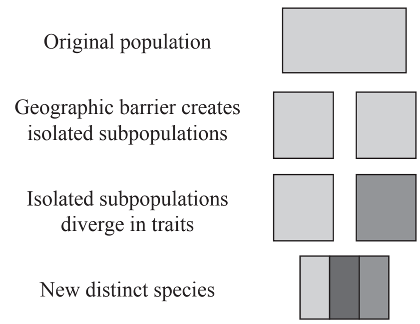
Lab 25. Mechanisms of Speciation: Why Does Geographic Isolation Lead to the Formation of a New Species?

Introduction

There have been a number of models that have been proposed to explain the process of speciation (i.e., the formation of a new species). One of these models, called allopatric speciation, suggests that new species can arise when a population is divided into two or more subpopulations by some type of geographic barrier (such as a mountain range or an ocean). The two isolated subpopulations then diverge into different species over time (see the figure to the right). This explanation of the model, however, is incomplete because it only suggests that two or more subpopulations can become separate species when a geographic barrier separates them; it does not explain what causes the two subpopulations to diverge into different species over time.

The model of allopatric speciation



Your Task

Use a computer simulation called *Bug Hunt Camouflage* to develop an explanation for how geographic isolation could lead to the formation of a new species. Your goal is to identify an underlying mechanism that can cause a physical characteristic (such as body color) found in two different populations of the same species to diverge when they live in different environments (seashore, glacier, or poppy field). This mechanism must be able to change a characteristic in the two populations enough so the individual members of one population will no longer interbreed with members of the other population.

The guiding question of this investigation is, **Why does geographic isolation lead to the formation of a new species?**

Materials

You will use the following materials during your investigation:

- An online simulation called Bug Hunt Camouflage, which can be accessed at *http://ccl.northwestern.edu/netlogo/models/BugHuntCamouflage*.
- Natural Selection and Species Concept Fact Sheet

Safety Precautions

1. Use caution when working with electrical equipment. Keep away from water sources in that they can cause shorts, fires and shock hazards. Use only GFI protected circuits.
2. Wash hands with soap and water after completing this lab. Follow all normal lab safety rules.

