrub or small tree, sexual reproduction (by seed)
    - Native to North America, distributed across most US and Canada, including northern Mexico.
    - It is susceptible to pests so if the weather changes in a way that is favorable for insects, it will affect the plants. Also, the wood is weak, so branches might break if snow or ice increase.

Activity 2 – Allele Frequency Game

With this activity you will learn how to calculate allele frequencies in a population and observe how allele frequencies may favor in response to natural selection or genetic drift. You have a bag of M&M's in two different colors. Let's assume these colors are 2 different types of alleles, for example: red and blue. Let's assume also that red is dominant over blue. This means that if you have a heterozygous individual (one of each color), the phenotype will be red, because red is dominant. Homozygous individuals will have two alleles of the same color.

1. We will create a population of 24 individuals. 6 individuals are homozygous red, 12 are heterozygous red and 6 are blue.

2. Lay out pairs of alleles on the table to create this population as specified above.

3. How many alleles does an individual have?

4. How many alleles in total do we have within this population?

5. How many total red alleles are in the population?

6. What is the proportion of red alleles? (divide the number of red alleles by the total number of alleles in the population)

7. How many total blue alleles are in the population?

8. What is the proportion of blue alleles? (divide the number of blue alleles by the total number of alleles in the population)

9. Both proportions (red and blue) should equal 1. Does the sum of the proportions you calculated add to 1?

10. Let's put all the alleles in a bag. This bag represents a population!

11. Let's see what happens in a new generation. For this, draw 2 alleles from the

bag at random. This represents an individual in the next generation!
What is the phenotype (color) of this individual? (Remember that red is dominant over blue) _____

12. Repeat the last step two more times. Now you have three individuals which constitute the new generation. Which is the phenotype (color) of each individual?

Individual 1:_____ Individual 2:_____ Individual 3:_____

13. Do you remember what the concept of genetic drift is?

14. Let's simulate what the effect of genetic drift would be in your population. Let's imagine that a tornado kills half of your population. For this, take half of the individuals from the bag, one at a time (remember that each individual has two alleles). Record those individuals in the Table below. Do not eat them! We will need them for later.

Individual	1	2	3	4	5	6	7	8	9	10	11	12
Phenotype (color)												
Genotype (heterozygous or homozygous)												

15. Now calculate how many red and blue alleles are left in your population. For this, look at the numbers you counted in 5 and 7):

Red:_____ Blue:_____

16. Now recalculate the proportions of red and blue alleles:

Red:_____ Blue:_____ (Remember the sum of both proportions has to be 1)

17. Are they different from the proportions on your original population? How? What was the effect of genetic drift in your population?

18. Do you remember what the concept of natural selection is?

19. Let's simulate the effect of natural selection in your population. Put all the M&M's on the table to recreate your original population of 24 individuals: 6 homozygous red, 12 heterozygous red and 6 blue. Let's imagine that a bird eats M&M's individuals and it prefers the red ones. Randomly take half of the red individuals out (remember that the red individuals can be homozygous red or heterozygous red), those are the ones that were eaten by the bird.
How many red individuals did you have in your original population?

_____

How many red individuals are left?

_____

_____

20. Now calculate the proportions of red and blue alleles in your new population:
Red:_____ Blue:_____ (Remember the sum of both proportions has to be 1)

21. Are they different from the proportions on your original population? How? What was the effect of natural selection in your population?

Activity 2 – Allele Frequency Game Answer Key

With this activity you will learn how to calculate allele frequencies in a population and observe how allele frequencies may favor in response to natural selection or genetic drift. You have a bag of M&M's in two different colors. Let's assume these colors are 2 different types of alleles, for example: red and blue. Let's assume also that red is dominant over blue. This means that if you have a heterozygous individual (one of each color), the phenotype will be red, because red is dominant. Homozygous individuals will have two alleles of the same color.

1. We will create a population of 24 individuals. 6 individuals are homozygous red, 12 are heterozygous red and 6 are blue.

