Adaptation to Changing Environments

1. Pre-Lab Reading

Chapter 18 "Evolution and the Origin of Species" Biology 2e, Openstax
Chapter 19 "The Evolution of Populations" Biology 2e, Openstax

2. Objectives

The purpose of this exercise is to explore factors that affect populations and contribute to the evolution of species of organisms.

Once you have completed this exercise, you should be able to:

1. Explain why genetic variability within a population is important for survival of a species in a changing environment.
2. Explain what a selective pressure is and how selective pressures lead to adaptation or extinction.
3. Describe the results of the three different types of natural selection.
4. Explain how competitors exert selective pressures on each other.
5. Explain how predators exert selective pressures on their prey.

3. Introduction

Looking at the world around you, it is evident that there is an incredible diversity of living organisms on Earth. Such diversity exists because the environment around us is also incredibly diverse, providing a wide range of different habitats for organisms.

Organisms are **adapted** to fit into the habitats in which they live. But how did these organisms become adapted in the first place? What happens if the habitat is altered through changes in the climate or the intervention of man? Is life doomed to extinction at

the hands of a changing environment? We will explore one idea of how adaptation occurs.

There are major differences between various kinds of life, such as dogs, cats, and birds. There are also substantial differences between kinds of dog-like animals such as domesticated dogs and foxes, between kinds of cat-like animals such as domesticated cats, lions and bobcats, and between kinds of birds such as canaries, penguins and parrots. These differences between kinds sometimes overshadow what may appear to be minor differences among individuals of the same group or species. But differences do indeed exist. Some are rather subtle while others are more obvious. One need only scan fellow classmates to convince oneself that there is a tremendous amount of **variation** among individuals, reflecting **genetic variability** built into the species *Homo sapiens* alone.

It is thought that some genetic variability is good (such as being able to run faster and avoid predators), leading to the increased production of viable offspring. On the other hand, some variability is bad (such as being clumsy, tripping over a rock, and getting eaten by a predator), leading to a decreased production of offspring.

Factors that operate on individuals and determine whether a given trait is good or bad are called **selective pressures**. A selective pressure may be physical (**abiotic)**, such as temperature (extremely cold weather selecting for individuals that may be hairy and can withstand the cold and against those who are not and can't withstand the cold), or selective pressures might be **biotic** (competitors using up needed resources so efficiently that weaker individuals perish).

Selective pressures either work for or against an individual. Since individuals that are selected for are leaving more offspring in the population, the population will tend to look more like those individuals and less and less like any individuals that are being selected against. This phenomenon is called **natural selection** and is a primary force in the process of **evolution**, how organisms change over time. Reproductive success can be measured as **fitness**, the number of viable offspring left in the next generation. If a particular inherited trait results in greater fitness, then natural selection would tend to favor that trait and we would expect evolution to occur.

It is thought that selective pressures operate on populations in three ways. First, there is **stabilizing selection** which occurs when the average individual is selected for and the extreme individuals are selected against. This will result in a population looking more like the average individuals. Secondly, there is **directional selection** which occurs when one of the extremes is selected for over the other extreme and even over the average individual. This results in the average expression of the trait shifting in the direction of the extreme that is being selected for. Third, **disruptional selection** occurs when both extremes are selected for and the average is selected against. This would result in two populations, one representing each old extreme with the old average being eliminated. Given enough time, these last two types of selection (directional and disruptive) are considered to be agents of evolution because they are causing the populations on which they operate to become different from what they were originally.

Getting back to the original questions, it is thought that as organisms move into new habitats, they meet new selective pressures. Some of these new pressures select for some traits that were previously selected against, and others select against some traits previously selected for, an idea known as **natural selection**. If enough genetic variability (producing different expressions of traits) is present in the population, the organisms become better and better adapted to the new habitat. If enough genetic variability is not present in the population, the organisms may face extinction.

This idea of adaptation as a result of natural selection is testable, as you will find out in this exercise that takes the form of a predator/prey interaction in which you become part of a pack of hungry predators in search of prey.

4. The Setting

Imagine that there has been a terrible drought, so bad that food supplies are extremely low and many animals are perishing. Almost like at an oasis in the middle of a desert, a small group of animals has congregated to feed on the seeds of some poor, hapless plants which, up to this point in time, have been surviving because of their drought tolerance. One type of plant produces 3 seed colors (white, mottled and red). A second plant, nearly dead because of competition for water with the first plant, produces

green seeds. The plants only grow in grassy areas, where they drop their seeds. The seeds of both plants are not particularly tasty and are usually overlooked, but these are not normal times.

⇒ Given this information, predict what will happen to the different populations of seeds as the "predators" (really herbivores) begin to feed on them in the grass. Record your hypothesis and prediction.

The predators are an interesting group also. A variety of animals, driven from their natural habitats by hunger, are represented. And, being from different habitats, they all have different adaptations for collecting food. There are:

- squirrels which use their **hands**
- finches which use their bills (**forceps**)
- anteater which use their tongues (**spatulas**)
- spoon-billed ducks (**spoons**)
- moles which use their claws (**forks**)

⇒ Predict what you expect to happen to their populations as they start to compete with each other for seeds. Which species will be the most successful? Why? The least successful? Why? Record your hypothesis and prediction.

