Lesson 7: How Can Selective Breeding Change a Population?

Overview:

Purpose:
The purpose of this activity is to 1) familiarize students with selective breeding as a mechanism that can change populations, 2) introduce the distinction between random vs. non-random selection events (genetic information passed to offspring vs. intentional selection by breeders), 3) introduce the distinction between selection of individuals to breed vs. selection of individuals to remove from a population and 4) show that selections events can progressively lead to rare recombinations of trait variations in offspring that meet a desired outcome in a population, when such selection is repeated over multiple generations.

Prerequisite Knowledge:
Students need to have developed a simple Mendelian model that explains genotype and phenotype of single gene traits to account for the patterns of inheritance before they encounter in this activity. Development of this model is not part of the BEAGLE unit. Students need to already know that:

- Organisms have traits that are primarily inherited. Some of these traits have two variations, others have multiple variations.
- Many inherited traits are determined by a single gene, each gene has two pieces of genetic information that can come in two different forms (alleles). An individual can possess two identical alleles, or two different alleles, one on each chromosome of a chromosome pair.
- Through meiosis each parent passes on one of their alleles for every gene to an offspring; for each offspring there is a 50/50 chance as to which allele they will receive from each parent.
- When there are two different alleles for a single trait, sometimes one allele masks the presence of the other allele. These alleles are said to assert a dominant expression over the other allele, so that the phenotype (or observable characteristics related to the trait) of the organism appears to be that of the dominant allele.

Development of Ideas:

New Scientific Principles

- **Selective breeding can change successive generations so that individuals appear very different from their ancestors because of three mechanisms: 1) random selection of alleles passed on through meiosis, 2) intentional selection of mates and 3) intentional selection of who to remove from the population.**

Description
In this activity students identify variations of traits that people might selectively breed for in cats and dogs. They then selectively breed birds in a computer simulation with a team of 3 other students to cooperate with each other and compete against other teams of students to see which team can most quickly develop a fancy breed of bird through selective breeding. After analyzing the results of the simulation, the class identifies the mechanisms of selection in the model, including selection of which individuals will reproduce and which individuals will be removed from a population as well as random allele selection (via. Meiosis) for passing on genetic information to offspring. And they describe how these mechanisms of selection influence the outcomes of the selective breeding process.

In their homework and out-of class reading they apply these experiences and understandings to describe how people have selectively bred dogs and foxes for different trait combinations and how selective breeding in corn has changed the traits variation of corn plants over time.

Learning Performances

- Identify two forms of intentional selections in selective breeding (who to breed and who to remove from a population).
- Explain how meiosis yields a new random sorting of alleles for a gene into each sex cells for every new offspring.
- Describe how the the interaction of meiosis and intentional selections of individuals when repeated over and over again in each new generation of offspring, help shift trait combinations in a population toward a desired outcome.

Related Benchmarks

- In organisms that have two sexes, typically half of the genes come from each parent. 5B/M1b*
- The sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations in the offspring of any two parents. 5B/H2
- People control some characteristics of plants and animals they raise by selective breeding.... 8A/M2*\
- New varieties of cultivated plants and domestic animals have resulted from selective breeding for particular traits. 5B/M3.

Time 1-1.5 periods

Materials

Per Student

- 1 computer per student with NetLogo installed on each computer along with a copy of the Bird Breeders.nlogo model file.

For Teacher

- 1 computer and projector or large display screen for the teacher to demonstrate the model.
- 1 computer projector or large display screen for the teacher to display the overhead transparencies.
- Transparencies 7.1, 7.2, 7.3

Instruction:

Launch:

Remind students of what they discovered in previous activities related to patterns of inheritance. Connect previously learned scientific principles learned about Patterns of Inheritance:

- organisms that sexually reproduce can generate new combinations of trait variations in their offspring, since each parent contributes half of the genetic information for every trait to their offspring.
- When a parent has two alleles for a trait, there is a 50/50 chance that an offspring inherits either of these alleles
- sometimes genetic information for trait variations is hidden or masked by expression of the dominant alleles for the same trait.

Introduce the idea of a **litter of offspring** as a number of siblings born all at once from two animals. Ask how many students have ever seen a litter of kittens, puppies, piglets, or rabbits?

Show the transparency of a litter of kittens (Transparency 7.1). Discuss what traits appear different in each of the kittens: What variations do students observe in kittens traits? On their activity sheets, have students write down some of the variations they see in spottedness. *Students may say "spotted" and "non-spotted.* On their activity sheets have students write down variations they see in the color of fur on the paws. *Students may say "gray", "black", "tan", "white", and "black and white". Specific wording of the variations or the number of variations recorded is not important. The goal is to recognize the idea of the trait being the "name of the category for the attribute" and the variations being the possible "values" and that traits can have more than 1 variation is the key idea.*

Ask students if they suspect that one or both of the parents have some of the same variations in their traits as the kittens? *Accept all answers. Students may argue its hard to now since parents don't always look exactly like their offspring.* Ask whether a kitten inherits alleles from only one parent or both? *Students should say both.*

And ask if all of these kittens were born from the same two parents why don't all the kittens look identical? *Students should say that different offspring may inherit a different half of genetic information from each parent for each trait.*

Introduce the idea of a gene pool by first asking whether the offspring (the kittens) of the cats would likely have the same alleles (genetic information). *Students should provide reasons why not. Since there are 5 very different looking cats, and only two parents, the genetic information (alleles) must be in different combinations or frequencies in the offspring than in the parents.*

Say that scientists often think about what alleles are in a population as well as what traits they can observe in the population, sinc what they see on the outside (the traits or the phenotype) might be different from the genetic information on the inside (the genotype). Say that when scientists refer to the all of the alleles in a population, they call this the **gene pool** of the population. Tell students that they already have provided an argument for why the gene pool of the parent generation (the mom and dad cat) must be different than the gene pool of their offspring (the litter of five cats)

Ask students why the gene pool of the entire kitten family (mom, dad, and all their offspring) would change each time a new kitten is born. *Accept all answers.*

Ask students what else besides new births would change the gene pool of the kitten family. *Students may say if a kitten or a parent cat dies, or if it is permanently removed from the population (given away to another family)).*

Review with students these previously learned ideas, covered in earlier class instruction and connect them to the example of the litter of kittens.

- The variations in traits (color of fur, spottedness) is the result of genetic information from each parent
- Each offspring can inherit one of two different alleles for a gene that determines a trait. Some traits are influenced by more than one gene.
- Each offspring develops rom a fertilized egg cell. That fertilized cell forms when a sperm cell from the male and the egg cell from the female merge.
- Different egg cells and different sperm cells may contain different genetic information (different alleles).
- Fertilized cells develop into kittens by cell division. With each cell division and duplicates its genetic information and divides until there are millions of cells. These cells organize into tissues, organs, and organ systems, and eventually a new organism (a kitten).
- In each of these body cells in a kitten there is identical genetic information. Part of this information came from each parent.

