# Lesson 14: What outcomes will result from both mutations and natural selection?

## Overview:

### Purpose:
The purpose of this activity is to discover how the combination of mutations, natural selection, and environmental change lead to adaptation.

### Connection to previous activities:
In previous activities students have explored the mechanisms and natural selection. In this model both mechanisms work together to generate adaptation in a population of bugs that becomes progressively better camouflaged over time and how that adaptation changes as environmental conditions change.

### Development of Ideas:

**New Scientific Principles**

- ***The longer a population accumulates mutations and interacts with and survives within a changed environment, the more it will tend to adapt to that environment.***

### Description
Students compete as a team in a bug hunt competition generating a simulated form of natural selection with an outcome being that a population of bugs becomes progressively better camouflaged over time. They see how mutation is modeled in the simulation, and investigate the outcome that results when the environmental conditions change in two independent computer explorations on their own. They compare their outcomes with a partner, and identify the aspects of the outcomes that are similar (progressively better adapted populations), and those that are different (variation and fluctuation in the individual traits in the population). And they identify how mutation and environmental condition changes contribute to both of these.

### Learning Performances
- Explain why different environmental changes and different mutations would result in the emergence of different outcomes from natural selection.
- Describe how the mechanism of mutation (which adds new variations to the population) in combination with natural selection leads to populations that have traits and variations progressively better adapted to a given environment over many generations.
- Explain why adaptations to one environment might be disadvantageous in other environments or if the environment changes.
- Describe why individual response to environmental conditions does not change genetic information in individuals and how natural selection and evolution emerge only from traits that are genetically inherited not through those acquired in a lifetime.

### Related Benchmarks
- 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 Hunters Camoflauge.nlogo model file on it.

For Teacher

- 1 computer and projector or large display screen for the teacher to demonstrate the models.
- Transparency projector
- Transparency 14.1

# Instruction:

## *Launch:*

Remind students that they have studied two ways that offspring might get different genetic information. One of these is recombination of chromosomes in sexual reproduction. The other is in mutation of genetic information in the sex cells from either parent.

Ask students describe what happens in the 3 major types of mutations (duplication, deletion, and insertion)
**Duplication** – *This is where the allele or gene that was already there was copied more times then necessary (e.g. a doubling of the number of genes for a trait).*
**Deletion** – *This is where the some or all of the alleles or genes that were there were deleted.*
**Insertion** – *This is where a new allele or gene is inserted into a chromosome between existing genes. If an existing gene or allele is altered, it can be thought of as a deletion and insertion mutation (since the old genetic information is no longer there).*

Ask students to imagine some possible outcomes of mutations for the following cases:

If they had a tall plant, that is purebred, and it consistently produces tall offspring, even when pollinated with a short plant (since tall is a dominant trait). But the tall plant undergoes a deletion mutation in the cells of its pollen. That pollen now has lost the genetic code for expressing the tall trait. What do you predict the height of the offspring of this plant will be when it is pollinated with a short plant? Probably short, since it now has no source of genetic instructions for creating the substance that would make it tall.

Ask students to give an example of a trait, which is critical to the survival of the organism. It should be a trait, whose genes, if they were deleted, would result in the death of the offspring that inherited it. *Answers may vary.*

Follow up by asking why would this missing gene be so critical to the ability of the organism to survive

Ask students for an example of a trait, that if the genes were **deleted** in it, probably would NOT result in the death of the individual offspring that inherited it? *Answers may vary.*
Ask students for an example of a trait, that if the genes were **duplicated i**n it, probably would NOT result in the death of the offspring that inherited it? *Answers may vary.*

Follow up by asking why would this missing or duplicated genes would not be critical to the ability of the organism to survive.

Tell students that in this activity they will be exploring the effects of first two forms of mutation: duplication and deletion and the role of this mutation can play in contributing to the effects of natural selection. And they will be exploring the effects of different environments on the outcomes of natural selection.

## *Explore:*

Next, introduce the Student Activity Sheet. Read the purpose and procedure of the activity with students.

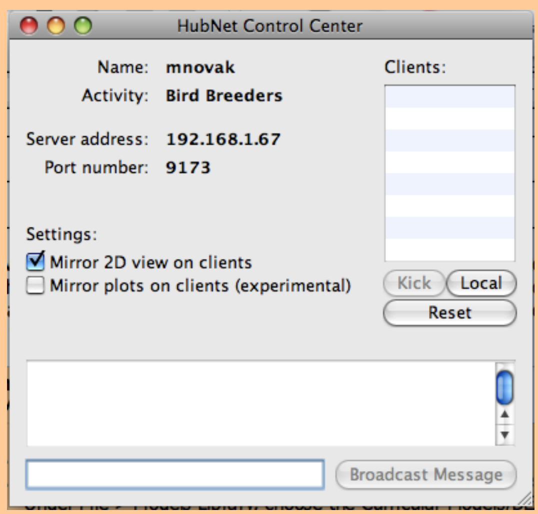
Then demonstrate the mechanisms of mutation included in the model, by projecting a display of the computer model. You will be helping students understand the mutation mechanism and how color variation in the bugs the outcome of 3 separate pieces of genetic information. Students will be recording some of what you are demonstrating on their paper before launching the model themselves.

**Opening the seventh model:**

- Open NetLogo on your computer
- *Find the BEAGLE pilot models folder on your computer. Double click on the "Bug Hunters Camouflage" model and open it.*

**Teacher Demo Directions:**

- A Start HubNet Activity box will appear.
- Enter your name in the session name and click the Broadcast server location check box. Say what you are doing out loud at each step to the students, as the team leader will need to launch the activity in a similar manner.
- A HubNet Control Center box will appear:



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

- *Join the simulation yourself by pressing the LOCAL button. A client interface will be launched for you to join the simulation as player 4.*

- *Tell students this is where again you would wait for your group members to join in now and that they will be assigned a larger team of 6 players today.*

- Adjust the CARRYING-CAPACITY slider to 2.

- Press SETUP.

- Press GO/STOP.

- Press the CLEAR ENVIRONMENT button to delete the photo of the glacier from the background. Tell students this will help them see the bugs that you are starting with easier.

- Adjust the MAX-MUTATION-STEP slider to "0". Tell students that this means that every bug that is produced is an exact duplicate of a parent bug.

- Eat just one of the bugs by using your mouse to point at them and click on them using the mouse button. *When you point and click on a bug it should disappear.*

  *Point out to students that they should see a new bug appear. It will be small at first, and then it will grow to be the size of the other bug. This bug is an offspring of the bug that is on the screen. Tell them that the bug was chosen to have an offspring was randomly chosen. Tell them the offspring will show up close to its parent bug, but not directly on top of it. Where it shows up represents where the parent bug laid an egg with this offspring in it. Tell them this is randomly chosen based on the OFFSPRING-DISTANCE slider. Here again the population is reproducing asexually, similar to how it did in the genetic drift model.*

- Repeat the previous step a few times, noting that the color of the new bug each time is identical to its parent

- Now turn the SHOW-GENOTYPE switch to "on".

  *Point out to students that they should see that there are two bugs, each with a label that is a series of 3 numbers, separated by dashes next to each them, that look like a locker combination (for example: 23-45-20). Tell them these numbers represent three genes.*

- Eat one the bugs.

- Repeat this previous step a few times, noting the numbers next to the bug each time. Students *should notice that each time you eat a bug, the new offspring bug is an exact duplicate in color and number of its parent.*

- Now adjust the MAX-MUTATION-STEP slider to "10".

- Eat one of the bugs.

- Repeat this step a few times, noting the color of the bug and numbers next to the bug each time.

*Tell students that they should notice that the offspring now has a color that is very close to the shade and color of its parent, but its has a set of numbers that are close to but no longer exactly the same as the numbers of its parent. Tell them that the first gene represents the % of red pigment that is produced by the protein that is built, the second gene represents the % of green pigment that is produced by a second protein that is built, and the third gene represents % of blue pigment that is produced by a third protein that is built.*

- Adjust the MAX-MUTATION-STEP slider to "50".
- Eat just one of the bugs.
- Repeat this step a few times, noting the color of the bug and numbers next to the bug each time.

*Tell students they should notice that the offspring now has a color that is more different in the shade and color of its parent, and has a set of numbers that are further away from the numbers of its parent.*

Explain to students that since the numbers represent three different proteins produced that all contribute to color pigmentation, there are many possible phenotypes that could result from a blended outcome from the genotype. If needed, you could put an example table of some of the color genes combinations and the phenotype that will result

| **Red-Green-Blue gene frequency** | **Observable color of the bug (Phenotype)** |
|---|---|
| **0-0-0** | **Black colored** |
| **30-30-30** | **Dark Gray** |
| **100-0-0** | **Red** |
| **50-0-0** | **Darker red** |
| **0-0-100** | **Blue** |

Ask if they have any questions about how to visualize the relationship between the genotype of the bugs (the protein production levels related to 3 genes and the resulting phenotype (the color of the bugs).

Tell students they are now going to explore the model you demonstrated using both a team based version of the model and after that they are going to use a single player version of the model.

Have students work in teams of 4 at first, with one student assigned the role of team leader and start the explorations in their activity sheets.

## ***Summarize:***

Ask students to share their answers for the multiple choice questions, explaining why the incorrect choices are not correct, if there is disagreement on the answer choices

**With a partner:** Which of the following best explains the mechanisms responsible for the causing the change in the colors of the bug population?