2. Lay out pairs of alleles on the table to create this population as specified above.

3. How many alleles does an individual have?

Answer: 2

4. How many alleles in total do we have within this population?

Answer: 48

5. How many total red alleles are in the population?

Answer: 24

6. What is the proportion of red alleles? (divide the number of red alleles by the total number of alleles in the population)

Answer: 24/48=0.5

7. How many total blue alleles are in the population?

Answer: 24

8. What is the proportion of blue alleles? (divide the number of blue alleles by the total number of alleles in the population)

Answer: 24/48=0.5

9. Both proportions (red and blue) should equal 1. Does the sum of the proportions you calculated add to 1?

Answer: 0.5+0.5=1

10. Let's put all the alleles in a bag. This bag represents a population!

11. Let's see what happens in a new generation. For this, draw 2 alleles from the bag at random. This represents an individual in the next generation! What is the phenotype (color) of this individual? (Remember that red is dominant over blue)

_____

2. Repeat the last step two more times. Now you have three individuals which constitute the new generation. Which is the phenotype (color) of each individual?

Individual 1:_____ Individual 2:_____ Individual 3:_____

13. Do you remember what the concept of genetic drift is?

Answer: Genetic drift is a change in the gene pool by chance

14. Let's simulate what the effect of genetic drift would be in your population. Let's imagine that a tornado kills half of your population. For this, take half of the individuals from the bag, one at a time (remember that each individual has two alleles). Record those individuals in the Table below. Do not eat them! We will need them for later.

Individual	1	2	3	4	5	6	7	8	9	10	11	12
Phenotype (color)												
Genotype (heterozygous or homozygous)												

15. Now calculate how many red and blue alleles are left in your population. For this, look at the numbers you counted in 5 and 7):

Red:_____ Blue:_____

16. Now recalculate the proportions of red and blue alleles:

Red:_____ Blue:_____ (Remember the sum of both proportions has to be 1)

17. Are they different from the proportions on your original population? How? What was the effect of genetic drift in your population?

Answer: Yes, the proportions are probably different. The conclusion is that genetic drift changed the proportions of red and blue alleles and thus the morphology of the individuals also change (there are more red or blue individuals now).

18. Do you remember what the concept of natural selection is?

Answer: Natural selection is when a phenotype gives an advantage of survival to an organism, then that organism survives and reproduces, passing along the genes behind that phenotype to the next generation. This makes the offspring better adapted to that particular environment.

19. Let's simulate the effect of natural selection in your population. Put all the M&M's on the table to recreate your original population of 24 individuals: 6 homozygous red, 12 heterozygous red and 6 blue. Let's imagine that a bird eats M&M's individuals and it prefers the red ones. Randomly take half of the red individuals out (remember that the red individuals can be homozygous red or heterozygous red), those are the ones that were eaten by the bird. How many red individuals did you have in your original population? _____ How many red individuals are left?

_____
_____

20. Now calculate the proportions of red and blue alleles in your new population: Red:_____ Blue:_____ (Remember the sum of both proportions has to be 1)

21. Are they different from the proportions on your original population? How? What was the effect of natural selection in your population?

Answer: Yes, the proportions are different. The conclusion is that because the bird prefers red individuals, the blue individuals will have a better chance to survive and thus the next generation will have more blue individuals because the proportions of blue alleles in this population increased

Activity 3 – DNA Extraction

In this activity, you will be able to extract DNA out of a plant using household ingredients and will be able to see it with your naked eye.

Materials:
- ½ onion
- 2 tbsp. dish detergent
- 1 tsp. salt
- ½ cup of water
- 1 coffee filter
- ¼ cup Ice-cold alcohol
- Immersion blender
- Plastic cup
- Paper towel
- Paper clip
- Spoon
- Ice

Procedure:
- Peel the onion half and put it in a container. With the help of an immersion blender, smash the onion as best as you can.
- In a plastic cup, mix together 2 tbsp. detergent, 1 tsp. salt and ½ cup of water. This will be your DNA extraction liquid.
- Add your extraction liquid to the smashed onion and mix gently with a spoon to avoid making bubbles. This will help breaking the cells to release the DNA.
- Using a coffee filter, pour the mixture into a clean plastic cup. Gently squeeze the filter.
- Slowly, pour the ¼ cup of cold alcohol down the side of the cup. Do not mix! Let sit for a couple of minutes. The alcohol will help separate the DNA from the rest of the onion mixture.
- You will see something white forming in between the alcohol and the onion mixture. That's the onion's DNA! With the use of a paperclip, gently pick up the strands of DNA.