Introduce the idea of selective breeding**.** Tell students that some people breed animals for many reasons. Say that in general, all animal breeders purposely select which parent animals they arrange to mate together in an attempt to try to get desirable variations in the offspring. When a population of dogs has a set of similar characteristics that are genetically inherited over generations that are different than other populations of dogs, it is called a breed of dog. Ask students to name some different breeds of dogs. *Answers will vary*

Show transparency 7.2, of a Chihuahua and Great Dane as two examples of different breeds of dogs. Tell students that these are separate breeds of dogs. Ask students what are some traits they think that all Chihuahuas' genetically inherit which makes them different than Great Danes. *Body size, pitch of bark, size of bones, ear shape, etc...*

Ask students to think about different types of dogs that people might selectively breed for desirable characteristics or different trait variations. Show Transparency 6.3 of different dogs. Ask student's what two breeds of dogs would they select for interbreeding if they were trying to get puppies with really long fur and a spotted coat? A small body size and pointy ears? *Answers will vary*

Tell students that one goal of selective breeding is to develop a **purebred** animal. A purebred animal is an individual animal that reliably passes on the genetic information for just one variation for each of many trait. Purebred animals have two copies of the same allele for these traits. Offspring of two purebred dogs with the same trait variation will show all the same traits as its two parents. For example, when one purebred dog of a specific breed (e.g. poodle) is mated with another purebred dog of the same breed, the offspring will have all of the same traits as its parents that would qualify it as a poodle. Or in other words, a purebred dog with black fur mated with another purebred dog of the same breed with black fur will always have offspring with black fur.

(This assumes no mutation in genetic information of the offspring from the parent. Do not bring this idea up at this time, but if students suggest the idea, then say that we will study that mechanism in future explorations, but that mechanism is not included in this model yet).

Next, introduce Student Activity Sheet . Read the purpose and procedure of the activity with students. Demonstrate the launching the HubNet Model as described here, if students have not done the activities in lesson set 1:

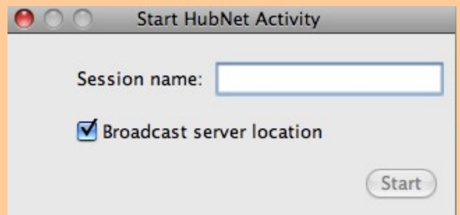
Directions for Opening the third model:

- Tell students that you will be showing the steps that the only the team leader does at first to setup the model for everyone else on the team to join.

- Open NetLogo on your computer

- In the NetLogo window, open the Model Library from the File Menu,
Under *File > Models Library*, choose the Curricular Models/BEAGLE evolution folder and open it. In the folder click on the "Bird Breeders" model and open it.

- A Start HubNet Activity box will appear:



- Enter your name in the session name and click the Broadcast server location check box.

- A HubNet Control Center box will appear:

- Click the mirror 2D view on clients check box so that it is checked.

- Remind students that the other 3 players will now need to join the simulation and instructions for this are separate from the instructions for the leader who starts the model. Direct students to look at those instructions on the second page of their activity guide. *Once the leader sees all the players names in the CLIENTS: list, press the GO button to start the model.*

- *Then the leader joins the simulation themselves by pressing the LOCAL button. A client interface will be launched for you to demonstrate the simulation as player 1.*

- *Tell your group members to read the instructions on the left side of the client carefully. Everyone is working together to try to achieve the end goal. Your team is trying to achieve this* *goal before any other team in the class. So, remind them to talk and plan together how reach your shared goal.*

- *Show examples of how to move the birds from a cage to a breeding site:*
  - *show two birds in a breeding site might not have offspring (one needs to be male and one needs to be female) - pose this as a mystery for how to determine which is which and give students a clue that the males may have a different trait variation than the females (teacher note: male birds have a head cap of feathers, females do not).*
  - *Show how birds can be brought back to cages and released into the wild (the white space outside the cages). Tell students that when eggs are laid, they will need to bring them back to their cages to hatch them.*
  - *Show how birds can be dragged to the DNA sequencer (the rack of test tubes that have the same player number next to them as the player) and that this will reveal the geneotype (all the alleles for this bird). Point out that not all birds may be purebred, they may have different alleles for the same trait. Either repeatedly experimenting with mating the birds together or having their DNA sequenced may help you determine if whether a bird is purebred for a given trait. While you can point out that the letters correspond to those that are used in modeling alleles in Mendellian genetics leave it a mystery as to which letters represent which alleles and which correspond to which traits.*

Assign a student leader for teams of 4 students. These teams of 4 students should sit near each other so that can talk and collaborate. Each student needs their own computer. Tell students that the student leader will be in charge of launching and running the activity as you did as a demonstration and that the rest of the team members will join using a HubNet Client application, as outlined in a separate section of their activity 6 sheets.

Explore:

Instruct students to begin the explorations on their activity sheets. As students are working in groups, as they work ask group members to verbalize what strategies they are using. Why are they choosing to keep some birds in their cages and let others go? Do the ever breed a bird more than once (why?) After 10-15 minutes, have students record their observations (even if they haven't met the scenario goal).

Summarize:

Have all students stop the simulation and record their observations and answer the follow-up questions.

Then ask students to write down ideas about what conditions are required for natural selection and what outcomes result from natural selection in the DISCOVERIES AND INSIGHTS section of the activity sheet.

Finally have students talk with a partner and select one idea they discovered today related to either question. Have students write this idea on a large piece of paper or a large post it note in dark pen/marker. Have one student from each pair of students bring their papers/post-its to the front of the room and stick them up on the board.

With the papers/post-its displayed for the class to look at together, lead a consensus building discussion. Facilitate the movement and reorganization/clustering of the ideas students brought up, under the headings listed below. The two main heading should be “mechanisms that change the population (through selective breeding)” and “the outcomes (of selective breeding)” This consensus building discussion and reorganization of the student descriptions of their discoveries will help students condense and summarize the big ideas from the day's lesson. If an idea that students suggest doesn't fit under these areas, don't leave it out. Rather, emphasize that the idea shared is another interesting discovery and that the main ideas that the students are responsible for knowing and reusing in future explorations are the ones organized under the areas listed. Try to write the categories in the student's own words, and using their own papers if possible. You may want to consider posting these big ideas in class, having students summarize these ideas now (or later) in their notes. Either way, try to use the students own words and the way the class expresses the ideas listed below, without feeling it is necessary to use this exact wording. Example of possible student responses they might contribute on their sheet or post it note are shown in italics. Ask students whether they agree or disagree with how the ideas or organized and whether this summary helps pull out the main points they discovered.