- Each bug chooses a form of camouflage to help them survive. The bugs choose best, then that survive to pas that choice on to their offspring. Which helps their offspring know what the environment around them looks like. These bugs have a competitive advantage in that environment. *The bugs aren't changing their genotype. No choices that individuals organisms make change their genes in the natural world, they only change the organism characteristics for that lifetime (for example there are chameleons and lizards that change their colors in response to their surrounding, rabbits that change their fur in response to the season, trees, change their colors in response to fall, etc... but these are changes to the individual organism, not to the genes that the organism will pass on to its offspring).*

- Birds unintentionally eat the easiest bug to find more often than hard to find bugs. Random mutations in the color of the bugs leads to slight variations in the offspring, some of which are harder to find and some of which are easier to find. As birds leave behind bugs that are more difficult to find, each new generation becomes progressively better camouflaged. *Correct answer.*

- Birds choose which bugs they want to survive. Each new bug that is born with mutations in its genotype. These mutations give more choices for the birds gives the birds. Since the bird prefers to leave behind the hard to find bugs to find bugs, it intentionally selects for camouflaged bugs in this environment.
- Every bug is programmed to adapt and evolve in its genotype. Each bug can develop any color necessary survival in any environment. Once a bug recognizes the environment it is in, it changes the genetic information in all of it cells to create a new protein that will lead to a trait variation to better help its offspring survive. *This sounds like it could be possible. The computer program itself could be designed so that the computer program wrote code so that the program read in the red-green-blue values of the background image, and then slowly changed the bugs to match those values. One way to convince yourself that the model is not preprogramed to evolve is either 1) start randomly clicking on bugs (anywhere on the scree) with your eyes closed to see that the bugs will not become better adapted or better camouflaged and so that result must be an outcome that you unintentionally generated. For students who want to investigate the model mechanisms further, suggest that they study the INFORMATION tab on the computer model, and start experimenting with changing the code in the PROCEDURE tab of the model to see how the model works.*

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 each 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.

**Conclusions & Big Ideas:** "What outcomes result from the combination of mutations, natural selection, and environmental change ?"

- Adaptation
    - *Example student idea: The bugs became camouflaged*
    - *Example student idea: The colors changed to look more like the environment*
    - *Example student idea: Bugs became harder to find the more you hunted them.*
    - *Example student idea: New colors appeared that weren't there at the start.*
    - *Example student idea: The bugs look very different than they did at the start.*

  ***Summarize with these ideas:***
    - ***Populations adapt to survive. Adaptation does not refer to how individuals respond to their environment, nor is it the result of individuals trying to intentionally "change their characteristics" to pass on to their offspring.*** *(While individuals adjust and respond to their surroundings (many organisms learn from their experiences, all organisms react to and respond to environmental stimuli), such adjustments are not considered adaptations, because such adjustment and responses to the environment does not change the genetic information to pass on to offspring, which is a critical outcomes that must occur if adaptations are to be passed on to future offspring in a population).*
    - **Adaptations to one environment give a population a competitive advantage for that environment, but may give it a competitive disadvantage for other environments Once the environment changes, adaptations that were advantageous before may no longer be.**

How do mutation, natural selection, and environmental change work together to contribute to this outcome?

- Mutation
    - *Example student idea: Mutations change what was there before to become slightly different*
    - *Example student idea: Mutations are random*
    - *Example student idea: Mutations occur in the genetic information.*

    ***Summarize with this ideas: Mutations are random changes to existing genetic information that leads to new genetic information that leads to new traits in offspring.***
- Environmental Change
    - *Example student idea: When the environment changes, what trait is good changes*
    - *Example student idea: Different colors are better for different places*
    - *Example student idea: You can blend in better if you are the color of the background*

    ***Summarize with this ideas: Changes to the environmental conditions change which trait variations give a competitive advantage.***
- Natural Selection
    - *Example student idea: Predators kill off the bugs that they can see*
    - *Example student idea: Some types of traits aren't good to have and get removed*
    - *Example student idea: The bugs that blend in have more offspring more often than dead bugs*
    - ***Summarize with this: Natural selection remove individuals with a competitive disadvantage and let the ones with more of a competitive advantage have more offspring.***

**New Scientific Principles**

- ***The longer a population accumulates mutations and interacts with and survives within a changed environment, the more it will tend to adapt to that environment.***

Tell students that they investigated two mechanisms of evolution today – natural selection and mutation, to see how a new outcome, adaptation emerged in a population as the environment change. They saw how this outcome emerged in three different environments today in class. Tell them if they'd like to participate in the model again, with the chance to see what adaptations might emerge in other environments as well, they can try a web based version of the model online.

This is the url: http://ccl.northwestern.edu/simevolution/obonu/obonu_bughunt_howtoplay.shtml
Tell them the web address is in their homework tonight and it is optional if they visit it, but that it can be a fun game to invite family and friends to participate in, and that anyone from anywhere around the world can join in to compete against you just like you did in class today. The web based version doesn't require NetLogo, it just requires a web browser. On the web based version you can also see a record of who won the title of top predator for the day, for the month, and for the year for each environment

***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 15: How Do Mates Influence Adaptation?

## Overview:

### Purpose:
The purpose of this activity is to revisit the mechanism of natural selection focusing on why the outcomes that result from sexual selection might be very different and sometime opposite of those resulting from natural selection from predators. Student explore how two interacting mechanisms of evolution lead to this outcome 1) populations become progressively better adapted to reproduce more readily in the environment over many generations 2) there can be variation in the specific outcome of trait variations that result from this process. The purpose of this activity is to recognize there are potential tradeoffs between adaptation for survival and adaptation for reproduction and to recognize that populations adapt to balance the pressures from both forms of selection, which vary depending on the environment.

### Connection to previous activities:
In previous activities students have explored the mechanism and outcomes of natural selection. The two previous models of natural selection relied on interactions with predators and the environment. In this model, students contrast the outcomes of natural selection from predation vs. those from sexual selection (a form of natural selection they have not studied yet). They have investigated how mutation is modeled in the BugHunt Camouflage simulation. The explorations in this activity use a similar model and set of modeling assumptions.

### Development of Ideas In this Learning Set:

**New Scientific Principles**

*IIndividuals of the same sex compete against each other for mates; this generates a form of natural selection (sexual selection) for heritable variations of traits that grant a competitive advantage for reproducing.*

### Description
Students compete as a team in a bug hunt competition generating two simulated forms of natural selection (one from predation and one from sexual selection), with outcome varying based on the environmental conditions: bugs become progressively better camouflaged over time in environments dominated by predators, bugs become progressively progressively less garish over time in environments without predators (but with mates). Students investigate the tradeoffs in adaptation when multiple selective forces are at work, so that sometimes adaptation through natural selection does not generate a single nor stable state in trait variation (when predation selection and sexual selection are balanced). And students recognize that tradeoffs can apply to trait variations that become too extreme. They compare their outcomes with a partner, and identify the aspects of the outcomes that are similar and those that are different and they identify how mutation and environmental conditions changes contribute to both of these.

### Learning Performances
- Explain why different environmental changes and different mutations would result in the emergence of different outcomes from natural selection.
- Describe how the mechanism of mutation (which adds new variations to the population) in combination with natural selection leads to populations that have traits and variations progressively better adapted to a given environment over many generations.

- Describe how sexual selection is similar to other forms of natural selection and how its selective pressures might counterbalance other selective pressures in the ecosystem.
- Describe how variations that grant competitive advantage either for survival or reproduction, but not for both, is an overall competitive disadvantage for contributing the gene pool of future generations.

## Related Benchmarks

- When an environment, including other organisms that inhabit it changes, the survival value of inherited characteristics may change. 5F/H6c
- Natural selection leads to organisms that are well-suited for survival in particular environments. 5F/H6a
- There is no perfect design. Designs that are best in one respect (safety or ease of use, for example) may be inferior in other ways (cost or appearance). Usually some features must be sacrificed to get others. 3B/E1*

**Time:** 1 period

## Materials

*Per Student*
1 computer per student with NetLogo installed on each along with a copy of the Fish Spotters model file on it.

For Teacher
Transparency projector or computer to project the transparencies
Transparency 15.1 and 15.2

# Instruction:

## *Launch:*

Put up transparency 15.1. Tell students to imagine that all of these fish are females and are the same age.

Ask students which variation might give the guppy a competitive advantage in one environment but a competitive disadvantage in another? *Students will probably mention color or patterns.*
Are there environments where small body size would give a competitive advantage? Large body size?
Are there environments where larger fins would give a competitive advantage? Which environments would smaller fins give a competitive advantage? *Accept all answers, but require students to explain why the trait variation would give a competitive advantage.*

Tell students that one thing they discovered in their activities, is the traits and variations that give a competitive advantage in one environment are not necessarily the same ones that give a competitive advantage in another environment, and so different environments lead to different results in the outcome of natural selection.

They also learned that mutation generates different variations in populations, so this too can lead to different results in the outcome of natural selection.

But the combination of mutation and environmental interactions through natural selection led to progressively better adapted populations over time to a particular environment when predators (the students) interacted with the population. Tell students that they will examine what the effects of mates and their selections will have on adaptations.