Question:

1. Compare your DNA extraction with groups that have extracted a different variety of onion. Do you see any differences? Why or why not?

Activity 3 – DNA Extraction Answer Key

In this activity, you will be able to extract DNA out of a plant using household ingredients and will be able to see it with your naked eye.

Materials:
- ½ onion
- 2 tbsp. dish detergent
- 1 tsp. salt
- ½ cup of water
- 1 coffee filter
- ¼ cup Ice-cold alcohol
- Immersion blender
- Plastic cup
- Paper towel
- Paper clip
- Spoon
- Ice

Procedure:
- Peel the onion half and put it in a container. With the help of an immersion blender, smash the onion as best as you can.
- In a plastic cup, mix together 2 tbsp. detergent, 1 tsp. salt and ½ cup of water. This will be your DNA extraction liquid.
- Add your extraction liquid to the smashed onion and mix gently with a spoon to avoid making bubbles. This will help breaking the cells to release the DNA.
- Using a coffee filter, pour the mixture into a clean plastic cup. Gently squeeze the filter.
- Slowly, pour the ¼ cup of cold alcohol down the side of the cup. Do not mix! Let sit for a couple of minutes. The alcohol will help separate the DNA from the rest of the onion mixture.
- You will see something white forming in between the alcohol and the onion mixture. That's the onion's DNA! With the use of a paperclip, gently pick up the strands of DNA.

Question:

2. Compare your DNA extraction with groups that have extracted a different variety of onion. Do you see any differences? Why or why not?

   Answer: The students will not see any differences between the DNAs. They must conclude that the DNA molecule is the same for the different onions and thus common to all living organisms.

Name: _____ Date: _____

Student Exploration: Natural Selection

https://www.explorelearning.com/

Vocabulary: biological evolution, camouflage, Industrial Revolution, lichen, morph, natural selection, peppered moth

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

The **peppered moth** (*Biston betularia*) is a common moth found in Europe, Asia, and North America. It is commonly found in two forms, or **morphs**: a dark morph and a light, speckled morph. Birds are a frequent predator of the peppered moth.

1. Which morph do you think would be easier to see on a dark tree trunk? _____
2. Which morph do you think would be easier to see on a light tree trunk? _____

Gizmo Warm-up

The *Natural Selection* Gizmo allows you to play the role of a bird feeding on peppered moths. The initial population of 40 moths is scattered over 20 tree trunks. Click on moths to capture them. Click the **Next tree** button (or the **spacebar** on your keyboard) to advance to the next tree.

How many moths can you find?

1. Check that LIGHT TREES is selected. Click **Play** ( ), and hunt moths for one year.
   A. How many dark moths did you capture? _____
   B. How many light moths did you capture? _____
   C. **Camouflage** is coloring or patterns that help an organism to blend in with the background. Which type of moth is better camouflaged on light bark? _____

2. If a forest contained mostly light-colored trees, which type of moth would you expect to be most common? _____

Activity A: **Light trees**	Get the Gizmo ready: • Click **Reset** ( ). • Check that the LIGHT TREES tab is selected.	

Introduction: Before the 19th century in England, the air was very clean. The bark on trees was usually light in color. Abundant **lichens** growing on tree trunks also lightened their appearance.

Question: How does the color of a peppered moth affect survival?

1. Predict: Over time, what will to happen to the populations of light and dark moths on light trees?

   _____

2. Experiment: Click **Play** and hunt peppered moths on light tree trunks for five years. In each year, try to capture as many moths as you can. Note: You can use the **spacebar** on your keyboard to quickly advance to the next tree.

   After 5 years, select the TABLE tab and record the percentages of each moth type. (Note: The table shows current populations of each moth, not the number of captured moths.)

Year	Dark moths	Light moths
0		
1		
2		
3		
4		
5		

3. Analyze: What do your results show? _____

   _____

4. Apply: Which type of moth do you think was more common before the 19th century, when most trees were light in color? _____

5. Extend your thinking: What strategies did you use to hunt for moths? _____

   _____

   _____

Activity B: **Dark trees**	Get the Gizmo ready: • Click **Reset**. • Select the DARK TREES tab.	