The underlined statement is the suggested category. The non-bold italics statements are possible student ideas. The bold italics statement can serve as another way to summarize what is common amongst the student ideas and each underlined category.

Conclusions & Big Ideas:

The original question our class had:
“ How Can Selective Breeding Change a Population?”

<u>The **mechanisms** that change the population:</u>

Intentional selection of which individuals will interbreed.

- *Example student idea: The breeders are selecting some birds to breed together and not others.*
- *Example student idea: If a breeder needs an offspring to have a certain variation, they may pick a parent that produced offspring with that variation before.*
- *Example student idea: Knowing the genotype of the parents help you pick which ones will breed true for certain traits.*
- ***Summarize with this idea:*** **Breeders intentionally select which individuals to mate together in an attempt to aggregate desirable traits or alleles in the offspring.**

Intentional selection of which individuals will be removed.

- *Example student idea: The breeders don't keep all the individuals. .*
- *Example student idea: There is limited space, so sometimes you have to get rid of the birds that aren't useful.*
- ***Summarize with this idea:*** **Breeders intentionally select which individuals to remove from their stock** (population)**.**

Random selection of which of the two alleles for each gene are passed on to offspring

- *Example student idea: Different offspring result from the same parents.*
- *Example student idea: Which allele an offspring gets from a parent for a gene is random.*
- ***Summarize with this idea:*** **Both meiosis and fertilization contribute elements of random selection toward which of the two alleles per gene is sorted/separated into which sex cell, and which sex cells fertilize one another.**

The **outcomes** of selective breeding that can result from these mechanisms are:

Many more possible combinations of traits are possible in offspring.

- *Example student idea: You can get many possible offspring from parents that have different traits.*
- *Example student idea: Sometimes there are more possible combinations of trait variations in offspring than you start with in the parents/*
- ***Summarize with this idea:* The sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations in the offspring of any two parents.**

The frequency of alleles in gene pools change over time .

- *Example student idea: The alleles you want in the offspring become more frequent as you keep breeding over and over again.*
- *Example student idea: Which alleles you have more of in your population changes over time.*
- ***Summarize with this idea: Gene pools change so that some alleles increase in frequency and others decrease in frequency (or sometimes are completely eliminated).***

Descendants can appear very different than their ancestors.

- *Example student idea: You can get many possible offspring from parents that have different traits.*
- *Example student idea: You are combining the alleles in new ways in the offspring.*
- *Example student idea: Sometimes there are more possible combinations of trait variations in offspring than you start with in the parents*
- ***Summarize with this idea: Small differences between parents and offspring can accumulate in successive generations so that descendants are very different from their ancestors.***

Now consolidate these ideas into these principles and leave these next to the driving question board

New Scientific Principles

- **Selective breeding can change successive generations so that individuals appear very different from their ancestors because of three mechanisms: 1) random selection of alleles passed on through meiosis, 2) intentional selection of mates and 3) intentional selection of who to remove from the population.**

Homework: *Assign the homework for this lesson. It is strongly encouraged that you read the jumpstart for the homework with the students to motivate the purpose of the reading.*

Lesson 8: "How Does Nature Select For Some Trait Variations Over Others?"

Overview:

Purpose:
One purpose of this activity is to engage in an exploration that shows how natural selection emerges from the interaction of these mechanisms: a) variation in heritable traits in a population and b) interactions in the environment give individuals with some variations a competitive advantage over other individuals. Another purpose is compare these mechanisms to those of intentional selection and random selection in selective breeding and describe the outcome of natural selection as a increase in the proportion of individuals with advantageous heritable trait variations in a population over multiple generations.

Connection to previous activities:
Students will have conducted a selective breeding program in the previous activity and should know how selection can generate new combinations of trait variation. They need to be familiar with at least one form of intentional selection and one form of random selection in selective breeding. For example, intentional selection occurs by humans (selection for removing from a population) and random selection for which chromosome is passed on to sex cells from each chromosome pair of the parent cell occurs with each cell division that creates sex cells.

Prerequisite Knowledge:
Students need to be familiar with examples of heritable trait variations in populations.

Students need to be familiar with some examples of asexual reproduction in plants and animals (e.g. bugs) and that cell division for reproduction creates exact genetic duplicates (clones) of offspring when individuals asexually reproduce from only one parent.

Development of Ideas:

New Scientific Principles

- **Natural selection tends to increase the proportion of individuals that have advantageous traits for a particular environment when there is some variation in the heritable traits within a population and when some of those traits give individuals a competitive advantage over others for surviving and reproducing.**

Description
In this activity students use a computer model to assume the role of predator in a population of prey (bugs). They hunt bugs using two different predation strategies, each of which generates a different selective pressure and a different outcome from natural selection. They compare how the competitive advantage for different variations of speed in the prey changes based on these two type of interactions that occur with the predator.

At the end of class, the teacher develops a class consensus on the big ideas for: the two conditions necessary for natural selection and how these two conditions lead to competitive advantage, preferential selection, and the change in distribution of trait variations in the population.

In their homework and out-of class reading they apply these experiences and understandings to describe how a population of prey and predators would change over time due to natural selection, why bugs have become more pesticide resistant over time, and what will eventually probably happen to populations of plants that pesticides are currently effective at killing off most of the individuals.

Learning Performances

- Compare the selection mechanisms in natural selection with those in selective breeding.
- Describe why natural selection requires trait variation in a population.
- Describe how natural selection mechanisms preferentially, but not intentionally, select individuals with specific trait variations to survive or reproduce more frequently than others.
- Explain how when the environment changes, natural selection can lead to populations particularly well suited to surviving in that new environment.

Related Benchmarks

- The variation of organisms within a species increases the likelihood that at least some members of the species will survive under changed environmental conditions. 5A/H1a
- Natural selection provides the following mechanism for evolution: Some variation in heritable characteristics exists within every species; some of these characteristics give individuals an advantage over others in surviving and reproducing; and the advantaged offspring, in turn, are more likely than others to survive and reproduce. As a result, the proportion of individuals that have advantageous characteristics will increase. 5F/H3
- Natural selection leads to organisms that are well-suited for survival in particular environments. 5F/H6a
- When an environment, including other organisms that inhabit it changes, the survival value of inherited characteristics may change. 5F/H6c

Time 1 period

Materials

Per Student

- 1 computer per student with NetLogo installed on each along with a copy of the Bug Hunt Speeds.nlogo model file.