Then ask if one of these females was more successful at reproducing offspring, what might be some of the factors that influence her reproductive success? *Answers may vary. Students may suggest variations in local environmental conditions, random interactions, or inherited traits. Accept all answers.*

What might be some variations inherited traits that give it a reproductive advantage over other individuals in the population? A*nswers may vary. Student may suggest traits such as color, speed, body size, rate of reproduction, size of brood (number of eggs), etc...*

Tell students that in general individuals that have traits that help them tend to live longer, would also seem to have an opportunity to leave more offspring behind. But longer survival alone does not always guarantee an individual will reproduce more offspring. Ask them to think of a behavioral trait for a fish, that might help it survive, but not help it reproduce. *Answers may vary. If students can not think of examples, tell them that they will investigate this question further in todays activity*

Tell students that in addition to competitive advantage for survival another important perspective for thinking about natural selection, is an individual's competitive advantage for reproduction. Natural selection for competitive advantage for reproduction, is often referred to as **sexual selection**

Tell students in this next model they will explore the mechanism of sexual selection further, by sometimes taking on the role of a female bug in a population of male bugs, competing against team mates to see who can reproduce more quickly. Sometimes they will take on a a role of predator similar to their competitions before. And sometimes they will split their team into predators and mates, to see what the evolutionary outcome would be when a population is experiencing natural selection from two or more different types of interactions.

## ***Explore:***

Next, introduce the Student Activity Sheet. Read the purpose and procedure of the activity with students.

Then demonstrate the mechanisms of sexual selection and new environmental changes in the model by projecting a display of the computer model. You will be helping students understand the mutation mechanism and how color variation in the bugs the outcome of 3 separate pieces of genetic information.

**Opening the seventh model:**

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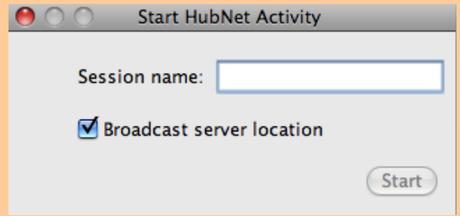
- Open NetLogo on your computer
- *Find the BEAGLE pilot models folder on your computer. Double click on the "Bug Hunters Spots" model and open it.*

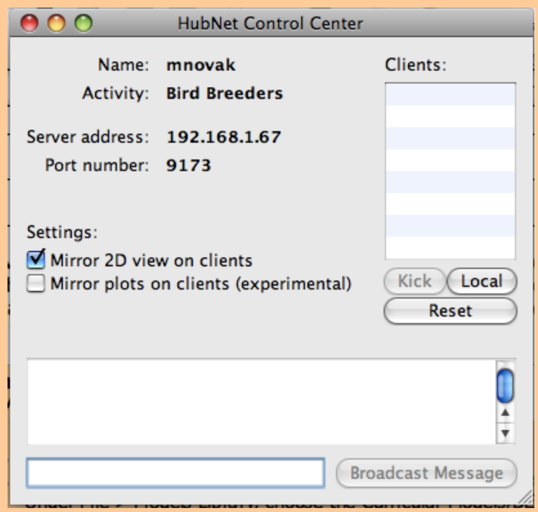
**Teacher Demo Directions:**

A Start HubNet Activity box will appear:




Enter your name in the session name and click the Broadcast server location check box. Say what you are doing out loud at each step to the students, as the team leader will need to launch the activity in a similar manner.

A HubNet Control Center box will appear:




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

*Join the simulation yourself by pressing the LOCAL button. A client interface will be launched for you to join the simulation as player 4.*

*Tell students this is where again you would wait for your group members to join in now and that they will be assigned a larger team of 6 players today.*

*Change the CLIENT-ROLES chooser in the model interface to "all mates". Tell students they need to set the CLIENT-ROLES chooser before they press SETUP and GO. Also remind them that they will be doing 3 different explorations The first one will be as "all predators", similar to the exploration yesterday, the second will be as "all mates", and the last one will be as a half and half split of "mates and predators".*

Adjust the CARRYING-CAPACITY slider to 3.

*Press SETUP. Tell students that this is when you can say go and compete for 3 minutes with the group.*

Press GO/STOP.

Press the CLEAR ENVIRONMENT button to delete the photo of the glacier from the background. Tell students this will help them see the bugs that you are starting with easier.

Tell students there will be three traits that can be inherited by bugs: their wing motion, wing size, and body color. Switch the WING-MOTION-MUTATIONS?, WING-SIZE-MUTATIONS? and BUG-COLOR-MUTATIONS? each to "on".

Tell students that as mate, when you select on a bug, another bug is randomly removed from the population to keep the carrying capacity the same, and the parent lays two eggs, and the parent itself dies. In this way two bugs are removed and two new bugs are created.

Click on a bug to show this point out that the two new bugs are similar to the parent that we clicked on, except they have slight mutations in their body size, color, and motion.

*Repeat these last two steps about 10 times, showing what happens.*

*Point out to students that they should see a new bug appear. It will be small at first, and then it will grow to be the size of whatever their genetic information specifies they will be. It is usually kind of close to the parent bug (but with possible mutations). Both offspring bugs show up somewhere near the parent bug, but not on top of it. One reason the parent bug is removed is that keeping it in one spot would allow you to repeatedly mate with it again and again. At some point that adult would die. Then it would not be able to mate. So for simplicity sake in this model, the adult dies off after it reproduces once (some bugs and animals in the world actually do this). In this model, the mating aspect of sexual reproduction is included, but the genetic reshuffling from chromosome splitting and recombining is not included. Think of the traits of these bugs as traits that are inherited and displayed only in the male bugs and all of the people competing in the game as female bugs.*

*Ask student which graphs show that the traits of this population have changes over time. Make sure to orient them to the histograms and bi-variate graphs that show this evidence of change over time.*

- *Now change the ENVIRONMENT to "poppyfield.jpg"*
- *Change the ENVIRONMETAL_MOVEMENT to 60%*
- *Change the ENVIORNMENTAL-MOTION to "wind"*
- *Now Press SETUP and GO.*

*Tell students to notice that the environmental background is no longer static. It appears as if there is a slight breeze or wind making the flowers and plant move. Tell them this more complex environmental background might influence the direction of natural selection, since every environmental change can cause corresponding changes in the evolution of populations.*

Tell students they are now going to explore the model in groups of 5-6 in explorations 1-3 and report out their data and observations. Tell them you will let them know when the three minute time limit for each exploration is over and they should stop the exploration at that time and answer the questions and that you will give them a few minutes for this before they start the next exploration.

Assign students their groups and cue the first exploration. As students work through the exploration, a lot approximately 7-8 minutes per exploration.

## ***Summarize:***

Ask students to think back to the first exploration and look at the Data and Explorations where they were all predators. As them to share what type camouflaging emerged in the population gave a competitive advantage in the first exploration. *Colors that blend into the surrounding environment*

What type of body size gave the bugs a competitive advantage? Small body sizes How do they know? *The graphs and histograms give evidence of this. The histogram of wing size compared to initial wing size shows a shift to the left over time.*

With wind in the environment, was there the most competitive advantage to moving a lot more than the wing, not moving at all, or moving a little bit? Most groups will report that a little bit of movement seems to be the trait variation that occurs most. What data did you collect to determine if one of these variations was giving a competitive advantage. *The mode of the histogram of number of bugs with a given amount wing motion shows a mode in between the minimum and maximum of wing motion values.*

Ask students to think back to the second exploration and look at the Data and Explorations where they were all mates. As them to share why camouflaging did not emerge in the population, and instead vary garish and easy to see colors emerged in the population. Why would easy to spot bugs give a competitive advantage in this environment? *Selection is now being driven by selection for mates. Easy to find mates reproduce more often, therefore contribute their genotype to the next generation of offspring. Over time, this sexual selection drives the population to adapt to a different environmental conditions, where there is a reproductive advantage for standing out and attracting attention, but no competitive disadvantage for survival for standing out.*

Does larger body size also contribute to standing out? What evidence did they find evidence for variation evolving in their population? *Yes, typically the variation for larger body size emerges as well. Evidence for this should be evident in the shift of the population histograms for Wing Size to the right over time (showing more individuals with larger body sizes) .*

Ask students if a particular variation in wing movement help the bug to stand out in the third exploration that had a mix of predators and mates interacting with the population. *Here answers may vary and the evidence is not clear for this being a competitive advantage. If there is wind, it might be that bugs that don't move at all are easier to spot then bugs that move as much as the wind. Or if there are bugs that move much more than the wind, they too are easier to spot. But if they move as much as the wind, maybe they tend to blend in more. On the other hand, maybe bug motion is a trait that gives very little competitive advantage for sexual selection in this environment, once the bugs are bright/garish and large... then they are easy to spot regardless of how they are moving.*

Tells students there are some animals that have strikingly noticeable physical traits or behaviors that make them stand out. There are some bird species were this is very noticeable. Ask students for example of birds that have behaviors or noticeable physical traits that make them easy to find in their surrounding. Students may mention local birds such as robins, cardinals, etc... which have bright plumage or birds that sing distinct songs, particularly during mating season (often spring time)

Put up Transparency 15.2. Ask students how many of them have seen this type of bird before in a zoo or in a picture. Tell students that this is a picture of male bird and female bird of the same species. The male bird is a peacock. It is in the top right corner of the picture and has large very brightly blue and green colored feathers with spots on its tale that it can unfolded into a big fan shape. Normally it does not make this big fan shape with its feathers. Only when a male peacock is near a female bird (shown in the bottom left of the picture), will they spread their feathers in a huge fan as shown in the picture and keep displaying these feathers in an attempt to try to attract the attention (and affection) of the female. When females are not nearby, it folds up these tail feathers so they are not as visible. Why would folding up the tail feathers give the peacock a survival advantage? *Because it makes it harder for predators to find the bird in the surrounding environment*

Why would unfolding the tail feathers near a female give a male peacock a reproductive advantage? *Because it makes it easier for a mate to find the bird in the surrounding environment.* Why doesn't the male always keep it feathers unfolded? *Because mates aren't always around, so it wouldn't be advantageous to be spotted when there are likely to be no mates nearby.*

Tell students there are other behaviors similar to this in other species, where males or females display certain behaviors, traits, or physical features only when the chances for reproducing with a mate are high, since those traits would normally give it a survival disadvantage by attracting unwanted attention from predators.