⇒ What do you think will be the primary selective pressure(s) on the seeds?

⇒ What do you think will be the primary selective pressure(s) on the predators?

5. The Exercise

An area of the lawn next to the building has been chosen to support plants producing upwards of 600 seeds. This upper limit to the number of plants (each seed representing a plant) is called the **carrying capacity** of the area and represents the number of individuals that can be supported by the area. **Six hundred** beans will be scattered over this selection of lawn. These 600 beans will include large numbers of white, mottled and red seeds from one species of plant and few green seeds from the other species of plant that is dying from a lack of water.

Everyone in the class will be assigned to be one of the animals listed above and will forage for food using its special foraging adaptation (hands, forceps, spatula, or fork). Everyone will also receive a plastic cup in which to store collected beans. This cup represents your stomach. Take care of it!

There are a few simple rules to follow:

1. Maintain a distance of 6 feet from other participants.
2. You can pick up beans ONLY with your adaptation. Unless your hand is your adaptation, you may not use your fingers or thumb for anything except grasping your adaptation.
3. Your cup (stomach) cannot touch the ground. You must move beans from the ground to your stomach using your feeding adaptation. You cannot lay the cup sideways and scoop beans into it.
4. You cannot make any competitor throw up (empty the cup) on purpose. However, should that happen accidentally, all spilled beans are fair game.
5. Do not start foraging until your instructor tells you to do so. You will be allowed somewhere between 1 -4 minutes to forage. Any beans not in a cup at this time must be put back.

After a round of foraging, everyone will count the number of each type of bean they have eaten. Enter your own data, plus the class's summary data on the data tables provided. Note that there are two sets of data tables. The first set is used to keep track of the numbers of beans eaten each time. The second set is a pair of summary tables. Be sure to fill these as you go along also.

The most successful 50% of the predators will reproduce while the least successful 50% will die. The "dead' will be recycled as progeny of the successful predators.

The total bean kill will be calculated. From this we will be able to determine the number of beans left on the lawn. It will be assumed that the beans left will grow into plants which will reproduce, bringing the total number of beans on the lawn back up to 600 each time.

The plants will reproduce and leave their offspring in proportion to their abundance on the lawn after the hunt. Those in greater abundance will leave more seed behind in the next generation than those in lesser abundance. The total number of any type of seed for a new generation will be computed as follows:

$$\frac{\text{\# of beans of a particular color left on lawn}}{\text{total \# beans left on lawn}} \times 600 = \text{\# beans of a particular color to be on lawn in next generation}$$

For example, if after a hunt it is determined that there are a total of 200 beans left on the lawn, of which only 20 are white. The next generation of white beans would be:

$$\frac{20 \text{ white}}{200 \text{ total}} \times 600 = 60 \text{ white beans to be on the lawn for the next hunt}$$

This means that 40 beans must be added to the lawn for the next generation.

Similar computations will be made for each bean color and the beans added to the hunting area before the start of each new hunt. Happy hunting!

6. Procedure

1. Devise a hypothesis describing which plant and which predator you believe will be most fit to withstand the drought. Then, answer the following questions in your lab notebook before proceeding. Your answers will serve as your predicted outcome to the hunts over four generations.
    a. What will happen to the different populations of seeds as the predators begin to feed on them in the grass?
    b. What do you expect to happen to the predator population as they start to compete for the seeds? Which will be most successful? Least successful?
    c. What are some of the primary selective pressures on the seeds? On the predators?

2. Pick a card that indicates what animal you will play at the beginning of the exercise.

3. Pick your feeding apparatus and proceed to the designated hunting ground outside.

4. Feeding time will be limited to 3 minutes. Begin and end feeding as instructed and return to the lab.

5. Count the number of each type of seed you collected and enter the number in the Hunt 1 Results table.

6. Fill in the rest of the table and determine how many seeds of each type need to be added to the lawn for the next hunt.

7. Complete the First Generation Hunt Results table. Determine which animals survive and which are reincarnated into offspring of survivors.

8. Repeat steps 3-7 for a total of 4 hunts.

9. Complete the tables.

7. Conclusion and Summary

1. There were both biotic and abiotic selective pressures acting on the plants in this exercise. Name one specific selective pressure of each type. (Review the scenario laid out in section 4). Which plant was best adapted to each selective pressure?

2. Did your plant results support your hypothesis? Explain.

3. For the plant that produced the three seed colors, which colors were selected for (i.e. which survived best)? Which were selected against? Assuming white seeds were on one extreme and red seeds on the other extreme, what type of selection was occurring (stabilizing selection, directional selection, or disruptional selection)? Support your position.

4. What type of predator seemed best adapted to feeding on the prey? Why?

5. Did competition occur among the predators? If so, what effect did it have?

6. Did cooperation occur among predators? If so, what effect did it have?

7. Do the results concerning the predators support your hypothesis? Explain.