For Teacher

- 1 computer and projector or large display screen for the teacher to demonstrate the model.
- Transparency projector or poster paper

Instruction:

Launch:

Remind students of what the forms of selection that were mechanisms of selective breeding:

- selecting which individual to breed together is a form of intentional selection – which individuals chosen for breeding changes the chances of acquiring the desired variations in an offspring.
- selecting which individuals to remove from a population is a form of intentional selection - which individuals removed from the population also removes more of that genetic information from the gene pool.
- 1 of 2 alleles from each chromosome pair is passed on to a sex cell; Which chromosome is in a sex cell that fertilizes an individual can not be predicted, so which genotype an offspring inherits from a parent,

can be thought of as a form of "random selection".

Tell students that they are going to compare forms of unintentional and intentional selection mechanisms in an asexually reproducing population that already has trait variations between individuals. Remind students of examples of asexually reproducing plants and animals and that offspring from each of these organisms is an exactly genetic duplicate of its one parent, and therefore has the same heritable traits as the parent. A set of example organisms in provided in Transparency 7.1.

Finally, demonstrate how intentional selection process works in the model and how asexual reproduction is modeled in the model.

Opening the fourth model:

- Open NetLogo on your computer
- In the NetLogo window, open the Model Library from the File Menu
- Under File > Models Library, choose the Curricular Models/BEAGLE evolution folder and open it. In the folder click on the "Bug Hunt Speeds" model and open it.

Exploration 1:

- Adjust the INITIAL-BUGS-EACH-SPEED slider to 1
- Press the SETUP button. Point out that the students should see 6 bugs appear on the screen, each a different color. Tell them that each color represents a bug that will move at a different speed.
- Press GO/STOP. Students should see these 6 bugs move about the screen.
- Ask students to watch the bugs move and ask them which color bugs are the fastest and and which are the slowest.
- Now use your mouse to click on one of the bugs. When you click on one of the bugs, point out to students that they should see it disappear. Then say that as you remove one bug, a new bug is born to replace it. Tell them that the new bug is randomly selected from the remaining population and an offspring from this bug is created. The offspring is simply an exact duplicate (in genotype and phenotype related to how fast it moves) of the bug that was selected to produce the offspring. The new bug has the same speed as the bug it was duplicated from (but it heads off in a different direction).
- Repeat step 8 a few times pointing out which bug is duplicated when you remove one until students see this happening at least once.
- Remind them that there were 6 variations of possible genotypes and phenotypes the bugs had in the population with regard to how fast they move and that color is a visualization tool that they can use to see how many fast bugs and slow bugs there are. They can also disable the color visualization, by turning the SHOW-COLORS? switch to "off" show them this now.
- Repeat step 8 a few times pointing out which bug is duplicated when you remove one. It may be hard to tell without the colors so ask the students to see if they can tell which is changing by

studying the Frequency of Bugs graph as you select bugs. Ask them to identify which color (or speed of bug) are there now more bugs of. Ask them to identify which there are less of than at the beginning. Point out that the total number of bugs hasn't changed, only the proportion of bugs with a certain variation.

- Then turn the SHOW-COLOR switch to "on" and tell them they will conduct different explorations with the SHOW-COLOR switch "on" and with it "off", but in all explorations the bugs inherit their speed asexually from one bug in the population. Color is simply a visualization tool to help see the variations more readily.

Before having students next work with this model on their own, explain to them of some of the simplifications that this model has in it and why they are there. Remind students that when you eat a bug in the model, a new bug immediately replaces it. When both of these events happen, one after the other, the size of the population of bugs doesn't change. One bug dies and a new one is born. Review with students that in a real ecosystem and based on what they observed in the bird bugs Predation model, that they know that the size of populations do change, (in part due to their interactions with other organisms in their ecosystem). Yet, while the size of populations fluctuated, they also discovered that population amounts often fluctuated around a relatively stable average value. As some individuals die, other are born to replace them. This stable state that the population size stays close to, can be described in terms of the the average amount of individuals that the resources in the ecosystem can support over a long period of time. Ask them to recall that this value is referred to as the carrying capacity of the ecosystem for that population.

Tell students that though they can set the carrying capacity to a fixed amount in the model (the average amount of individuals in the ecosystem over time), the mechanisms they investigated in earlier models that caused population amounts to fluctuate (such as the variations in the resources necessary for survival) have been removed intentionally, so that they can more easily study the effects of a new type of selection on a population with variations of a trait. This model also does not include the variation that results from sexual reproduction. This type of variation is what you explored in the Plant Hybridization and Bird Breeder models. The bugs in this model, instead, reproduce asexually., producing individuals with identical traits (clones) as the parent.

Tell students that in later models, the added complexities of population fluctuation and sexual reproduction will be reintroduced, but that for now, the reproduction mechanism in the model has been simplified to clarify the discoveries they can make about how the frequency of trait variations and the gene pool change as a result of a new form of selection. *Again, in this model that simplification is that when one individual dies (or is removed) from the population, another asexual offspring (genetically identical regarding its walking speed) is produced from one bug in the remaining population of bugs.*

Explore

Instruct students to begin the explorations on their activity sheets. *After students finish the first exploration, find opportunities to ask individual students who are in explorations 2 and 3 to verbalize what is happening to the average speed of the bug population over time. Ask them why there are more of one variation of bug than another. Ask them to try to verbalize why the bug population becomes slower in exploration 3 but faster in exploration 2.*

Remind students to finish the Data and Observations section and Follow-up questions individually and stop their before moving on to Discoveries and Insights section.

Summarize:

Ask students to share reasons (from their follow-up questions) for why slower bugs have a competitive advantage for survival in exploration 3 (when students waited for all the bugs to run into their cursor to catch them)? *students should say faster bugs run into the predator more often and are removed more often than slower. So slower bugs run less risk of encountering a predator. A bug that didn't move at all would never run into this type of predator.*

Ask students to share reasons why faster bugs have a competitive advantage for survival when you were chasing all the bugs around to try to catch some? *Students should say that faster bugs are harder to catch. Just when you seem to have them lined up under your cursor, they tend to move out from under it before you can press the button. Because of this, sometimes you miss catching the fast ones Slower bugs are easier to catch. So, more of the time you try to click on them you actually succeed. A bug that didn't move at all would be the easiest one to catch and you probably could successful catch (with one click) every stationary bug (if there were any).*

Build class consensus on the following ideas – in exploration 1, the selection was more similar to selective breeding than explorations 2 and 3, because you were focussed on intentionally trying to change the traits of the populations, explorations 2 and 3, the same result occurred, but it was unintentional on your partner. In all the explorations, selection is occurring, but the manner of selection is different. When humans engage in the selection (like in selective breeding) it is also sometimes called **artificial selection**. When objects or creatures or events in nature are unintentionally selecting what individuals survive and reproduce and causing the distribution of inherited traits variations in the population to change it is called **natural selection**. It is called natural selection, because it is also a process in which "favorability" is not necessarily intentionally chosen by any individual. Instead, interactions in nature are doing the selecting. Bugs, birds, plants, and any other organisms, and even non-living interactions from the environment (such as weather, geography, etc..) all can cause natural selection to occur, without intending to.