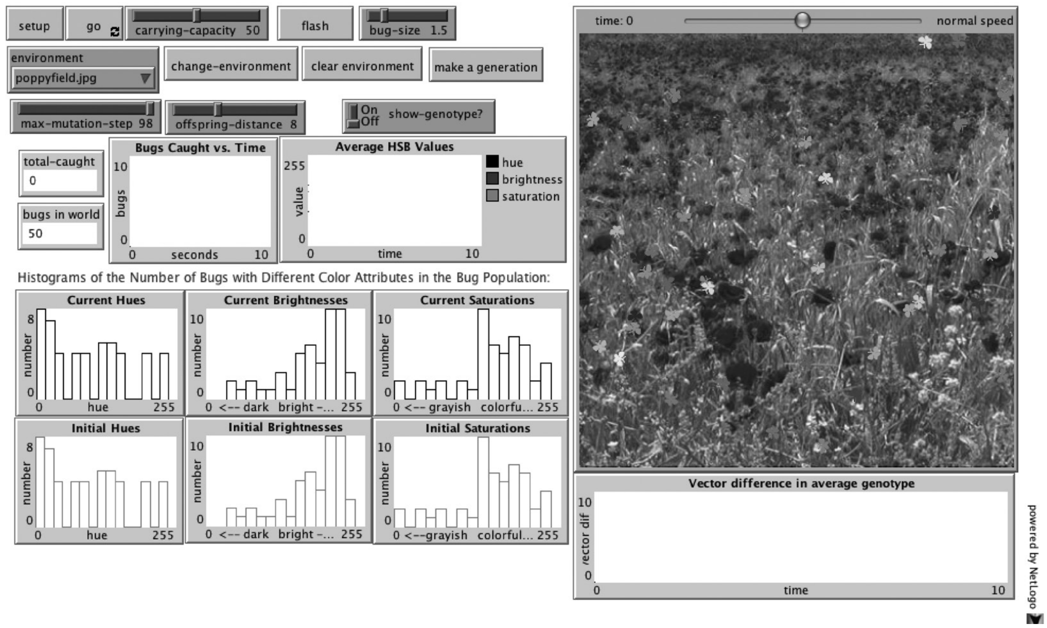
Getting Started

Bug Hunt Camouflage simulates a population of bugs that all belong to the same species. However, the bugs in this population are not all the same color. You will be acting as a predator by using the mouse to eat the bugs (your prey) by clicking on them. When a bug is eaten, it is replaced through reproduction by a bug in the simulated environment. The new bug will appear near the parent bug and will start out as a small dot and then grow after a few seconds. The new bug will usually have the same characteristics as one of the bugs that have not been eaten yet. Some offspring, however, will have a slightly different coloration than the parent it came from because the simulation will allow the pigment genes to drift (to simulate the effect of random mutation). You can also create an entire new generation of bugs at any time by clicking the "Make a Generation" button. When you click this button, all of the bugs in the environment produce one offspring.

The simulation also allows you to adjust the following factors (see figure at the top of the following page):

- The number of bugs in the environment (0 bugs to 100 bugs),
- The size of bugs in the environment (0.5 to 5),
- The nature of the environment (seashore, glacier, or poppy field), and

A screen shot from the *Bug Hunt Camouflage* simulation.



- How much the pigment gene can drift from the parent value when a new bug is produced (0 to 98).

The simulation also allows you to keep track of a number of characteristics of the bugs and the environment over time:

- How many bugs you have caught (total-caught).
- How many bugs are in the world (bugs in world).
- Your progress and performance as a predator (bugs caught vs. time).
- How the average values for the hue, saturation, and brightness of the bugs change over time (average HSB values).
- The distribution of hues in the starting population (initial hues).
- The distribution of hues in the current population (current hues).
- The distribution of saturations (of colors) in the current population (current saturation) and starting populations (initial saturation). Low values represent "grayish" colorations and high values represent "vivid" colorations.
- The distribution of brightness (of colors) in the current (current brightness) and starting (initial brightness) populations. Low values represent "dark" colorations and high values represent "light" colorations.
- How the average values of the genotype of the population change over time (vector difference in average genotype). The plot shows the vector difference between the average value of red gene frequency, green gene frequency, and blue gene frequency for the current population compared with the initial population.

To answer the guiding question using this computer simulation, you must determine what type of data you will need to collect, how you will collect it, and how you will analyze it. To determine *what type of data you will need to collect,* think about the following questions:

- How will you determine if the characteristics of a bug population change over time?
- What will serve as your dependent variable (e.g., number of bugs caught, hues, brightness, saturation)?
- What type of measurements or observations will you need to record during your investigation?

To determine *how you will collect your data,* think about the following questions:

- What will serve as a control condition (glacier, poppy field, seashore)?

- What types of treatment conditions will you need to set up and how will you do it?
- What factors will you need to keep constant during each simulation?
- What should the characteristics of the initial population of bugs be at the beginning of each simulation?
- How long will you need to run the simulation (e.g., for three minutes or until 60 bugs are caught)?
- How many trials will you need to conduct for each treatment?
- How often will you collect data and when will you do it?
- How will you keep track of the data you collect and how will you organize the data?

To determine *how you will analyze your data,* think about the following questions:

- How will you determine if the environment affected the characteristics of a bug population?
- What type of calculations will you need to make?
- What type of graph could you create to help make sense of your data?

Investigation Proposal Required? ☐ Yes ☐ No

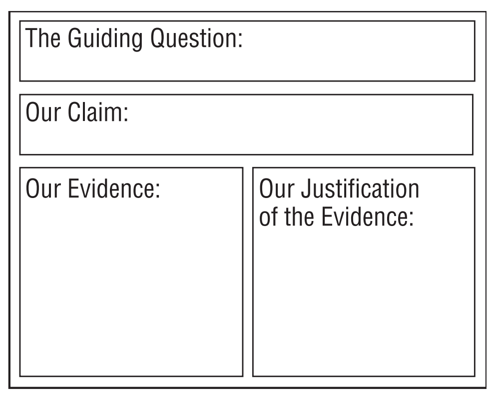
Connections to Crosscutting Concepts and to the Nature of Science and the Nature of Scientific Inquiry

As you work through your investigation, be sure to think about

- the importance of identifying causal relationships in science,
- the importance of looking at proportional relationships in science,
- how scientists use models,
- how theories are developed rather than discovered, and
- the different types of methods that scientists use to test ideas.