Introduction: The 19th century was the time of the **Industrial Revolution** in England. Most of the new industries used coal for energy, and the air was polluted with black soot. In forests near factories, the soot coated trees and killed lichens. As a result, tree trunks became darker.

Question: How did air pollution affect moth populations?

1. Predict: Over time, what will to happen to the populations of light and dark moths on dark trees?

   _____

2. Experiment: Click **Play** and hunt peppered moths on dark tree trunks for five years. In each year, try to capture as many moths as you can.

   When you are done, select the TABLE tab and record the percentages of each moth type.

Year	Dark moths	Light moths
0		
1		
2		
3		
4		
5		

3. Analyze: What do your results show? _____

   _____

4. Apply: Which type of moth do you think was more common during the 19th century? Why?

   _____

   _____

5. Draw conclusions: **Natural selection** is the process by which favorable traits tend to increase in frequency over time. How does this experiment illustrate natural selection?

   _____

   _____

_____

6. Think and discuss: Did the changes you observed in the moth populations result from individual moths changing colors? Or did they occur because the best-hidden moths survived and reproduced, passing on their colors to their offspring? Explain your answer.

_____

_____

_____

_____

_____

7. Extend your thinking: **Biological evolution** is the process by which populations of organisms change over time. How could natural selection lead to evolution? If possible, discuss your answer with your classmates and teacher.

_____

_____

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Student Exploration: Evolution: Mutation and Selection

https://www.explorelearning.com/

Vocabulary: adaptation, allele, allele sequence, chromosome, evolution, fitness, gene, genotype, mutation, natural selection, phenotype, trait

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

1. Imagine a white lizard and a brown lizard sitting on a brown rock. A hawk is circling overhead hunting for its next meal. Which lizard do you think the hawk would most likely try to catch? Explain your choice.

   _____

   _____

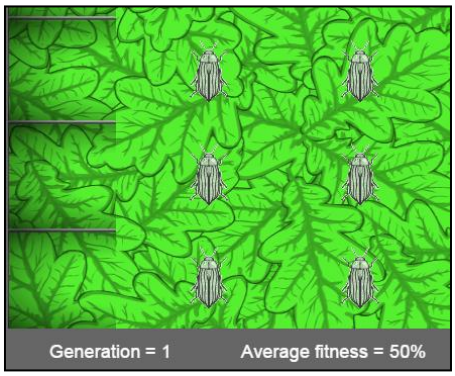
2. Now imagine that the same two lizards were sitting on a dune of white sand. Which lizard do you think the hawk would then most likely try to catch? Why?

   _____

   _____

Gizmo Warm-up

How long could a parrot survive in Antarctica? It would probably not survive long. Parrots do not have **adaptations**—or helpful characteristics—to survive icy cold weather. Because of this, a parrot is not fit for Antarctica. **Fitness** describes how well an organism can survive and reproduce in an environment.



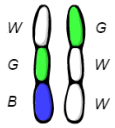
In the *Evolution: Mutation and Selection* Gizmo, you will see how a species' fitness can change over time as it becomes better adapted to its environment.

3. On the SIMULATION pane, what is the **Average fitness** of the population? _____

4. On the CONTROLS pane, experiment with the **Background color** sliders.

   A. Which background color results in the highest fitness? _____

   B. Which background color results in the lowest fitness? _____

Activity A: **Inherited variation**	Get the Gizmo ready: • Set **Red** to 100, **Green** to 255, and **Blue** to 50.	

Introduction: An organism's **traits**, or characteristics, are controlled by **genes**. Genes are located on rod-like structures called **chromosomes**. Different versions of genes that code for the same trait are called **alleles**. In this Gizmo, there are 3 genes on each chromosome. For each gene there are eight possible alleles: *W* (white), *R* (red), *G* (green), *B* (blue), *C* (cyan), *M* (magenta), *Y* (yellow), and *K* (black).

Question: Where does variation in a population come from?