Discuss whether each of the mechanisms that were in the model that are contributing to a change in the speed in the population by natural selection?

__y___ There is variation in a trait and this variation is inherited - *if there was no variation there would be no change in the traits in the population and therefore no natural selection.*

__y___ Bugs reproduce offspring – *if bug didn't reproduce, natural selection might still be occurring (since the distribution of traits in the population change), but reproduction reinforces the effects of natural selection, since only individuals that survive can pass on their traits to their offspring*

__n___ Individual bugs learn to avoid the predator (you). *The bugs aren't changing their behavior at all. Even if they were, when an individual changes its behaviors (by learning) this is not something that can then be inherited or passed on through genetic information.*

__n___ The computer model is preprogramed to always give the same result *Every model gave slightly different results, and will every time you run it (due to the random distribution of bugs at SETUP, the randomness of your own actions), but natural selection will always result when you hunt and the result will be different whether you chase the bugs or whether you wait for the bugs to come to you.*

__y___ The predator (you) selects some variations to remove more often than others. *You do remove some variations more than others. The removal is not ALWAYS of one type, but it tends to be one type more than other types. And this tendency is not a result of your intending it to happen, it is a natural outcome of the way you interact with the model.*

__n___ The bug that reproduces is always the same variation chosen from the population. *The bugs that reproduces is chosen randomly, so this is not occurring.*

__n___ The predator has to intentionally decide what variation of bug it is selecting to remove. *While you could simulate this by trying to do this, that was probably not running through your mind when you did the exploration. If it was this intentional selection would be a form of artificial selection. When you are not trying to purposefully select out a certain variation it is natural selection. So natural selection is an unintentional* *process.*

__n__ The same bug speed gives the same competitive advantage in every situation. *In different situations different bug speeds have different competitive advantages. In the situation where you chase bugs, faster bugs have a competitive advantage for survival. In the situation where you wait for for bugs, slow bugs have an advantage. Maybe in an environment that had both types of predators (one that chases and one that waits), no speed would have a competitive advantage or maybe average speeds would have a competitive advantage.*

Now ask students to write down ideas about what conditions are required for natural selection and what outcomes result from natural selection in the DISCOVERIES AND INSIGHTS section of the activity sheet. Then have students talk with a partner and select one idea they discovered today related to either question (about conditions or outcomes). Have students write this idea on a large piece of paper or a large post it note in dark pen/marker. Have one student from each pair of students bring their papers/post-its to the front of the room and stick them up on the board.

With the papers/post-its displayed for the class to look at together, lead a consensus building discussion. Facilitate the movement and reorganization/clustering of the ideas students brought up, under the headings listed below. This consensus building discussion and reorganization of the student descriptions of their discoveries will help students condense and summarize the big ideas from the day's lesson. If an idea that students suggest doesn't fit under these areas, don't leave it out. Rather, emphasize that the idea shared is another interesting discovery and that the main ideas that the students are responsible for knowing and reusing in future explorations are the ones organized under the areas listed. Try to write the categories in the student's own words, and using their own papers if possible. You may want to consider posting these big ideas in class, having students summarize these ideas now (or later) in their notes. Either way, try to use the students own words and the way the class expresses the ideas listed below, without feeling it is necessary to use this exact wording. Example of possible student responses they might contribute on their sheet or post it note are shown in italics. Ask students whether they agree or disagree with how the ideas or organized and whether this summary helps pull out the main points they discovered.

The underlined statement is the suggested category. The non-bold italics statements are possible student ideas. The bold italics statement can serve as another way to summarize what is common amongst the student ideas and each underlined category.

Conclusions & Big Ideas: "How Does Nature Select For Some Trait Variations Over Others?" - Answer: by Natural Selection

It occurs when these <u>conditions or mechanisms</u> exist:

- **There is variation in heritable traits.** *(in every species such variation exists).*
- **Some variations give a competitive advantage for survival**
- **The individuals with variations that do not grant a survival advantage die more frequently due to interactions with the ecosystem.** *The interactions between the environment and the population unintentionally select individuals with a variation(s) of the trait that gives a competitive disadvantage for survival to die more often or more quickly than the other individuals.*
- **The surviving individuals reproduce.** *As a result the surviving individuals are more likely to reproduce (either asexually or sexually), and create more offspring.*

These are some outcomes of natural selection:

- **The proportion of individuals that that have advantageous characteristics will increase;** *the proportion of corresponding genetic information also increases in the gene pool of the population.*
- **Natural selection leads to organisms that are well-suited for survival in particular environments. 5F/H6a**
- **But when an environment, including other organisms that inhabit it change, the survival value of inherited characteristics may change.** *(e.g. in one environment when you were a predator chasing bugs, faster bugs had a competitive advantage for survival, and for a different environment when you waited for bugs to come to you, slower bugs had a competitive) advantage for survival)*

- ***Now consolidate these ideas into these principles and leave these next to the driving question board***

New Scientific Principles

- **Natural selection tends to increase the proportion of individuals that have advantageous traits for a particular environment when there is some variation in the heritable traits within a population and when some of those traits give individuals a competitive advantage over others for surviving and reproducing.**

Homework: *Assign the homework for this lesson. It is strongly encouraged that you read the jumpstart for the homework with the students to motivate the purpose of the reading.*

Lesson 9: How Do Random Selection Events Alone Change Gene Pools?

Overview:

Purpose:

The purpose of this activity is to describe how random fluctuations in gene frequency in a population are the result of the random sorting and recombination of genes in sexual reproduction (through meiosis and fertilization) and to explain why this drift in gene frequency can result in the loss of alleles from a gene pool.

Connection to previous activities:

Students have identified random events and processes that can affect which individuals might survive or reproduce in a population. They should understand that random selection occurs when sex cells are made by splitting up chromosomes from a parent cell for every potential offspring. They have explored how genetic drift occurs in a population of asexually reproducing bugs. They should understand why this results in a reduction in diversity of genes in a gene pool and a reduction in diversity of observable trait variations in a population.