Argumentation Session

Argument presentation on a whiteboard



Once your group has finished collecting and analyzing your data, prepare a whiteboard that you can use to share your initial argument. Your whiteboard should include all the information shown in the figure on the right.

To share your argument with others, we will be using a round-robin format. This means that one member of your group will stay at your lab station to share your group's argument while the other members of your group go to the other lab stations one at a time to listen to and critique the arguments developed by your classmates.

The goal of the argumentation session is not to convince others that your argument is the best one; rather, the goal is to identify errors or instances of faulty reasoning in the arguments so these mistakes can be fixed. You will therefore need to evaluate the content of the claim, the quality of the evidence used to support the claim, and the strength of the justification of the evidence included in each argument that you see. In order to critique an argument, you will need more information than what is included on the whiteboard. You might, therefore, need to ask the presenter one or more follow-up questions, such as:

- How did you use the simulation to collect your data?
- What did you do to analyze your data? Why did you decide to do it that way? Did you check your calculations?
- Is that the only way to interpret the results of your analysis? How do you know that your interpretation of your analysis is appropriate?
- Why did your group decide to present your evidence in that manner?

- What other claims did your group discuss before you decided on that one? Why did your group abandon those alternative ideas?
- How confident are you that your claim is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your original argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most valid or acceptable answer to the research question!

Report

Once you have completed your research, you will need to prepare an investigation report that consists of three sections that provide answers to the following questions:

1. What question were you trying to answer and why?
2. What did you do during your investigation and why did you conduct your investigation in this way?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!

Natural Selection and Species Concept Fact Sheet

The Theory of Natural Selection

The fossil record provides convincing evidence that species evolve. In other words, the number of species found on Earth and the characteristics of these species have changed over time. However, these observations tell us little about the natural processes that drive evolution. A number of different explanations have been offered by scientists in an effort to explain why (or if) evolution occurs. One of these explanations is called natural selection. The basic tenets of natural selection are as follows (Lawson 1995):

- Only a fraction of the individuals that make up a population survive long enough to reproduce.
- The individuals in a population are not all the same. Individuals have traits that make them unique.
- Much, but not all, of this variation in traits is inheritable and can therefore be passed down from parent to offspring.
- The environment, including both abiotic (e.g., temperature, amount of water available) and biotic (e.g., amount of food, presence of predators) factors, determines which traits are favorable or unfavorable, because some traits increase an individual's chance of survival and others do not.
- Individuals with favorable traits tend to produce more offspring than those with unfavorable traits. Therefore, over time, favorable traits become more common within a population found in a particular environment (and unfavorable traits become less common).

How Biologists Define a Species

A species can be defined as "a population or group of populations whose members have the potential to interbreed with one another in nature to produce viable, fertile offspring, but who cannot produce viable, fertile offspring with members of other species" (Campbell and Reece 2002, p. 465). This definition is known as the biological species concept. A group of individuals can therefore be classified as a species when there are one or more factors that will prevent them from interbreeding with individuals from another group.

In nature, however, the biological species concept does not always work well. A bacterium, for example, reproduces by copying its genetic material and then splitting (this is called binary fission). Therefore, defining a species as a group of interbreeding individuals only works with organisms that do not use an asexual form of reproduction. Most plants (and some animals) that use sexual reproduction can also self-fertilize, which makes it difficult to determine the boundaries of a species. Biologists are also unable to check for the ability to interbreed in extinct forms of organisms found in the fossil record.

Therefore, many other "species concepts" have been proposed by scientists, such as the ecological species concept (which means a species is defined by its ecological niche or its role in a biological community), the morphological species concept (which means a species is defined using a unique set of shared structural features), and the genealogical species concept (which means a species is a set of organisms with a unique genetic history). The species concept that a scientist chooses to use will often reflect his or her research focus. All scientists, however, are expected to decide on a species concept, provide a rationale for doing so, and then use it consistently.

References

Benton, M. J. 1995. Diversification and extinction in the history of life. *Science* 268 (5207): 52–58.

Campbell, N., and J. Reece. 2002. *Biology*. 6th ed. San Francisco: Benjamin Cummings.

Lawson, A. 1995. *Science teaching and the development of thinking*. Belmont, CA: Wadsworth.