What are some example of animals that use sound to attract the attention of a mate? *Birds, wolves, coyotes, some insects. Students may give other examples* What are some examples of animals that use movement to attract the attention of a mate? *Many insects, birds, and mammals perform courtship dances or rituals that a very dance-like. One purpose of these is to attract the attention of a mate. Students may give other examples.*

Displaying traits that increase the chances of reproducing with a mate, when there is no mate around does not give an individual any competitive advantage for reproduction. So, why do flowers of the same species all tend to bloom at the same time of year? *If they bloom at a time of year no other flowers are blooming, they won't be able to pollinate or be pollinated from any other flowers of the same species.*

Tell students Individuals with heritable traits that grant a competitive advantage for reproduction will tend to mate more often or more successfully. The resulting competition for mates generates a specific form of natural selection, called **sexual selection**.

Ask students whether sexual selection leads to outcomes that are the same as natural selection for survival. *Students should say it sometimes leads to very different and (and sometimes opposite) of what one would expect from natural selection for survival. Students may say that trait variations that increase chances for reproductions may be the ones that would also make it less likely for that individual to survive.*

*Tell students that i*f variations in traits grant one type of advantage but not another (competitive vs. reproductive), the individual on one hand may not survive, or on the other hand may survive but not reproduce. In order for an individual to be able to contribute their genetic information to the gene pool of future generations, there must be some balance between having traits that allow them to survive (until they can reproduce) and having traits that allow them to produce offspring successfully. Give so*me examples such as singing a song to call a mate only when mates are also ready to reproduce, flowering during a certain week of the year when other flowers of the same species are flowering, displaying feathers that attract attention only when a mate is nearby, etc..).*

## Conclusions & Big Ideas:

How Do Mates Influence Adaptation?

### New Scientific Principles

*Individuals of the same sex compete against each other for mates; this generates a form of natural selection (sexual selection) for heritable variations of traits that grant a competitive advantage for 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 16: Do adaptations in one population influence adaptations in other populations?

## Overview:

### Purpose:

The purpose of this activity is to revisit the mechanisms of evolution as two populations interact together over time. Student explore how evolution in only population leads to different outcomes in that population than when evolution occurs in both populations. They reason about how the interactions between the population generates feedback between the evolution of both populations – each populations' evolution influencing the evolution of the other population. The purpose of this activity is to recognize that evolution of all populations on Earth is interconnected the evolution of other populations, and the evolutionary interactions that occur now will affect the evolutionary interactions that occur in the future, and the interactions in the past affected the interactions of the present.

### Connection to previous activities:

In the two previous activities students have explored how multiple evolutionary mechanisms interact together to influence the outcome of evolution. Earlier activities related to ecosystems had students thinking about how interactions between populations directly and indirectly influence the size of other populations. In this activity the investigate how multiple evolutionary mechanisms interact together between two populations. They extend their thinking to the complex set of interactions that exist in real-world food webs, both between other populations and between populations and the abiotic environment

### Development of Ideas:

**New Scientific Principles**

- In an ecosystem, new adaptions in any one population tend to generate additional selective pressures for new adaptations in all the other populations.

### Description

Students explore a model of two interacting populations, testing how evolutionary outcomes change when only one population evolves but interacts with another population that can not evolved compared to interacting with a population that can also evolve.

In the homework consider the indirect effects of coevolution in various ecosystems and read about the coevolution of pollinating insects and flowers.

### Learning Performances

- Explain how the outcomes of evolution between interacting populations would be different than if each population evolved without interacting with each other.
- Describe how coevolution is a mutually reinforcing mechanism, the results of evolution that result in one population (accumulating traits that grant a competitive advantage), can contribute to new selective pressures on the other population, which increases the rate accumulation of traits that grant a competitive advantage in that population; describe why coevolution generally results in faster rates of evolutionary change in both populations than would occur in one population alone.
- Provide examples of coevolutionary interactions that have a delayed or accumulated affect on

individuals.
- Describe how evolution of populations would have an effect on the interactions with the abiotic environment.
- Give an example series of interactions that would leads to indirect coevolution between two populations.
- Describe how the evolution that a population experiences now affect the evolution that will occur in the future, and the evolution that a population experienced in the past, affected the evolution that is occurring now.

## Related Benchmarks

- When an environment, including other organisms that inhabit it changes, the survival value of inherited characteristics may change. 5F/H6c
- Benefits and costs of different adaptations include consequences that are long-term as well as short-term, and indirect as well as direct.(modified version of 7D/H1)

**Time:** 1 period

## Materials

*Per Student*
- 1 computer per student with NetLogo installed on each along with a copy of the Bug Hunt Coevolution.nlogo model file on it.

For Teacher
- 1 computer and projector or large display screen for the teacher to demonstrate the models (teacher models should include Bug Hunt Coevolution.nlogo model file on it
- Transparency projector
- Transparencies 16.1

# Instruction:

### *Launch:*

Remind students of the first model they studied of an ecosystem, which had grass, bugs, and birds in the model. Ask students which organism produced its own food, and which one ate which.

Draw this diagram on the board to represent which organism ate which. Label this diagram as a "simple food chain or food web"

```
plants ------------------>  bugs ----------------->  birds
          is food for                is food for
```

Ask students why changing the number of bugs affect the number of birds in the ecosystem . Why would changing the number of plants affect the number of birds in the ecosystem? Why would changing the number of birds in the ecosystem affect the number of bugs in the ecosystem? Why would changing the number of birds in the ecosystem affect the number of plants in the ecosystem?

Tell students that even though, the arrows that show the food relationships of who eats who point in one direction, the interactions between populations work in both directions.  Write up a new diagram on the board to represent which organisms interact with each other.  Label this diagram as a “population interaction diagram”

| plant population | <---------------------> interacts with | bug population | <----------------------------> interacts with | bird population |
|---|---|---|---|---|

Tell students that up until now they have studied how **one** population of individuals evolves when multiple mechanisms of evolution are at work.  But in the first models they explored they saw how populations of producers, predators, and prey all interact to cause changes in the size of each others population.  The changes in the size of the predator population affects the size of the prey population and this in turn effects the size of the producer population, which this in turn effects the size of the prey population which this in turn effects the size of the predator population.

**Opening the 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 Coevolution” model and open it.

**Demonstration**

- Set the initial values to:

| Setting | Value |
|---|---|
| INITIAL-BUG-SPEED | 2 |
| INITIAL-BIRD-SPEED | 0 |
| INITIAL-BUG-VISION | 1 |
| INITIAL-BIRD-VISION | 0 |
| BUG-SPEED-MUTATION | 1 |
| BIRD-SPEED-MUTATION0 | 0 |
| BUG-VISION-MUTATION | 0 |
| BIRD-VISION-MUTATION | 0 |
| NUMBER-BUGS | 10 |
| NUMBER-BIRDS | 0 |
| SHOW-VISION-CONE? | “Off” |

- Press SETUP, and then GO/PAUSE to run the model.

- Click on the bugs using the mouse. Tell students that the model so far looks and behaves a lot like the Bug Hunt Speeds model they used before. Point out that one difference is that all the bugs were set to start out at the same speed (point to the INITIAL-BUG-SPEED) slider, and that if this is set to 0, then the offspring would be identical, and if this is set to something other than 0, offspring can inherit slight difference in speed.

- Click on a few more bugs and ask students to point the AVG. SPEED vs. TIME graph. Tell students that this is one place they may begin to see evidence of adaptations in speed.

- Tell students that the bugs in this model have a second heritable trait, called vision. Vision is the distance at which they first can see a predator. When they see a predator they will flee from it by turning completely around and heading in the opposite direction they were moving. As the model is running turn the SHOW-VISION-CONE? To "On". Tell students that is also something that could be set to mutate (getting longer or shorter in each offspring) if the BUG-VISION-MUTATION slider were set to something other than 0.

- Now tell the students that you are going to add automated birds to the ecosystem that can inherit the same trait variations as birds do – speed and vision.

- Set the NUMBER-BIRDS to 10 and press SETUP again, but do not run the model (make sure GO is not active). Tell students that these birds will turn toward the nearest bug that is in their vision cone. And any bug they find they eat and gain energy from. Birds that gain the most energy reproduce more frequently than others and the bird with the least energy is removed from the population every time a new bird is born. So now when they run the model, they will no longer be hunting the bugs. These computer generated birds will be doing that. Ask students if they have any additional questions.

- Tell students they will investigate the affects of evolution in both populations at first when neither the bugs or birds can see (vision of 0) and then after that they will have a chance to design an experiment to where they can choose what combinations of vision and speed mutations in which population they want to investigate.