Prerequisite Knowledge:

Students should have already developed a simple Mendelian model that explains genotype and phenotype of single gene traits to account for the patterns of inheritance before they encounter in this activity. Development of this model is not part of the BEAGLE unit. Review and application of these ideas, however is embedded in the previous Bird Breeders activity. Students need to already know that:

- Organisms have traits that are primarily inherited. Some of these traits have two variations, others have multiple variations.
- Many inherited traits are determined by a single gene, each gene has two pieces of genetic information that can come in two different forms (alleles). An individual can possess two identical alleles, or two different alleles, one on each chromosome of a chromosome pair.
- Through meiosis each parent passes on one of their alleles for every gene to an offspring; for each offspring there is a 50/50 chance as to which allele they will receive from each parent.
- Two parents that sexually reproduce can generate new combinations of trait variations in their offspring, through the recombination of genetic information passed on from each parent.
- When there are two different alleles for a single trait, sometimes one allele masks the presence of the other allele. These alleles are said to assert a dominant expression over the other allele, so that the phenotype (or observable characteristics related to the trait) of the organism appears to be that of the dominant allele.

Development of Ideas:

New Scientific Principles

- **The mechanisms of sexual reproduction can result in some alleles being passed on more frequently than others to each new generation (genetic drift);**
- **Because of genetic drift chance alone can result in the disappearance alleles from a gene pool over time.**

Description

Students experiment with fish reproduction in fish tank, noting changes in allele frequency in sex cells and body cells and the resulting trait variations due to results of meiosis and fertilization events. At the end of class, the teacher develops a class consensus on the big ideas for how genetic drift is due to fundamentally random processes and that it can result in the persistence of some traits and the elimination of other traits in a population over time that have no survival or reproductive advantage for the organism.

In homework and students apply these understandings to describe why population fragmentation from geographic barriers in combination with the mechanism of genetic drift could lead to to separate populations with very different gene pools and traits in their descendants.

Learning Performances

- Explain why a population may show only one trait variation in a given generation, yet have two alleles for the variations of that trait in its gene pool.
- Describe how alleles change in frequency in a gene pool through sexual reproduction.
- Explain why it is likely that one of two alleles for a trait will often be lost from a gene pool in a small population that reproduce for many generations at about the same carrying capacity.
- Explain how geographic barriers would contribute to offspring populations that look very different from one another, each less diverse than their ancestor population.

Related Benchmarks

- Chance alone can result in the persistence of some heritable characteristics having no survival or reproductive advantage or disadvantage for the organism. 5F/H6b

Time: 1 period

Materials

Per Student

- 1 computer per student with NetLogo installed on each along with a copy of the Fish Tank Genetic Drift.nlogo model file.

For Teacher

- 1 computer and projector or large display screen for the teacher to demonstrate the model and a projector or the computer to display the overhead transparency.
- Transparency 9.1

Instruction:

Launch:

Ask students to name some traits that are primarily inherited in humans. Ask for examples in birds and dogs and plants as well.

Remind students that some traits have two variations and other have multiple variations. Remind students that populations that sexually reproduce can generate new combinations of trait variations in their offspring, through the recombination of genetic information passed on from each parent.   Ask student to identify how this can occur.

Students should recall that:

- There traits are determined by a single piece of genetic information (a gene), each gene has two pieces of genetic information that can come in different forms (alleles). An individual can possess two copies of genetic information either as identical alleles or as two different alleles, one on each chromosome of a chromosome pair.
- Each parent passes on one of their alleles for every gene to an offspring; for each offspring there is a 50/50 chance as to which allele they will receive from each parent, since chromosomes are independent sorted when sex cells are crated through meiosis.

Also remind students that alleles are small sections of genetic information on a chromosome. This section of genetic information is like a catalyst or enzyme that helps cells produce a new substance that contributes to the new trait. Recessive alleles are often genetic information that give no instructions about creating a new substance for a trait. Dominant alleles are genetic information that instructs cells to create a new substance for a trait. They discovered in the past when there are two different alleles for a single trait, sometimes one allele masks the presence of the other allele, since if one set of instructions says nothing about creating a substance for a trait, and another set of instructions says to create a new substance for a trait, the net result will still to be to create the substance for the trait. These alleles are said to assert a dominant expression over the other allele, so that the phenotype (or observable characteristics related to the trait) of the organism appears to be that of the single allele, which is the set of instructions for creating a substance. Give an example of genotypes vs. phenotypes for Mendelian genetics if needed.

Show students Transparency 9.1. Identify that the the picture shows a nucleus, and the 46 chromosomes found in the nucleus of humans. The chromosomes have been color coded to match up with another chromosome that is the same length. In this way we can see on the bottom left that there are clearly 23 pairs of chromosome.

Ask students where an individual gets one of the chromosomes in pair 1 from? The other chromosome? Where do they get one of the chromosomes in pair 2 from? The other chromosome?

Reintroduce the idea of a **gene pool.** Remind students that they explored the idea of a gene pool in the selective breeding activity with the birds. Ask students to describe how the gene pool of the ending population was different than the gene pool of the initial population. And ask why every additional offspring that is born has an affect on the gene pool of the population.

For students who may not have done the selective breeding activity with the birds or as a review, you can (re)introduce the idea of gene pool with a short example related to sex chromosomes. Tell these students that a gene pool is all the chromosomes and their related alleles in a population. Provide an example of a family of a mom and dad and two children related to X and Y chromosomes. Draw the genotype for each member of a family that has two daughters (mom – XX, dad – XY, daughter 1 – XX, daughter 2 – XX), and ask the students which there is more alleles of in this gene pool X's or Y's? Then ask students to compare this family's gene pool to a 2nd family's gene pool. In the second family, there is a mom and dad and two sons. In this family, asj how would the proportion of X chromosomes in their gene pool compare to the first family? *It would be lower (5 of the 8 chromosomes are now X instead of 7 out of 8)*. Ask how would the proportion of Y chromosomes in their gene pool compare to the first family? *It would be higher (3 of the 8 chromosomes are now Y instead of 1 out of 8)*.

Summarize by pointing out that he proportion of alleles in the gene pool of one family might be very different than the proportion of alleles in another family and the same is true for different populations. For example, one population may have more dominant alleles in their gene pool than recessive, while another population might have only recessive alleles for a given trait in their gene pool.

Tell student that they will study how gene pools change over time by working with a model of a fish. In this model they will keep track of alleles for only 5 genes, and use only 5 pairs of chromosomes in the simulated body cells of these creatures to keep track of what alleles are in the gene pool of the population. Remind students that even though they are only keeping track of 5 pairs of chromosomes in the model, many species of organisms in the real world have many more pairs of chromosomes.

Opening the fourth model:

- Open NetLogo on your computer
- In the NetLogo window, open the Model Library from the File Menu
- Under File > Models Library, choose the Curricular Models/BEAGLE evolution folder and open it. In the folder click on the "Fish Tank Genetic Drift" model and open it.