6. Observe: Hold your cursor over one of the insects. The two rod-like structures under **Genotype** on the right side of the Gizmo represent chromosomes. The three letters next to each chromosome represent alleles.

   Which alleles does the insect have? _____

   The alleles carried on an organism's chromosomes make up the organism's **genotype**.

7. Observe: An organism's alleles combine to produce a trait. The physical expression of that trait is a **phenotype**. In the Gizmo, phenotype is expressed in red, green, and blue values.

   A. What is the phenotype of the insect? Red: _____ Green: _____ Blue: _____

   B. What color is the insect? _____

8. Run Gizmo: Move the **Sim. speed** slider all the way to the left. Click **Play** (▶). You will see the insects move to the left in pairs. The pairs mate and produce a set of four offspring. As soon as you see at least one offspring with an oval around it, click **Pause** (⏸). Move your cursor over the circled offspring.

   A. What is its genotype and phenotype? _____

   B. How does its genotype and phenotype differ from the non-circled offspring?

   _____

9. Explain: The change in the circled offspring's genotype was caused by a **mutation**. A mutation is a change in a gene. Mutations happen when a mistake is made when a cell's chromosomes are copied. How might mutations introduce variation into a population?

   _____

   _____

(Activity A continued on next page)

Activity A (continued from previous page)

10. Collect data: Move the **Mutation rate** slider to 3.0, and click **Play**. Allow the Gizmo to run for another 10–15 generations. (You can see the generation number below the insects.)

    Click **Pause** when the parents are ready to have offspring. Find a set of two parents that has four *different* chromosomes. (If you can't find any, allow the Gizmo to run a few more generations and try again.) Write the allele sequences for these parents in the table below. Note the labels for each of these chromosomes: A1, A2, B1, and B2.

Organism:	**Parent A**	**Parent B**
Allele sequence of chromosome 1:	(A1)	(B1)
Allele sequence of chromosome 2:	(A2)	(B2)

    Click **Play**, and then click **Pause** immediately after the offspring are produced. Write the allele sequences of chromosomes 1 and 2 for each of the offspring of your selected parents.

Offspring	**Allele sequence of chromosome 1**	**Allele sequence of chromosome 2**
Offspring 1	( )	( )
Offspring 2	( )	( )
Offspring 3	( )	( )
Offspring 4	( )	( )

    Label the offspring chromosomes A1, A2, B1, or B2. Circle any mutated chromosomes.

11. Analyze: Study the completed table.

    A. Look at the inheritance patterns. What do you notice? _____

    _____

    B. Can a single offspring inherit both chromosomes from one parent? _____

    Explain: _____

    C. Did any mutations occur in this set of offspring? _____

    If so, which chromosome mutated? _____

12. Challenge yourself: You have already learned that mutation is one source of variation in a population. Based on what you have just seen, what is a second source of variation?

    _____

Activity B: **Survival of the fittest**	Get the Gizmo ready: • Click **Reset** ( ). • Set **Red** to 255, **Green** to 0, and **Blue** to 130. • Set the **Mutation rate** to 1.0.	

Question: Are some organisms more likely to survive and reproduce than others?

1. Count: Move the **Sim. speed** slider all the way to the left. Click **Play**.

   A. After the parents mate, click **Pause**. How many offspring are there? _____

   B. Click **Play**. After the birds eat, click **Pause**. How many offspring are left? _____

   In nature, as in the Gizmo, more offspring are born than can survive long enough to reproduce. Because of this, the offspring must compete with one another for survival. In this Gizmo, the insect offspring compete to avoid being eaten by birds.

2. Observe: Move the **Sim. speed** slider one notch to the right. Click **Play**, and wait for about 20 generations to pass. You should see a variety of insect phenotypes. (If not, click **Play** and wait until you do.)

   A. What different colors of insects do you see? _____

   _____

   B. How do you think this variation might affect the competition between the offspring?

   _____

   _____

3. Analyze: Scroll over the insects and note their fitness (shown under the **Phenotype**). The fitness of an organism reflects how likely it is to survive and produce offspring. Each insect is given a percentage that reflects its chances of surviving to reproduce.