## ***Explore:***
Ask students to read their activity sheet and begin their explorations.

## ***Summarize:***

Ask student to share their results from the last investigation, and to provide evidence for how their results support their claim that the evolution of the birds is (or is not) influencing the bugs and vice versa.
*Answers may vary, but what is a common piece of evidence is that the outcomes tend to not the same when only one interacting population evolves and the other is "fixed" in some variation, then when both populations can evolve simultaneously. In some cases where there are similar evolutionary outcomes (faster speeds for example), coevolution might still push one population to reach that adaptation more quickly or more slowly when the populations are mutually reinforcing (or counterbalancing) each others adaptations in unison.*

Ask students to try to explain how each population is influencing each other's evolution, in other words why do the bugs evolve differently if they interact with evolving birds as opposed to interacting with an unchanging population of birds. *Accept all answers*

Tell students that what they have discovered is that the evolution of one species in an ecosystem affects the evolution of other species that interact with it. This form of mutual affect on each other's evolution is called **coevolution.**

The effects of coevolution are often explained by using an analogy of "arms races" that occur between countries in the world. Arms races are ways to describe a form of competition for military superiority that countries engage in without actually going to war or without actually conquering one another. Over long periods of time, countries that are rivals often engage in an arms race to develop new technologies, weapons, and strategies to give them military advantage over another each country. But each innovation often only gives a small advantage for a brief amount of time, since the other country typically develops a technology, weapons, or strategy to respond to or thwart the advantage. Each country continues to try to develop a new innovative military advantage and each country then develops a response. This leads to a cycle hat repeats. In the end, each country is using up resources, developing weapons, and making military advances. But in the end all of these advances give no country an advantage. Instead, both simply allow them to stay caught up with each other.

*Coevolution can be compared to this arms race idea and it has some useful similarities in outcomes. In coevolution a species that evolves, often gains a brief competitive advantage, but these advantages disappear as the other species it interact with evolve responses to thwart their advantage. In the end, the evolution of both species is simply allowing them to stay caught up in the competition with each other. Students may have seen this in the evolution of bug speeds over time of both the bugs and the birds.*

Put up transparency 14.1. Ask students to consider all the interactions that occur between the populations on the food web. Use a transparency to change each arrow to a double-headed arrow as you talk with the class. Then ask how the evolution of one population might affect another population in the ecosystem? For example how might the evolution of a plant affect the animals that consume it? In what ways? How might the evolution of a plant, indirectly affect another plant in the ecosystem?

Now add some abiotic factors to the transparency, such as water in the soil. Ask students why the evolution of a plant might affect the water in the soil? *Answers may vary, but all growth in plants relies on the use of stored food that come from the conversion of water and CO2 to food through photosynthesis. So any change in a trait would have an indirect affect on the amount of water the plant takes out of the soil.* Draw a two headed arrow between the water and a plant on the transparency. Then ask why this would also affect other plants in the ecosystem. *Students should say that other plants might compete for the same water in the soil. If one species of plant takes more or less water as it evolves that would affect the amount of water left for other species of plants, which would in turn affect their evolution.*

Add a double sided arrow between the water and all other plant species on the transparency. Point out that water is not the only abiotic factor in the environment that might be an indirect link for the coevolution of different populations and they could add others, such as rocks, temperature, amount of light, etc...

Summarize that when evolution occurs in two interacting populations, the outcomes in one population affect the outcomes in the other population. This is called coevolution.

Ask student whether coevolution is something that is continually occurring between populations or does it happen only some of the time? *Students should say all the time because 1) new adaptations in one population generate 2) new interactions 3) generating forms of natural selection 4) generating new adaptations in the other population. This leads to a repeating cycle of each population influencing the evolution of the other population.*

Ask students whether coevolution tends to affect the rate of evolution in a population? *Students should say it often affects the rate of some developing an adaptation that would otherwise occur in the population if it evolved without interacting with another population.*

Ask students whether coevolution occur between any two populations in a food web, even if they aren't directly connected with an arrow? Students should say coevolution can occur through indirect effects between many populations – *such as where the evolution of population A then influences the evolution of population B, which then influences population C, which then influences population B, which then influences population A again.*

## Conclusions & Big Ideas:

How do adaptations in one population influence adaptations in other populations?

- **New Scientific Principle**
- In an ecosystem, new adaptions in <u>any</u> population tend to generate additional selective pressures for new adaptations in <u>all</u> the other populations in the ecosystem.

***<u>Homework:</u>*** *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 17: Why Do Some Species Go Extinct?

## Overview:

### Purpose:
The purpose of this activity is to introduce the idea of species, identify reasons why some species go extinct, but not others, and to identify why sudden changes in environmental conditions tend to lead to greater amounts of extinction than slow changes in environmental conditions.

### Connection to previous activities:
In previous activities students have explored how coevolution between two interacting populations leads to a cycle of reinforcing evolutionary outcomes in both population. They have determined that variation and changes in environmental conditions cause different outcomes from natural selection, and they have determined that some traits have a competitive advantage for certain environments and not others, and that the competitive advantages for traits that grant survival advantage are different (and sometimes opposing) ones than those for reproduction.

### Development of Ideas:

**New Scientific Principles**

- Species extinction is influenced by 1) the amount of resources necessary for survival available in the species' ecosystems, 2) the size of the population 3) the other populations the species is competing agains (directly or indirectly), 4) the amount of trait variation and diversity of the alleles in the gene pool of the species, and 5) the size and abruptness of environmental changes.

### Description
Students apply various definitions of species it to different populations of organisms to determine whether two populations are separate species. They then apply the definition to the concept of extinction. The identify factors that could lead to extinction and compare various conditions for each factor, identifying which condition level would lead to a greater chance of extinction for a population.

### Learning Performances
- Apply the definition of species to different populations of organisms.
- Identify how population levels would contribute to whether species are at risk of going extinct
- Identify how changes in environmental conditions could contribute to whether species would go extinct.
- Identify how abrupt or gradual changes in population interactions could contribute to whether a species would go extinct.
- Compare abrupt vs. gradual environmental changes and explain why evolution is more likely to help a species from going extinct when an environmental change is gradual.

### Related Benchmarks
- Changes in environmental conditions can affect the survival of individual organisms and entire species. 5F/M2b
- Most species that have lived on the earth are now extinct. Extinction of species occurs when the environment changes and the individual organisms of that species do not have the traits necessary to

survive and reproduce in the changed environment. 5F/M4** (NSES)

**Time:** 1 periods

## Materials

*Per Student*

- Activity sheet 17

For Teacher

- Transparency projector
- Transparencies 17.1, 17.2

# Instruction:

## *Launch:*

Ask students to imagine they are walking out of the school and across the street they a small animal running around the corner of the building. How would they know if that animal was a cat? *Student will describe many of the characteristics and visible traits of a cat.* Record these on the board.

Point out that these sort of descriptions might be useful ways to determine what type of animal it was they saw.

Then put Transparency 15.1 up, showing the picture of the raccoon. Tell students to look at the list they generated on the board. According to the list, would this animal be a cat? *Based on typical responses (has fur, small body, colors of its fur, pointy ears, long tail, claws and paws, sharp small teeth, etc...) the list will probably suggest that this would also be a cat, even though it is a raccoon.*

Students will say its obviously not a cat because of other characteristics... for example: rings on its tail, dark eyes, bigger body and rounded chest cavity, sharper claws, etc... Write some of these other characteristics next to those of the cat.

Then say, if you describe more of the traits that cats have in common and raccoons have in common you might have a better chance of determining that they are different types of animals.

Say that another important way that scientists try to explain what they mean when they say "a different type of animal" is to introduce the idea of a **species**. Write the word species on the board: A species is a group of organisms belong that are capable of interbreeding to produce fertile offspring.

Ask students to look at this definition and to use it to consider what it means for house cats and raccoons. Since raccoons and house cats are not capable of interbreeding together, they are considered different species of animals.

Then ask students about roses and corn. These two plants are not capable of interbreeding together. So then would they be different species or the same? *Different species.*

Ask students if they think dandelions and roses would be considered the same species or different and why? *Students will probably say that they are different species, because they have never heard of or seen an offspring of a rose and dandelion. Or they may say that they could be the same species if they were found to be able to interbreed together.*

Point out that there are lots of animals that show variations in type, but those different types are not always different species. For example dog breeds are all the same species. Even wolves and dogs are the same species. Ask students why? *They should say because the wolves and dogs can interbreed together.*

Ask students to estimate how many species of mammals they think are on Earth. Ask students to estimate how many species of plants they think their on Earth. Have students share some estimates and reasons for these predictions. Put up Transparency 15.2 to show the number of species of these on Earth as well as the total number of species on Earth.

Ask students if the number of species on Earth has always been the same. And write this as a question on the board "Do the number of species on Earth always stay the same?" Have students share reasons why the number of species on Earth have changed over time. Some students will point out that species can go extinct. Ask to share examples of other species they have heard of or studied that they went extinct. Some students might suggest that new species have come into existence in the past If so ask them to explain their thinking further about examples.

Underneath the question "Do the number of species on Earth always stay the same?" , write the answer the class has agreed upon (yes) and point out that if the number of species on Earth is not always the same, then two types of changes in species number could be occurring at any time – the number of species might be decreasing or the number of species might be increasing. Underneath this then write two sub questions – "What causes some species to disappear (go extinct) and where would new species come from?"

Tell students that many of them have probably heard of examples (such as dinosaurs or woolly mammoths) of species that have gone extinct. And many probably have also heard of species that are endanger of going extinct and are on the "endangered species" list. But many of them may not have heard of examples of new species that were not here in the recent past. Tell students that they will learn about examples new species that people have observed emerge in populations and ecosystems, and they will investigate both parts of the question, thinking about what causes species to go extinct and where new species come from.

Underline the first part of the question. "<u>What causes some species to go extinct a</u>nd where would new species come from?" Ask the class to brainstorm a few factors that might cause a species to go extinct. Write these factors on the board. Then, tell students that there may be more factors than those just listed. But in a group they will explain why a couple of factors from the list or new ones the group identifies would affect whether a species will go extinct. But first, each group will need to identify two conditions for the factor. Show a few examples of how to do this. For example, if students put the word "shelter" on the board, two relevant conditions for this factor would be "lots of available" and "little available". Another factor might be food. Two conditions could be "lots of available food" and "little available food". Or the two conditions could be "lot of variety of different food sources" "little variety in different food sources". Its not critical what the two conditions are for each factor, but it is important to identify to different conditions to use in the explanation of why the factor would influence whether a species will go extinct, since you could use the conditions to explain which condition would be more likely to cause extinction and why. Do one of the factors together as a class. For example, for shelter – the reason for why it might influence extinction could be -
"A population that has lots of available shelter will have lots of this resource necessary for survival for the individuals in the population. More shelter gives a better chance of more individuals surviving. More individuals surviving gives less a chance that the population will drop to zero from other factors."