Demonstrating the Model:

- Set the initial values to:

Setting	Value
TANK-CARRYING-CAPACITY	20
INITIAL-FEMALES	50%
INITIAL-ALLELES-BIG-B	50%
INITIAL-ALLELES-BIG-G	50%
INITIAL-ALLELES-BIG-F	50%
INITIAL-ALLELES-BIG-T	50%
AUTO-REPLACE?	"On"
SEE-BODY-CELLS?	"Off"
SEE-SEX-CELLS?	"Off"

- Press the SETUP button. Point out that the students should see 20 fish that have a variety of different trait variations.
- Direct student attention over to sliders for INITIAL-ALLELES. Tell students that they will explore how these alleles affect the genotypes of the fish and how this then affects the phenotypes of the fish.
- Press GO/STOP. Students should see these fish move about the screen.
- Tell students that they will be able to see a karyotype of each individual fish by turning SEE-BODY-CELLS? "on". Turn this on to show this.

- Tell students that they will also be able to see the karyotype of each sex cell produced by each parent. Turn the SEE-SEX-CELLS? "on". Tell students you are going to remove a fish now by clicking on it. When you do so, explain that another offspring was created from two randomly selected fish (a mom and dad) to replace the one you removed. Do this a few times, directing student attention to the sex cells moving from one parent (the male) to the other parent (the female). The male sex cell karotype has a blue triangle and the female sex cell karyotype has a pink triangle).

- Then turn the visualization of the fish off, since having too much on the screen at once may make it hard to see what is there. Turn the SEE-FISH? "off". You may wish to pause the model by pressing GO/STOP as sex cells are traveling from one fish to another.

Explore:

Instruct students to begin their explorations of the model by reading the directions and answering the questions on their activity sheets.

Summarize:

Ask students what we discovered today that helps us both the lesson question and the unit question. Have students write their ideas down in the DISCOVERIES AND INSIGHTS section of the activity sheet. Then have students talk with a partner and select one idea they discovered today related to "How Do Random Events Change the Frequency of Alleles in a Population?" Have students write this idea on a large piece of paper or a large post it note in dark pen/marker. Have one student from each pair of students bring their papers/post-its to the front of the room and stick them up on the board.

With the papers/post-its displayed for the class to look at together, lead a consensus building discussion. Facilitate the movement and reorganization/clustering of the ideas students brought up, under the headings listed below. This consensus building discussion and reorganization of the student descriptions of their discoveries will help students condense and summarize the big ideas from the day's lesson. If an idea that students suggest doesn't fit under these areas, don't leave it out. Rather, emphasize that the idea shared is another interesting discovery and that the main ideas that the students are responsible for knowing and reusing in future explorations are the ones organized under the areas listed. Try to write the categories in the student's own words, and using their own papers if possible. You may want to consider posting these big ideas in class, having students summarize these ideas now (or later) in their notes. Either way, try to use the students own words and the way the class expresses the ideas listed below, without feeling it is necessary to use this exact wording. Example of possible student responses they might contribute on their sheet or post it note are shown in italics. Ask students whether they agree or disagree with how the ideas or organized and whether this summary helps pull out the main points they discovered.

The underlined statement is the suggested category. The non-bold italics statements are possible student ideas. The bold italics statement can serve as another way to summarize what is common amongst the student ideas and each underlined category.

Once all the consensus building discussion is complete post the scientific principles below on the driving question board (and/or have students keep track of these in their notebooks).

Conclusions & Big Ideas:

As a class: : How do Random Selection Events Change Gene Pools?

- Randomness in sexual reproduction
  - *Example student idea: Some creatures just mate with whoever*
  - *Example student idea: You might run into one mate instead of another.*
  - *Example student idea: Which egg / sperm fertilize each other is kind of random*
  - ***Summarize with this previous idea from activity 7 (Bird Breeders model) and extend it: (Old idea) The random sorting and recombination of genes in sexual reproduction (through meiosis and fertilization) results in a variety of possible gene combinations in the offspring of any two parents. (New part) Some other aspects of mating also may include additional random events (such as which mate you meet first).***

- Randomness in death
  - *Example student idea: Sometimes things just die for no apparent reason.*
  - *Example student idea: You can't always predict which individual will die first.*
  - *Example student idea: Not all death is due to competitive disadvantages.*
  - *Example student idea: Some deaths may be due to random variation in the distribution of resources, so unintentional competition emerges, leading to death of some.*
  - ***Summarize with this previous ideas from activity 3 (Bug Hunt Consumers model) and extend it: (Old idea) some individuals will be more successful than others at consuming/using limited resources in an ecosystem, simply because the distribution of resources around each individual vary. (New part) ...so some deaths can be said to be due to random events.***

- Change in allele frequencies that result
  - *Example student idea: Sometimes one allele becomes more frequent than another.*
  - *Example student idea: Allele percentages go up and down in the population.*
  - *Example student idea: If an allele disappears it is gone from the gene pool.*
  - ***Summarize with this idea: This random sorting and recombination of genes can result in some alleles being passed on more frequently than other alleles in each new generation. This result in fluctuations in allele frequencies in a gene pool over time is called genetic drift.***
  - ***Summarize with this idea: Because of genetic drift, chance alone can results in the disappearance alleles from a gene pool resulting in a reduction of diversity of traits in the population over time.***

Now consolidate these ideas into these principles and leave these next to the driving question board

New Scientific Principles

- **The mechanisms of sexual reproduction can result in some alleles being passed on more frequently than others to each new generation (genetic drift);**
- **Because of genetic drift chance alone can result in the disappearance alleles from a gene pool over time.**

Homework: *Assign the homework for this lesson. It is strongly encouraged that you read the jumpstart for the homework with the students to motivate the purpose of the reading.*

Lesson 10: How do population sizes and barriers affect genetic drift?

Overview:

Purpose:

The purpose of this activity is to 1) describe the relationship between population size and the rate of gene loss from a gene pool and 2) explain why barriers that cause reproductive isolation of a genetically diverse ancestor population would likely lead to offspring populations that have different gene pools from on another. .

Connection to previous activities:

Students should understand the genetic drift is primarily the result of random sorting and recombination of genes can result in some alleles being passed on more frequently than other alleles in each new generation through meiosis and fertilization.. This result in fluctuations in allele frequencies in a gene pool over time is called genetic drift. Because of genetic drift, chance alone can results in the disappearance alleles from a gene pool resulting in a reduction of diversity of traits in the population over time.