   Compare the fitness percentages to the insect colors. How does fitness relate to the color of the

   insects? _____

   _____

4. Predict: How do you think an insect's fitness will affect is chances of being eaten by birds?

   _____

   _____

5. Collect data: In nature, chance alone can affect whether an individual survives. However, general trends in survival rates can be seen by studying a larger group of individuals.
   Move the **Sim. speed** slider all the way to the left. Click **Play**, and then click **Pause** when all the offspring are visible. Write the generation number and the average fitness of all the offspring in the first two spaces of the table below.
   Next, click **Play**, and then click **Pause** immediately after the birds have fed and the 10 survivors are visible. Mouse over each survivor and record its fitness. Find the average fitness of the survivors by adding these values and dividing by 10.

   Repeat this experiment two more times, recording your results in the table.

Generation	Ave. fitness	Survivor fitness values	Ave. survivor fitness

6. Recognize trends: Study the table above. What trends do you see? _____

   _____

   _____

7. Analyze: In most situations, were the fittest insects or the least fit insects most likely to survive? Explain how the data from your experiment supports your answer.

   _____

   _____

8. Think and discuss: The principle of **natural selection** states that the best adapted organisms are most likely to survive and reproduce. Was this demonstrated in your experiment? Explain.

   _____

   _____

   _____

Activity C: **Evolution**	Get the Gizmo ready: • Click **Reset**. Set **Red** to 100, **Green** to 255, and **Blue** to 50.	

Introduction: You learned in activity B that fit individuals have a better chance of surviving and reproducing than individuals that are less fit. In this activity, you will observe how natural selection affects a population over time.
Question: How does a population change over time?

1. Experiment: Set the **Background color** to the values shown in the last column of the table below. Record the **Average fitness** of generation 1 in the second column of the table. Move your cursor over the insects and find the individual with the greatest fitness. (In the first generation, all the insects will have the same fitness). Record that individual's phenotype in the table's third column.

   Move the **Sim. speed** slider a quarter of the way to the right. Run the Gizmo, and complete the table for each listed generation. (The generation number does not have to be exact.)

Generation number	Average Fitness	Fitness of Fittest Individual	Phenotype of Fittest Individual (R, G, B)	Background color
1				red = 100 green = 255 blue = 50
25				
50				
75				
100				
150				
200				
300				

2. Describe: Examine the data collected for trends.

   A. How did the phenotype of the fittest individual change over time? _____

   _____

   B. How did the population's fitness change over time? _____

   _____

   The process by which populations change over time is known as **evolution**. This Gizmo only demonstrates how one trait—body color—can evolve.

3. Predict: Based on what you have just seen, how do you think the population will evolve if you made the **Background color** purple?

   _____

4. Test: Set **Red** to 120, **Green** to 0, and **Blue** to 160 to make a purple background. Click **Play**. After 300 more generations have passed, click **Pause**.

   Was your prediction correct? Explain. _____

   _____

5. Make connections: Why do you think it is necessary for there to be variation in a population in order for evolution by natural selection to occur?

   _____

   _____

6. Make connections: Why is it necessary for traits to be inherited for evolution to take place?

   _____

   _____

   _____

7. Apply: Look carefully at the picture below and you will see an insect called a katydid. Katydids evolved from grasshoppers through natural selection. Use what you have learned to explain how this could have happened.

   _____

   _____

   _____

   _____

   _____

   _____

Name: _____ Date: _____

Student Exploration: Rainfall and Bird Beaks

https://www.explorelearning.com/

Vocabulary: adaptation, beak depth, directional selection, drought, evolution, natural selection, range, stabilizing selection

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
During the voyage of the HMS *Beagle* (1831–1836), the young Charles Darwin collected several species of finches from the Galápagos Islands. Two of Darwin's finches are shown below.

Geospiza magnirostris

3. Which species do you think is best adapted to a diet of small, delicate seeds? Explain why you think so.

_____

_____

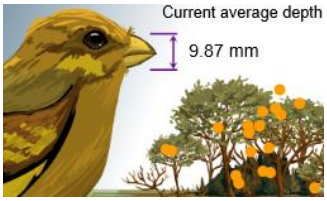
Geospiza fortis

4. Which species do you think is best adapted to a diet of large, tough-to-crack seeds? Explain.

_____

_____

Gizmo Warm-up
Darwin's finches are one of many types of animals on the Galápagos Islands that have unique **adaptations**, or traits that help an organism survive in its environment. The *Rainfall and Bird Beaks* Gizmo™ allows you to explore how rainfall influences the range of beak shapes found in a single finch species.