## ***<u>Explore:</u>***

Now assign groups to pick two factors (or create two new ones) to fill out on the first sheet of the activity. For each factor they should agree on two conditions to talk about in the explanation of why the factor might influence whether a species goes extinct.

## ***<u>Summarize:</u>***

Have students share out one of the factors, conditions, and reasons. Then put up Transparency 17.3 and tell students that as a class we will discuss each of these factors, decide which condition would give a higher risk of extinction for a population in the near future and why.

## Conclusions & Big Ideas:

Let students lead the reasoning for this and record what the class agrees upon for which population is at higher risk of extinction in the near future and why. Students should write down agreed upon conclusions as the class reaches consensus on each factor.

Students may have alternate reasons and therefore alternate predictions for which factor would give a higher risk of extinction. Ask students to defend their claim using mechanisms of evolution where possible. When alternate reasons and predications are defended, let the students decide which one they wish to record on their sheet.

### New Scientific Principles

- Species extinction is influenced by 1) the amount of resources necessary for survival available in the species' ecosystems, 2) the size of the population 3) the other populations the species is competing agains (directly or indirectly), 4) the amount of trait variation and diversity of the alleles in the gene pool of the species, and 5) the size and abruptness of environmental changes.

***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 18: Where Do New Species Come From?

## Overview:

### Purpose:
The purpose of this activity is to understand how new species can form from old species through the mechanisms of evolution covered so far in the unit (coevolution, genetic drift, variation in environmental conditions, sexual selection) .

### Connection to previous activities:
In previous activities students have explored how coevolution between two interacting populations leads to a cycle of reinforcing evolutionary outcomes in both population. They have determined that changes in environmental conditions cause different outcomes from natural selection, and they have determined that some traits have a competitive advantage for certain environments and not others. In learning about sexual selection they have discovered that traits variations that grant survival advantage may be different than those that grant reproductive advantages. Students will develop explanation of how coevolution from sexual selection can lead to speciation by evolving behaviors that ensure reproductive isolation. Students will describe how such speciation as a beneficial tradeoff for gaining greater survival advantage at the expense of a smaller set of mates.

### Development of Ideas:

**New Scientific Principles**

- **New species can emerge when there is a competitive advantages for survival from maintaining more specialized gene pools in different groups of individuals; this will tend to reinforce adaptations that lead to more reproductive isolation between those groups.**
- **New species can emerge when geographic isolation, mutation, and genetic drift lead to separate descendent populations that have traits or genes that make individuals from each population reproductively incompatible with each other.**

### Description
Students revisit the definition of a species and discuss whether genetic drift alone could account for why new species emerge. They then use a computer model of plants in an ecosystem to explore how speciation always emerges from a single population over time under certain conditions. They then reason about an alternate set of mechanisms that would lead to speciation more rapidly and more frequently: where genetic drift initiates the pathway to speciation But sexual selection and coevolution are the driving mechanisms that continue to reinforce the emergence of this outcome. They study examples of how speciation has been created in laboratory conditions with human intervention and contrast the mechanisms at work in real world ecosystems when new species emerge.

### Learning Performances
- Describe what a species is and identify which species an individual belongs to.
- Describe speciation in terms of tradeoffs between gains and losses in competitive advantage for survival vs. competitive advantage for reproduction.
- Describe how genetic drift in combination with geographic isolation could lead to the emergence of new species.
- Describe how coevolution and sexual selection could lead to the emergence of new species even when

geographic isolation is not present.
- Compare alternate models for speciation, describing differences in outcomes and processes include rate of speciation, permanence of speciation, and which model better represent the conditions and outcomes of speciation experiments in laboratories and observations of speciation having occurred in real world ecosystems.

## Related Benchmarks

- The basic idea of biological evolution is that the earth's present-day species are descended from earlier, distinctly different species. 5F/H1*

## Time: 1 periods

## Materials

*Per Student*
- 1 computer per student with NetLogo and Plant Speciation.nlogo model file on it.

For Teacher
- 1 computer and projector or large display screen for the teacher to demonstrate the models (teacher models should include Plant Speciation.nlogo model file on it
- Transparency projector
- Transparencies 18.1, 18.2

## Instruction:

### *Launch:*

Ask students to describe what makes a one population of organisms a different species than another. population of organisms Students should recall different species a group of organisms that are incapable of interbreeding to produce fertile offspring.

Ask students for some examples of different species and emphasize that these populations can't interbreed to produce fertile offspring. Tell them it could be because of traits differences that make their reproductive structures incompatible, trait differences that make their reproductive behavior incompatible or, genetic information differences that give conflicting or incompatible information on what substances to make.

Remind students that they have determined that the number of species on Earth hasn't always been the same and they have identified lots of factors in the environment that could cause species to go extinct. Remind them that yesterday they introduced the question, “What causes some species to disappear (go extinct) and where would new species come from?

Point out that they have answered some of the first part of the question, but not the second. Underline the second part of the question from yesterday.. “What causes some species to go extinct and where would new species come from?”

Tell them that there are many species of animals and plants on earth now that were not here in the distant past. Ask students to take out activity sheet 16 and make some predictions about how new species are formed and where they come from.

Ask students to share their predictions, writing on the board the pieces of their predictions that the class agrees upon. The pieces that they agree upon, probably will include:

- all new species come from existing species
- evolutionary mechanisms might be responsible
- not sure what evolutionary mechanisms would cause this to happen.

Introduce the word **speciation**. Tell them that this refers to whenever a new species is formed from an old species. When this happens, an existing population forms two separate groups within the population. Individuals in one group for some reason can no longer interbreed with individuals from the the other group. So, really speciation refers to when one existing species separates or break apart into two or more new species.

Ask students to suggest any mechanisms of evolution that could work together to generate this outcome. *Accept all answers at this point.*

Tell students that they will be investigating speciation further in their exploration of a computer model today. Demonstrate the model.

**Opening the 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 "Plant Speciation" model and open it.

**Introducing the Model:**

- Set the CHANCE-FLOWER-TIME-MUTATION slider to 0 %.
- Set the CHANCE-TOLERANCE-MUTATION slider to 0 %.
- Press SETUP. Tell students to notice where section of the screen the plants are placed in.
- Press GO/STOP. Point out that the day monitor is steadily increasing and when it reaches 365, it will set back to 0 and the year will go up by one.
- Tell students the model is running very fast right now, so you are going to slow it down so they can see when the plants are flowering. Adjust the speed slider at the top to slower and keep running the model until the students see the plants make flowers and the flower disappear.
- Tell students that all of the plants flowered at the same time of year, pollinated with one one another (or self-pollinated), and then lost their flowers. Show that the FLOWER-DURATION slider (which is set to 10) determines how long the flowers remain on the plant and right now the graph of FLOWER-TIMES shows that all the plants are flowering in the middle of the year.
- Keep running the model for a few years and show that the plants are steadily expanding into more of the ecosystem as they reproduce, drop their seeds nearby the parent plant.
- Then say that you want to see what happens after many years, and so are going to speed the model up by changing the speed slider back to "normal" and switching the VISUALIZE-TIME-STEPS to "years". Run the model for over a hundred years.
- Then pause the model and ask students to notice where there are more plants, in the green or the blue section of the ecosystem. Ask them to explain how it shows this on the graph of FLOWER-TIMES, noting that there are 2 over lapping bars showing that all the plants have the same flower time still since they all started with the same flower times and had no mutations in their genetic information for this in the offspring since the CHANCE-FLOWER-TIME-MUTATION is set to 0 %.

*Tell students that in this model there are different types of soil. Green soil is typical soil like you might find in a backyard garden, but blue soil is contaminated soil. The contaminated soil has bits of metal that have dumped on the ground from a nearby mine. The metal is the contaminated soil is slowly dissolving into the water in the soil in this area.*

Tell them that they can see that the initial population of plants in the model is setup to survive better in the normal soil based the results right now in the model. These plants have little tolerance for metals and will not survive as well or for as long the contaminated soil. They have roots that do well absorbing water from normal soil, but don't do well when they absorb water with metal dissolved in it.

If an offspring of one of these plants has a mutation in their genetic information that produces a substance that leads to greater metal tolerance, then it will survive a little bit better in contaminated soil. But this competitive advantage comes with a tradeoff. Though mutation for increased metal tolerance creates a substance inside the plant that allows it to survive better in contaminated soil, this substance also slows down its overall growth rate (since the plant is diverting some of its energy and build materials to creation of this new substance). So plants with greater tolerances for metal soil would grow slower in normal soil, compared to plants that don't have the mutation.

