I'm Looking Over a White-Striped Clover: A Case of Natural Selection

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Case Objectives

By the end of this case, you will:

- Understand the process of natural selection and the importance of environment-specific adaptations.
- Be able to use the terms *variation, adaptation, natural selection,* and *evolution* as they apply to this and other scientific studies.
- Gain experience with the scientific method and be able to propose hypotheses and justifications to explain the distribution of the two variants of white clover.
- Design experiments to test hypotheses and describe data that would support these hypotheses.
- Understand and synthesize information in figures and tables.

Part I—"I'm Looking Over. . ."

White clover *(Trifolium repens)*, a small perennial plant, is found throughout the world, and has two forms. One variant has entirely green leaves *(plain)* and the other has green leaves with a prominent white stripe *(striped).*

Both variants of white clover (plain and striped) are found along the coast of Long Island, New York. Most of Long Island is only a few feet above sea level. A series of low grass-covered hills separated by shallow depressions covers the area behind the oceanfront dunes. The shallow depressions reach to the water table, so they tend to be permanently moist year round and do not freeze in winter. Water drains away quickly from the low hills, which tend to dry out many times over the year and freeze in the winter. The habitat in the shallow depressions is more hospitable to molluscs (snails and slugs) that feed on clover. One type of clover is more common in shallow depressions while the other type is more likely to be found on low hills.

At the end of the case, we will come back to New York and ask you to predict which type of white clover is most abundant in each microhabitat. But first, let's consider the abundance of these two types of clover on a larger scale.

Figure 1, below, shows the relative frequency of white clover variants in Minnesota and North Carolina.

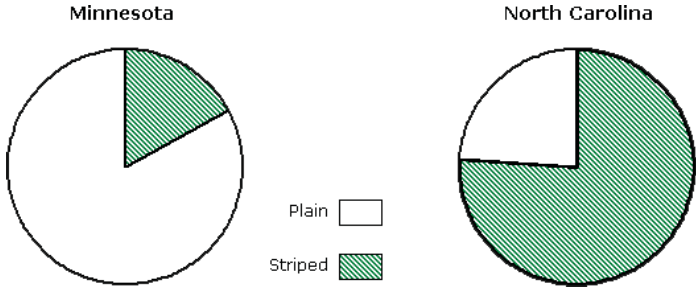

Table 1 provides additional information on Minnesota and North Carolina.

Table 1		
	Minnesota	*North Carolina*
Latitude	43–49° N	34–36° N
Mean elevation	0.365 km	0.213 km
Ave. monthly temp. range	–19.4° to 28.6° C	–2.6° to 31.3° C
High temperature	45.6° C	43.3° C
Low temperature	–51° C	–37° C
Mean # days with high above 32° C*	14	38
Mean # of days with low below 0° C*	154	75
Ave. yearly precipitation	66–76 cm	107–117 cm
Presence of herbivores (molluscs such as snails, slugs)	smaller population, not present in winter	larger, more active population, present all year

Data from Netstate.com and National Oceanic and Atmospheric Administration.
*Data for capitol cities (St. Paul , MN, and Raleigh, NC).

Exercise 1

A habitat is defined as the place and conditions under which an organism lives. This includes physical factors such as temperature, soil type, availability of nutrients, and availability of moisture as well as biological factors such as presence of herbivores, competitors for nutrients, and pathogens. Using the information in Table 1, briefly summarize the habitat features for white clover in each state.

Part II—Unlucky Clover

Some variants of white clover produce cyanide (CN), which is a powerful poison. Two gene products are required to produce active cyanide. One gene encodes an inactive cyanide-sugar complex that is stored in the plant cell's cytoplasm. The other gene encodes an enzyme that cleaves the sugar to activate the cyanide. This enzyme is stored in the cell wall. In general, striped clover contains cyanide; plain clover does not.

In consistent freezing temperatures, plant cell membranes (surrounding organelles and the cell itself) can burst. This is why the parts of plants above ground die back in colder climates. Root cells, however, are less likely to burst because they are underground and often store sugars, which protect the cell from freezing (just like antifreeze). This allows perennial plants to survive and grow again in the spring. Like the damage caused by freezing, herbivores can also damage plant cells. In the process of eating a leaf, herbivores destroy the membranes and organelles of the cells that make up the leaf.

Exercise 2

a. Why do you think the two gene products are stored in different parts of the cell?

b. Suggest at least two ways these products might come together to make active CN in nature.

c. Suggest a reason that clover may produce cyanide. That is, what advantage does a plant gain by producing cyanide? Also suggest a possible disadvantage of producing cyanide. Or might there be no advantage?

d. It takes energy for an organism to produce a particular structure such as a stripe on a clover leaf that is otherwise plain. Why might cyanide-producing clover produce striped leaves?

e. To explore this idea a little further, consider the following results of the hypothetical experiments shown below. In each situation, snails that have been taken from a wild habitat where both types of clover are present were put in a Petri dish containing varying types of clover. How would you interpret each result?