1. The **beak depth** of a finch is the distance from the top of the beak to the bottom, as shown.

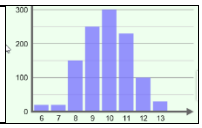
   A. What is the current average beak depth in the Gizmo? _____

   B. Select the HISTOGRAM tab. Do all the finches have the same beak depth? _____

2. Click **Play** ( ) and let the simulation play for five years with average rainfall (10 inches/yr). Select the GRAPH tab and view the **Finches vs time** and **Beak depth vs time** graphs.

   A. How does the finch population change? _____

   B. Does the beak depth change significantly? _____

Activity A: **Normal years**	Get the Gizmo ready: • Click **Reset** ( ).	

Introduction: The Galápagos Islands are very dry, with an average rainfall on some islands of only five inches per year. The amount of rainfall has a large impact on the abundance and types of seeds that are available to be eaten by finches. In the process of **natural selection**, only the finches that are best adapted to the available seed types survive and have offspring.

Question: How is the finch population affected by a period of average rainfall?

1. Observe: With the **Rain** sliders set to 10 inches, click **Play**, and then **Pause** ( ) after one year has passed. Select the TABLE tab and look at the **Month** and **Finches** columns.

    A. How did the finch population change over the course of one year? _____

    _____

    B. The finches have their young during the rainy season. Based on the table, which part of the year do you think is the rainy season? _____

2. Analyze: Click **Reset**, and choose the HISTOGRAM tab. The bars represent the numbers of finches that have different beak depths. The **range** of beak depths is equal to the difference between the largest and smallest beaks.

    A. What is the average beak depth of the current finch population? _____

    B. What is the range in beak depths in the population? _____

    C. Do most of the finches have beak depths near the lower extreme, the middle, or the higher extreme of the range? _____

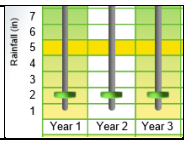
3. Experiment: Click **Play**, and observe the histogram as the simulation plays for five years.

    A. What is the average beak depth now? _____

    B. What is the current range of beak depths? _____

    C. Based on what you have seen, are finches with very small, medium, or very large beaks most likely to survive in times of normal rainfall? Justify your answer.

    _____

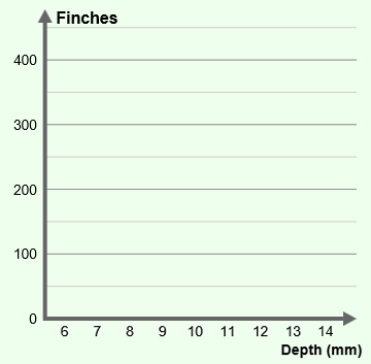
Activity B: **Drought**	Get the Gizmo ready: • Click **Reset**.	

Introduction: In years of extreme **drought**, Galápagos plants don't produce new seeds. The small, delicate seeds get eaten up quickly, leaving behind only the largest, toughest seeds.
Question: How does drought affect the finch population and average beak depth?

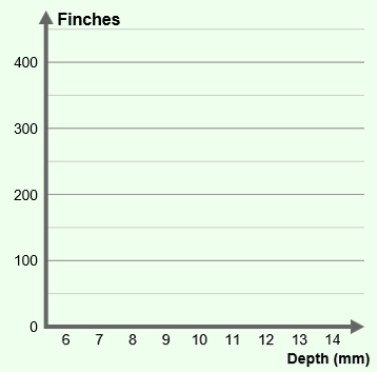
13. Form hypothesis: What type of beak do you think will be best for finding food in a drought?

_____

14. Predict: Select the HISTOGRAM tab. On the left side below, sketch the current histogram and list the average beak depth and range of beak depths. On the right side, sketch what you think the histogram will look like after five years of drought. Explain your prediction.