To help visualize metal tolerance, plants will look "bluer" the more mutations they have that give them more tolerance for metal. Right now all the plants have no tolerance for metal because they all started with no tolerance for metal, and incurred no mutation for this (the CHANCE-TOLERANCE-MUTATION is set to 0 %)

**Continue Introducing the Model:**

- Change the SHOW-LABELS-AS chooser "metal tolerance" and press GO/START to resume the model. As the model is running tell students that this SHOW-LABELS chooser can help you inspect each individual plant. Right now they are all the same, but later in your explorations when you add mutations in, there will be differences in this value.
- Tell students that the graph of TOLERANCES also shows that all the plants are the same value, and shows that there are more plants growing in the normal soil – shown by the green bar, then growing in the blue soil – shown by the blue bar. Remember when you study these graphs that the green and blue bars are not the number of green and blue plants, but rather the number of plants growing on the left side of the ecosystem (green soil) vs. the number of plants growing on the right side of the ecosystem (blue soil).
- Then change the SHOW-LABELS-AS chooser to "metal in soil" and press GO/START to resume. Tell students, notice that the amount of metal in the soil varies from 0-100, so there can be spots where there is a little bit of metal contamination, such as a value of "2" or "12" and areas where the soil has a little less than complete contamination, such as "95" or "88". But, "50" marks the division between the right side of the screen which is considered "bluish" or mostly contaminated soil, and the left side which is considered "greenish" or mostly clean soil.
- Then change the label SHOW-LABELS-AS chooser back to "none" and pause the model.

## *Explore:*

***(TEACHING ALTERATE: This lesson tends to work well as a teacher led interactive discussion and exploration. The transparencies at the end of the lesson have the teacher walking through the steps in the speciation process that happens during the model run. Since that careful analysis of the graphs and the discussion about how coevolution is driving reproductive isolation should happen at some point in the lesson, it can work very well to simply work the student activity as the teacher, but have the students make predictions, write down observations, exploring the model together as a class).***

If you rather have students conduct the explorations independently, have them being their activity sheet now.

***Summarize:***

*Review the answers to exploration 2, reminding students that in exploration 2, flower time could change, but metal tolerance could not (its mutation % was set to zero).*

Ask students: even though individuals can get a mutation that would allow it to open its flower much later than any other flower in the population, why would this individual have a competitive disadvantage for reproducing new offspring? *Students should reference the mechanism of sexual selection. Address the idea of decreased competitive advantage for reproduction, if you don't "mate" at the same time the rest of the potential mates do. So its best to be close to the average mating time. Very late or very early blooming plants may not be able to reproduce with any other plant, so their genes are removed from the gene pool when they die, because they have no offspring.*

*Ask students how does the shape of the FLOWER-TIME graph from this last model run support the claim that individuals that flower earlier than the average flower time or later than the average flower time, have a lower chance of having offspring? Students may point to features of the graph that support the idea that most of the plants appear in the middle of the range of flower times. Most of the plants are clustered close to the average flower-time, and very few are surviving to the left or right of the average in the distribution graph.*

*Tell students that genetic drift could cause the average to slowly drift higher or lower over time, but sexual selection would a continuous mechanism that would cause the shape of the graph to remain the same and the distribution to say clustered around the average.*

Ask students to study the results of exploration 3. Ask students why weren't there many plants in the population with a tolerance in between 10 and 90? Show the example graphs in part d of transparency 18.1 a reference. *Students should say that this is because the environment doesn't have much "partially clean" or "partially contaminated" soils. Most of the left side of the ecosystem is very close to 0 metal and most on the right side of the ecosystem is very close to 100 metal.*

Ask students how natural selection leads to this outcome. *Students should use the idea of competitive advantage in different portions of the environment. For example: tolerances that match these metal levels have the greatest competitive advantage (depending what side of the ecosystem they are growing on), anything else would have less of a competitive advantage.*

Point out that any one of these outcomes shows that the population of plants on the left side of the ecosystem no longer breed with the population of plants on the right side of the ecosystem (in most cases), because there is very little (if any) overlapping blue and green bars. Tell students that the interbreeding of these sub-populations may still occur in one or two cases occasionally (due to mutation), there is apparently a mechanism or combinations that is forcing these sub-populations apart, strongly pushing them in them away from being reproductively compatible. In some cases it has pushed the population toward forming two separate species, and in other cases it has pushed the population into forming three separate species, by fragmenting the flower time of one of the populations. The two primary mechanisms of evolution at work here are two forms of natural selection: natural selection for survival and sexual selection. But they are interacting in an unexpected way due to the environmental variation in the ecosystem.

Ask students to describe what sort of trade off is occurring in the evolution of the plants, between survival advantage and reproductive advantage. *Students should say that the plants are getting more survival advantage, but less reproductive advantage.*

Tell student that if a population speciates then the tradeoff of these two advantages must result in an overall advantage for both sub-populations. In this case, the overall advantage is allowing each sub-population to become specialized to survive very well in a different part of the environment. *But it is at the expense of not staying interbreed-able with every other plant. Anywhere ecosystem with large variation in the environment could lead to this type of specialization through speciation.*

Tell students that this is one possible set of mechanisms of evolution that could lead to speciation, but is not the only combination of possibilities. This set of mechanisms involved: 1) genetic drift leading to slightly different populations in an ecosystem with two distinct areas with different environmental conditions. In this environment, there was a 2) competitive advantage to having one trait variation in one environmental condition and a competitive advantage to having the other trait variation in the other environmental condition. A second trait variation (flower time) provides a potential opportunity to generate a "barrier" to interbreeding with all the plants and permitting interbreeding only with plants that would likely give offspring a competitive advantage. This is what begins to emerge as it becomes advantageous for the flower time for one plant to be similar to the flower time of another plant with the same metal tolerance,but slightly different than the flower time of other plants. This slight difference makes it more likely for "similar" metal tolerance plants to interbreed and less likely for dissimilar metal tolerance plants to interbreed. Coevolution continues to reinforce this slight difference until two populations with very different flower times emerge and remain non-interbreed-able.

Point out that any behavior, structure or chemical process that makes two individuals incapable of interbreeding would classify it as two separate species. In this case it was flower time. But there are other possibilities – mating behavior, physical structure, and biochemical processes are all potential barriers to creating fertile offspring (or offspring that can continue to interbreed). Tell students that some animals can interbreed, but have such different genetic information, that their offspring are infertile – the genetic information from both parent is compatible enough to make a living offspring but is not compatible for developing sex cells in that offspring. Give an of example of Horses, Donkeys, and Mules. Horses and Donkeys are considered separate species because their offspring, Mules, can't reproduce and make more offspring.

Then tell students that genetic incompatibility for making a living offspring is another barrier to different animals reproducing. Since if one potential parent passes on genetic information that gives conflicting genetic information compared to the other potential parents genetic information the offsprings cells would not be able to produce the necessary proteins and related traits to allow that organism to grow and repair the necessary cells and structures in their bodies. If mutations that create incompatibilities start to accumulate through genetic drift between two populations that are separated, this too might lead to the emergence of two separate species.

Summarize that all new species will come from existing species; all existing species came from ancestor species and that new species form from old populations that used to be one species, when that population fragments or breaks apart into two or more non-interbreeding populations.

Tell students that there are two important sets of mechanisms that cause speciation. One set is the kind that drove the plants to become separate species. In environments with variation in conditions and in populations with variations in traits, not reproducing with the part of the population can increase the chances for offspring survival in one part of the environment.

Tell students that another set of mechanisms can cause speciation. Whenever two parts of a single species become geographically isolated from one another, mutation and genetic drift will start accumulate more and more differences in the organisms in each population over time. If these differences start influencing how the chromosomes match up in meiosis or fertilization or the behaviors and reproductive structures of individuals , then differences will lead populations to become progressively more incompatible for ever interbreeding back together in the future. This can lead to separate species as well.

## Conclusions & Big Ideas:

Where Do New Species Come From?

### New Scientific Principles

- **New species can emerge when there is a competitive advantages for survival from maintaining more specialized gene pools in different groups of individuals; this will tend to reinforce adaptations that lead to more reproductive isolation between those groups.**
- **New species can emerge when geographic isolation, mutation, and genetic drift lead to separate descendent populations that have traits or genes that make individuals from each population reproductively incompatible with each other.**

***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 19: Why Are There So Many Species on Earth?

## Overview:

### Purpose:
The purpose of this activity is connect how environmental variation influences speciation. Students will determine that a single species that migrates into multiple environments not already filled with species that are competing for the same resources will adaptively radiate into separate species through natural selection, genetic drift, and mutation over time.

### Connection to previous activities: ß
In previous activities students have discussed causes for extinction of species and mechanisms of evolution that lead to speciation. They have noted that most of the species that were once on Earth are now extinct. Though new species can form from old species, accounting for the shear numbers of existing species on earth currently requires understanding that species rapidly adaptively radiate to take advantage of ecosystems that have little or no competition in them for the same resources necessary for survival.

### Development of Ideas :

**New Scientific Principles**

- **In every ecosystems in the world there are many type of potential interactions within the food web and between the abiotic environment; this results in many unique possible opportunities for organisms to adapt to fill these vast number of different niches.**
- **New species tend to form to fill available niches when 1) old species go extinct or 2) new ecosystems form or 3) a mutation generates an innovative and advantageous new trait.**

### Description
Students explore structure and function relationships related for food gathering in a hand-on lab, using everyday tools to compete for gathering seeds in various environments They discover that not all adaptations and structures are advantageous in every environment, and some adaptations that give a competitive advantage in one environment, give a disadvantage in another.

### Learning Performances
- Compare structural traits that have different levels of completive advantage for survival in different environmental conditions.
- Identify the mechanisms that would lead to a single species to adaptively radiate.
- Describe why adaptive radiation occurred in the Galapagos Finches.
- Explain that the large number of species in the world are due, in part many unique opportunities (niches) for organisms to get the resources they need to survive within ecosystems.