Development of Ideas:

- **New Scientific Principles**
  - **Genetic drift typically causes smaller populations to lose diversity from their gene pools more quickly than larger populations.**

Description

Students continue their work with the Fish Tank genetic drift model. They discover that the specific types of alleles that are lost from genetic drift are not predictable, they find that smaller populations and small gene pools lose alleles more quickly due to genetic drift than larger populations and larger gene pools, and the discover that barriers between sections of a population effectively reduce large populations into smaller ones, leading to quicker loss of alleles in these populations and to fragmentation of the gene pool in each, so that each sub-population often appears different from one another. At the end of class, the teacher develops a class consensus on the big ideas for genetic drift related to barriers and reproductive isolation.

In their homework students learn about how population bottlenecks and founder effects are related to the outcomes of genetic drift.

Learning Performances

- Explain why genetic drift always will tend to result in more similar individuals over time in a populations even though the specific similarity is difficult to predict.
- Compare the rate of genetic drift in different population sizes.
- Predict and test how barriers contribute to the effects of genetic drift and lead to the fragmentation of gene pools.
- Describe the causes and outcomes of the founder effect.
- Identify some environmental interactions that might lead to a population bottleneck.

Related Benchmarks

- Chance alone can result in the persistence of some heritable characteristics having no survival or

reproductive advantage or disadvantage for the organism. 5F/H6b
- Small differences between parents and offspring can accumulate ....- in successive generations so that descendants are very different from their ancestors. 5F/M1

Time: 1 periods

Materials

Per Student
- 1 computer per student with NetLogo installed on each along with a copy of the Fish Tank Genetic Drift.nlogo model file.

For Teacher
- Transparencies or poster paper to record conclusions and big ideas.

Instruction:

Launch:
Remind students that they learned in the previous activity that genetic drift is result of random selection mechanisms at work in sexual reproduction or random selection mechanisms at work in which organisms in a population survives. Tell students that any random selection mechanism that influences survival or reproduction can result in genetic drift.

Tell them that the goal of the lesson today is to understand some how population size and gene pool diversity are effected by genetic drift due to any type of random event that contributes to the selection of who survives or reproduces.

Explore:
Instruct students to begin the explorations on their activity sheets.

Summarize:
Ask students what we discovered today that helps us both the lesson question and the unit question. Have students write their ideas down in the DISCOVERIES AND INSIGHTS section of the activity sheet. Then have students talk with a partner and select one idea they discovered today related to the lesson question. Have students write this idea on a large piece of paper or a large post it note in dark pen/marker. Have one student from each pair of students bring their papers/post-its to the front of the room and stick them up on the board.

With the papers/post-its displayed for the class to look at together, lead a consensus building discussion. Facilitate the movement and reorganization/clustering of the ideas students brought up, under the headings listed below. This consensus building discussion and reorganization of the student descriptions of their discoveries will help students condense and summarize the big ideas from the day's lesson. If an idea that students suggest doesn't fit under these areas, don't leave it out. Rather, emphasize that the idea shared is another interesting discovery and that the main ideas that the students are responsible for knowing and reusing in future explorations are the ones organized under the areas listed. Try to write the categories in the student's own words, and using their own papers if possible. You may want to consider posting these big ideas in class, having students summarize these ideas now (or later) in their notes. Either way, try to use the students own words and the way the class expresses the ideas listed below, without feeling it is necessary to use this exact wording. Example of possible student responses they might contribute on their sheet or post it note are shown in italics. Ask students whether they agree or disagree with how the ideas or organized and whether this summary helps pull out the main points they discovered.

The underlined statement is the suggested category. The non-bold italics statements are possible student ideas. The bold italics statement can serve as another way to summarize what is common amongst the student ideas and each underlined category.

Once all the consensus building discussion is complete post the scientific principles below on the driving question board (and/or have students keep track of these in their notebooks).

- **Conclusions & Big Ideas:**
- **As a class: :** How do population size and barriers affect genetic drift?
- Population size affects genetic drift
    - *Example student idea: The larger the population size the longer it takes to lose a type of allele from the gene pool.*
    - *Example student idea: When you have less alleles in the gene pool to start with, its easier to lose some types of them quicker. Some creatures just mate with whoever*
    - *Example student idea: The odds of losing an allele go up the smaller the population is.*
    - ***Summarize with this idea: Genetic drift typically causes smaller populations lose diversity from their gene pool more quickly than larger populations.***
- Barriers that break populations into isolated sections affects genetic drift
    - *Example student idea: Barriers make populations smaller and make them each have smaller gene pools*
    - *Example student idea: Barriers speed up genetic drift.*
    - *Example student idea: Barriers prevent reproduction happening between the isolated sections of the population.*
    - ***Summarize with this idea: When offspring of a population become isolated from one another their descendants may appear very different from one another and from their ancestor population after experiencing the effects of genetic drift.***
- Outcomes
    - *Example student idea: You don't know which allele or trait will be lost due to genetic drift..*
    - *Example student idea: You know you are going to lose alleles, but you can't tell which ones ahead of time.*
    - ***Summarize with this old idea from the previous activity: Some traits that organisms have in the real world may not be the result of natural selection nor due to a competitive advantage from that trait. Rather, they may simply be the result of the "luck of the draw" from the effects of genetic drift.***
- ***Now consolidate these ideas into these principles and leave these next to the driving question board***
- **New Scientific Principles**
    - **Genetic drift typically causes smaller populations to lose diversity from their gene pools more quickly than larger populations.**

Homework: Assign the homework for this lesson. It is strongly encouraged that you read the jumpstart for the homework with the students to motivate the purpose of the reading.

Assessment Opportunity:

Write a scientific explanation (including a claim, evidence from the lab activities, and scientific principles we agreed upon) to answer this lesson set question: "Why do some trait variations sometimes become more common?"

Scientific Explanation Rubric

<table>
<tr><th colspan="2" rowspan="2">Component</th><th colspan="3">Level</th></tr>
<tr><th>0</th><th>1</th><th>2</th></tr>
<tr><td colspan="2">(C) Claim
A conclusion that answers the original question.</td><td>No claim</td><td>A vague or inaccurate claim</td><td>An accurate and and specific claim</td></tr>
<tr><td colspan="2">(E) Evidence
Data/observations that are provided to support the claim.</td><td>No data provided</td><td>Some of the needed data is provided</td><td>All necessary data is provided.</td></tr>
<tr><td rowspan="2">Reasoning

It explains why the data counts as evidence for this claim.</td><td>(PM) Principles & Models
The principles or models related to the data and the claim.</td><td>None are included</td><td>Some are included</td><td>All are included</td></tr>
<tr><td>(L) Links
Interpretation of what the data means and connections between the data, the principles/models, and the claim.</td><td>Unconnected</td><td>Partially connected</td><td>Fully connected</td></tr>
</table>