Initial beak depths



Beak depths after 5 years (predicted)

Initial number of finches: _____

Initial average depth: _____

Initial range of beak depths: _____

Explanation: _____

_____

_____

15. Experiment: Use the sliders to set the **Rain** to 2 inches for each of the five years in the simulation. Click **Play**, and wait for five years. Observe the beak of the finch.
    A. How does the beak depth change over time? _____
    B. What is the final average beak depth? _____
    C. What is the final range of beak depths? _____

16. Describe: Compare the final histogram to the initial histogram. How have the finches been affected by drought? Describe at least two changes that you notice.

_____

_____

17. Analyze: Was the increase in the average beak depth caused by an increase in large-beaked finches or a decline in small-beaked finches? Explain your answer.

_____

_____

_____

18. Draw conclusions: What do you think caused the changes in the finch population and average beak size during the drought?

    _____

    _____

    _____

19. Interpret: **Directional selection** occurs when individuals at one end of a range are more likely to survive than intermediate individuals or individuals at the opposite end of the range. **Stabilizing selection** occurs when intermediate individuals are the most likely to survive.

    Is directional selection, stabilizing selection, or both operating in this example? Explain.

    _____

    _____

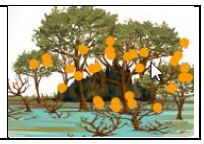
    _____

20. Think and discuss: **Evolution** is the process by which populations of organisms can change over time. How is directional selection related to evolution?

    _____

    _____

    _____

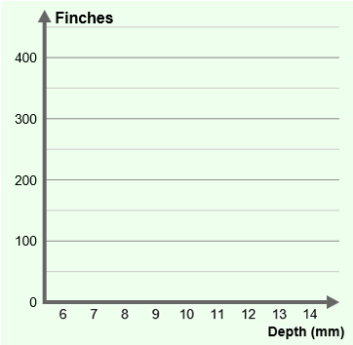
Activity C: **Rainy days**	Get the Gizmo ready: • Click **Reset**.	

Introduction: In years of abundant rainfall, there can be 20 inches or more of rain. In these years, plants produce an enormous number and variety of seeds.

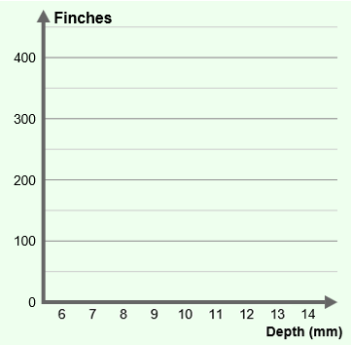
Question: How does plentiful rainfall affect the finch population and average beak depth?

1. Form hypothesis: What beak shape do you think will be best for finding food in a period of abundant rainfall? _____

2. Predict: Select the HISTOGRAM tab. On the left side, sketch the current histogram and list the average beak depth and range of beak depths. On the right side, sketch what you think the histogram will look like after five years of abundant rain. Explain your prediction.



Initial beak depths



Beak depths after 5 years (predicted)

Initial number of finches: _____

Initial average depth: _____

Initial range of beak depths: _____

Explanation: _____

_____

_____

3. Experiment: Click **Reset**. Use the sliders to set the **Rain** to 20 inches for each of the five years in the simulation. Click **Play**, and wait for five years. Observe the beak of the finch.

   A. How does the beak depth change over time? _____

   B. What is the final average beak depth? _____

   C. What is the final range of beak depths? _____

4. Describe: Compare the final histogram to the initial histogram. How have the finches been affected by abundant rain? Describe at least two changes that you notice.

_____

_____

5. Analyze: Was the decrease in the average beak depth caused by an increase in small-beaked finches or a decline in large-beaked finches? Explain your answer.

_____

_____

_____

6. Draw conclusions: What do you think caused the changes in finch population and average beak size during the period of abundant rain?

_____

_____

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7. Extend your thinking: Most scientists think that a small group of finches colonized the Galápagos Islands thousands of years ago. They would have been the only seed-eating birds on the islands. Suppose one island was very dry and another had plentiful rainfall.

    A. How would the finch populations on these islands change over time? _____

    _____

    _____

    _____

    B. What might happen to the finch populations after millions of years? _____

    _____

    _____

    _____