### Related Benchmarks
- The basic idea of biological evolution is that the earth's present-day species are descended from earlier, distinctly different species. 5F/H1*
- The continuing operation of natural selection on new characteristics and in diverse and changing environments, over and over again for millions of years, has produced a succession of diverse new species. 5F/H10** (SFAA)
- Evolution builds on what already exists, so the more variety there is, the more there can be in the future.

But evolution does not necessitate long-term progress in some set direction. Evolutionary change appears to be like the growth of a bush: Some branches survive from the beginning with little or no change; many die out altogether; and others branch repeatedly, sometimes giving rise to more complex organisms. 5F/H9

**Time:** 1 periods

## Materials

*Per class*
Rice (uncooked) – 2 cups per class
2 cups of Rice (cooked)
2 cups of Rice (uncooked)
2 cups Sunflower seeds with shells (about 2 cups)
2 cups Corn Kernels

8 large plastic tubs

1 bag of play sand
1 bag of gravel
1 bag of rocks

*Per set of 6 students*
- 6 cups pre-labeled as A, B, C, D, E, F
- 1 pair of chopsticks
- 1 turkey baster
- 1 large plier
- 1 needle nose plier
- 1 tweezer
- 1 spring loaded clothes pin

*For Teacher*
- Transparency projector
- Transparencies 17.1, 17.2, 17.3
- Timer or wall clock

## *Additional preparation (for each class period)*

Take two tubs and label each as the Blue Station.
In each tub place half of bag of play sand and wet it a bit. Shape it into various mounds and place clumps of cooked rice around on the terrain.

Take two tubs and label each as the Yellow Station.
In each tub place half a bag of gravel and place half of the corn kernels in each. Mix the gravel and corn so that it is partially buried.

Take two tubs and label each as the Gray Station.
In each tub place half a bag of rocks and scatter half of the dry rice grains around the tub and mix in with the

rocks.

Take two tubs and label each as the Green Station.
In each tub place half of the seeded sunflower seeds and scatter them around the bottom of the tub.

Place tubs in the room spread out, so that students can rotate to a new station after completing the last one. Here is a suggested order

1). Blue
2). Yellow
3). Gray
4). Green
5). Blue
6). Yellow
7). Gray
8). Green (after green student groups will loop back to the first station)

# Instructions:

## *Launch:*

Remind students that they have read that there are over 1.5 million species of animals, plants, and algae on Earth. Tell students that there are over ¼ of a million species of beetles alone.

Remind students that they have discovered some ways that new species form from old species, but that they also have found that many species go extinct. Then ask students why are there so many species. Why not fewer? *Accept all answers.*

Tell students they will discover part of the answer to that question today, and will determine one of the main reasons why there are so many species on Earth.

Have students read the purpose and complete the prediction section of their student activity 17.

Then have students read through the procedure on the 2nd page of their activity sheet. Review the directions with them.

Assign groups of 4 students, passing out 4 different lettered cups to each member of the group. Not all letters will be used by each group. One at a time call each beak shape up to take a tool to use in the activity. Assign groups to a starting station and have them fill in the station color they start at in their Data and Observations chart and have them fill out the next 3 color stations they will go to.

Tell students when you will start the timer for the 2 min. competition. Stop the timer after 2 minutes. Have students count their seeds and record their results in their table (including those of each group member) and return any uncracked and collected seeds to the tubs (ideally back in a manner similar to how the tub was set up)

Student groups should now rotate to the next station and should repeat the competition in the new environment. After 4 stations of results, all groups should return to the class seats and return their tools and cups. Students should next get ready for sharing out and recording class results.

Put up Transparency 17.1 and have all students find their results for the Blue station and put a check mark on that row. Have each group report out their results and total the results for all groups on the Transparency.

Then repeat this for Yellow station results, gray station results, and green station results.

Have students spend 5 minutes working with a partner to complete the Making Sense of the Data section.

Then ask students what their responses to the multiple choice questions were and summarize that one important finding they should realize is that in different environments, different tools give different competitive advantages. Likewise, *in different environments, different traits give different competitive advantages.*

Go over the last three responses that students answered with a partner as a class. Ask students to describe the type of conditions that tend to lead to speciate. *Students should say either environmental variation or geographic isolation.*

Ask students to describe the mechanisms of evolution contribute to speciation. *Students may suggest sexual selection, natural selection, environmental variation, mutation, genetic drift, and adaptation.*

Ask students why it why would it be advantageous for separate species with specialized adaptations for different environments, to put up barriers for not interbreeding with each other. *Students should say not interbreeding prevents genetic information for disadvantageous traits from entering into the population.*

Place Transparency 17.2 on the overhead and ask students if they have been to hardware store and seen that they sell many different types of tools. Point out that this photograph shows just some of the different types of pliers that can be found at the hardware store. Ask students why there are so many pliers for sale? Why not sell just one type of plier? *Accept all responses.*

Ask students if some pliers might be easier to work with under a sink, to grab something very far away, with little room to work, narrow opening, etc.. Ask student if some pliers are better at for interacting with different objects (screws, bolts, nails, etc..)? Summarize the idea that no one plier is the best tool for every environment, which is why there are so many different pliers.

Tell students that this is one of the reasons why there are so many species on Earth. There are so many environments and in different environments there are often more than one ecosystem and in a single ecosystem there are often different conditions in different parts of the ecosystem and there are also many different types of interactions that occur between populations within an ecosystem.

To get a sense of why so many species can be found on Earth, tell them you are going to show them an example set of environments and ecosystems in a small area on Earth.

Place Transparency 17.3 on the overhead and ask students if they every heard of the Galapagos Islands. Tell students that they are a small chain of islands in the middle of the Pacific ocean. Show them the map and show that the islands were formed by volcanoes millions of years ago (the topography map shows the craters of the cones of these volcanoes). Also show them that there are many ecosystem found on each island. Show them the cross section of different climates on a typical island. Tell them that after the islands formed millions of years ago, one single species of bird colonized these islands from South Africa. Since that time that single species has speciated into since many different species.

Ask them why many species developed from a single species? What would the different beak shapes allow the birds to do? Do they think they would find the same kind of species on all islands or would different species live on different islands? What if the environmental conditions were slightly different on different islands? Would they find the same species of birds living in each ecosystem? Would all species shown on the transparency eat the same type of foods? Would the same plants grow in dry ecosystems as in wet? Would the same kind of seeds develop from different plants?

Point out to students that the different beak shapes and sizes indicate that the birds must use these different structures of beaks for different functions. And sure enough, on the side of the chart of birds, they can see that some of the birds are tree finches, others, are ground finches. Some eat small seeds, others eat large seeds. The size and shape of the beak allows them to gather, open, and eat food that other finches can't.

Tell them that there are no species in an environment hat are taking advantage of the resources available in the ecosystem, the first species to enter the environment will speciate into enough new species so that each can take advantage of different environmental conditions in different ecosystem or parts of the ecosystem Adaptation of each new species allows each to develop specialized structures for unique parts of the ecosystem or ecosystems. When this process occurs it is called adaptive radiation, which indicates that a single species forms new species, each adapting new structures that are different from the ancestor species.

In general, geographically isolated regions or "separated" ecosystems, lead to speciation. Separated ecosystems, do not need to be physically isolated – they can simply have relatively abrupt changes in environmental conditions from one location to another. Even a single condition change in an ecosystem from one location to another, might create an ecological "**niche**" (or small space) which would act like a miniature ecosystem within an ecosystem. Niches can be thought of as ways in which an organism makes a living within any environment.

Speciation often leads to "filling" most of the niches of ecosystems with new species. Niche filling can be thought of a "adaptive radiation" - where a speciation drives single species to multiple species, each one becoming specialized in taking advantage of different niches and different (sub)ecosystems over time. Adaptive radiation is most clearly seen in environments where there is clear variation in environmental conditions. A single species that migrates into multiple environments will adaptively radiate into separate species through natural selection, genetic drift, and mutation over time. Since other existing species already existing in these environments undergo population fluctuations and coevolve, new species can also sometime adaptively radiate to outcompete existing species for resources in ecosystems and drive those species to extinction. So as new species are formed, other species often go extinct.

Ask students why these situations might lead to speciation:
- When a family of turtles colonizes a set of newly formed lakes
- When seeds from a plant thousands of miles away wash up on some newly formed volcanic islands

Students should say adaptive radiation can occur when an new opportunity arises in an environment with unoccupied areas within an ecosystem or new ecosystems. The first population to colonize this new environment may diversify rapidly and speciate in order to develop and maintain specialized adaptations to various environmental conditions.

Ask students why these situations might lead to speciation:
- When the environmental conditions change enough to cause extinction of many of the native species of bugs in an ecosystem.

*Students should say when species go extinct, new species adaptively radiate as new opportunities become available (from a lack of competition for resources necessary for survival)*

Tell students that one other situation that can tend to lead to speciation is when a mutation that generates a novel trait that permits innovative new ways to interact with the environment. Give this example: the evolution of a fourth cusp in mammals permitted a vast increase in the range of foods which can be fed on; this increased the number of environments that mammals could survive in with this trait, and led to the emerge of large number of niches that could be filled with additional new adaptations in those environments.

## Conclusions & Big Ideas:

Why Are There So Many Different Species?

### New Scientific Principles

- **In every ecosystems in the world there are many type of potential interactions within the food web and between the abiotic environment; this results in many unique possible opportunities for organisms to adapt to fill these vast number of different niches.**
- **New species tend to form to fill available niches when 1) old species go extinct or 2) new ecosystems form or 3) a mutation generates an innovative and advantageous new trait.**

***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<br>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<br>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<br>It explains why the data counts as evidence for this claim.</td><td>(PM) Principles & Models<br>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<br>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>