Table 2

Clover presented to snails	*Snail response*	*Interpretation*
plain leaves	eaten	
striped leaves and plain leaves	plain leaves eaten	
striped leaves	not eaten	
plain leaves painted with white stripe	not eaten	

Exercise 3

To understand why cyanide producing/striped clover is found at a higher frequency in North Carolina than in Minnesota, you must consider the "fitness" of each variant in the different habitats available in the two states. Fitness is determined by the ability of an organism to survive, grow, and reproduce in a particular habitat. You have probably heard the term "survival of the fittest," but if an organism is not able to also grow and reproduce, it will not be able to pass any of its alleles (genetic information) on to its offspring. An organism that has high fitness does well in its habitat and passes those favorable alleles onto its offspring when it reproduces.

Go back and review the habitats you described in Exercise 1 and think about the factors that would be important for plant fitness. Then list the ecological differences between North Carolina and Minnesota that might affect the fitness of each variant. In other words which factors might increase plant growth, survival, and reproduction in each habitat, and which factors might inhibit them?

Part III—Investigating Clover Distribution

Now that you have considered the different habitats in which the white clover is found and the factors affecting fitness in clover, you will develop hypotheses to explain the observed distribution of plain and striped clover. A hypothesis is a tentative answer to a well-framed question. This means that one has developed an explanation of an event based on preliminary data, observations, and perhaps the work of other scientists. Scientists use observations and data to develop and justify their hypotheses. A hypothesis is presented as a statement, not a question, and must be both *testable* (there must be some way to test if it is valid) and *falsifiable* (it must be possible to show that an incorrect hypothesis is false).

Exercise 4

Based on the data presented above and the differences in habitat between Minnesota and North Carolina, propose a hypothesis to explain each of the following: a) the higher frequency of plain clover in Minnesota, and b) the higher frequency of cyanide producing/striped clover in North Carolina. Justify the reasoning leading to each of your hypotheses. Be specific in terms of which variables (conditions) affect the frequency of each type of clover in each habitat. Remember to write your hypotheses as statements, not as questions.

Exercise 5

Are your hypotheses the same for the different habitats? Explain why individuals or populations from the same species may show different traits in different habitats. Use the term "selection pressure" in your explanation. Selection pressure refers to the influence a particular factor has on the ability of an organism to survive and reproduce.

Exercise 6

Once a scientist has formed a hypothesis, the next step is to test it with observations or experiments. Experiments should test only one variable at a time, and keep as many other factors as possible constant (which doesn't mean "unchanging," but only that they are the same for all experimental groups). Design experiments to test at least one hypothesis for *each* habitat.

Exercise 7

For each of the experiments you proposed in Exercise 6, describe data that would *support* your hypothesis and data that would *falsify* your hypothesis.

Part IV—What Did You Learn?

You have already thought about and used several concepts from evolutionary biology that aid in our understanding of how organisms adapt to their habitats. Now let's formally define them.

Variation

Differences among individuals of a species; different forms of the same trait.

Natural Selection

Differential survival and reproduction of individuals bearing different forms of the same trait.

Evolution

Genetic change in a population over time.

Adaptation

The evolution of a trait that increases the likelihood of survival and reproduction of an organism in a particular environment.

Exercise 8

a. What are examples of variation in the clover?

b. Refer back to Figure 1 showing the relative frequency of plain and striped clover in Minnesota and North Carolina. Explain why there is variation in the frequency of each type of white clover between each of these areas.

c. Adaptation in the white clover means that over time there is an increase in the frequency of particular traits that would help individuals in that population of white clover survive and reproduce in that particular habitat. What are examples of possible adaptations in the clover? Remember, adaptations are specific to a particular habitat.

d. Comparing the white clover populations in Minnesota and North Carolina, what would you need as evidence that evolution has occurred?

e. Several factors may exert selection pressure on different traits in white clover in each habitat. What factor would you propose is exerting the strongest selection pressure on the production or nonproduction of CN in white clover in Minnesota? In North Carolina?

Part V—Checking Your Understanding

Exercise 9

Based on your understanding of the clover case and the definitions provided above, which of the following statements are true? Explain *why each of the correct statements is true* or *correct each of the false statements* to produce a true statement.

a. Natural selection can fully be explained by the phrase "survival of the fittest."
b. Variation is necessary for natural selection to occur.
c. Adaptation is defined with respect to local environmental conditions (e.g., heat, cold, rainfall, competitors, herbivores).
d. Natural selection acts on populations, not individuals.

Exercise 10

a. Predict which variant of white clover would be most frequent in each of the microhabitats on Long Island (refer to Part I).
b. Write a paragraph that describes the distribution of clover in the microclimates of Long Island using the terms *variation, adaptation, natural selection,* and *evolution.* Be sure to fully describe each of these terms in your detailed paragraph.