CASE STUDY

ADAPTATION AND THE PEPPERED MOTH

Objective

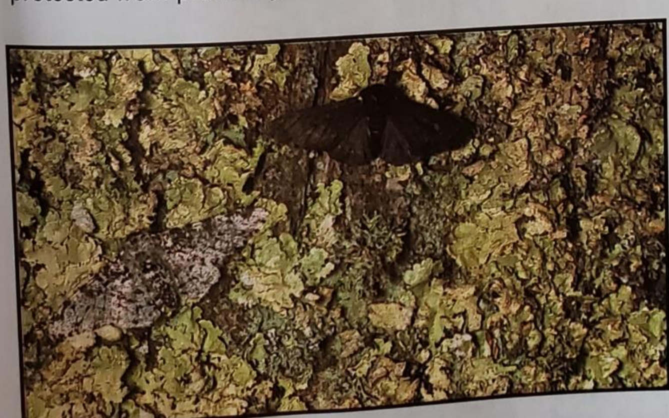
To examine how changes in the peppered moth are an example of a workable adaptation.

Background Information

Although uncertain about the mechanisms involved, Darwin felt that natural selection was the basis of evolutionary change. Today, scientists know that while the effect of natural selection may be subtle and complex, the basic concept is simple. Every population has a broad range of inheritable variations. Some characteristics make an organism better adapted to survive and reproduce, while others impede adaptation. Organisms that are best adapted will be most successful at reproducing, and relatively more of their offspring will enter the population. Over time, an increasing proportion of the population will have the adaptive trait.

The Case Study

In 19th-century England, collecting butterflies and moths was a popular hobby. Records indicate that one species, the peppered moth (*Biston betularia*), was especially common during the first half of the century. It had a whitish appearance with minute dots and speckles, from which it got its common name. The pigmentation gave it a remarkable resemblance to the light-colored lichens on the tree barks on which it rested. Because it was difficult to see, it was protected from predatory birds.



a)

b)

Whitish and melanic forms of white and black peppered moths (a) on light-colored bark, and (b) on polluted background.

The first *melanic*, or black, specimen was recorded near Manchester, England, around 1848. The difference between the black and white forms is due to a single mutation. The factor that produces black forms is dominant to the factor that produces the normal, whitish appearance. Although melanic forms were quite rare at the time, the mutation is known to occur quite frequently. There is little doubt that melanic individuals appeared before 1848, but they would have been at a distinct disadvantage. Their dark color would have made them easy prey for insect-eating birds.

The industrial revolution, which reached its peak in Manchester in the mid-1800s, introduced an unpredictable change to the environment of the peppered moth. Industrial fumes, containing excessive amounts of sulfur dioxide, destroyed almost all the lichens in the region. The tree bark became coated with coal dust, soot, and other dirt, and the adaptive advantage of the peppered moth was quickly diminished. In fact, the melanic individuals now had a selective advantage as they were more difficult for predators to see against the background of soot-stained tree bark. Eventually, this selection pressure caused the population to change from one dominated by light-colored individuals to one dominated by melanic individuals.

From what has been presented so far, answer the following questions:

a) What might have caused the appearance of the first melanic form? Explain.

b) If the environment caused the selection pressure for change, what was the actual selecting agent in this case?

Repeated studies and experiments have been undertaken during this century to determine the extent of the selection pressure on the peppered moth in both polluted and nonpolluted locations. In one experiment, recordings have been made from direct observations of large numbers of both melanic and normal forms of *Biston betularia.* The procedure involved the release of both types of moths, followed by tabulations based on recapture rate. The results (shown in the table below) have enabled scientists to calculate the selection pressure against melanic forms as well as that against normal whitish forms.

	No. released		No. recaptured		% recaptured	
Location	M	N	M	N	M	N
Nonpolluted	473	496	(30)	62	6.3	12.5
Polluted	447	137	(130)	(18)	27.5	13.0

Adapted from H.B.D. Kettlewell, *Annual Review of Entomology 6* (1961): pp. 245–62. Note: M = melanic, N = normal; numbers in parentheses have been rounded to the next highest whole number.

c) What might have happened to the moths that were not recaptured?

d) How can you account for the differences in the recapture numbers for polluted and nonpolluted sites?

e) What generalization do the results suggest about environmental selection for the two forms of moth?

f) Explain why the melanic form is more abundant today than in the early part of the 19th century.

Case-Study Application Questions

1 Even a population that is 98% melanic retains the factor for light color in some of its members. What would happen if the environmental conditions were again reversed?

2 Explain the following statements as they apply to this case study:

- Evolution and adaptation need not always involve long periods of time.
- While the change was quick, it was actually quite small.
- Evolution and adaptation usually occur by means of small changes. ■

CASE STUDY

RESISTANCE TO DDT

Objective

To investigate the connection between pesticides and natural selection.

Background Information

Environmental change introduced by human activities provides good evidence for natural selection. Examples of such activities include the extensive use of drugs and antibiotics to treat certain kinds of pathogens, and the use of pesticides to control diseases such as malaria and yellow fever. Bacteria and insects, like all living organisms, demonstrate variability. Variability results from mutations and chromosomal rearrangements, which are present in a population at very low levels at all times. This variability enables natural selection to take place.

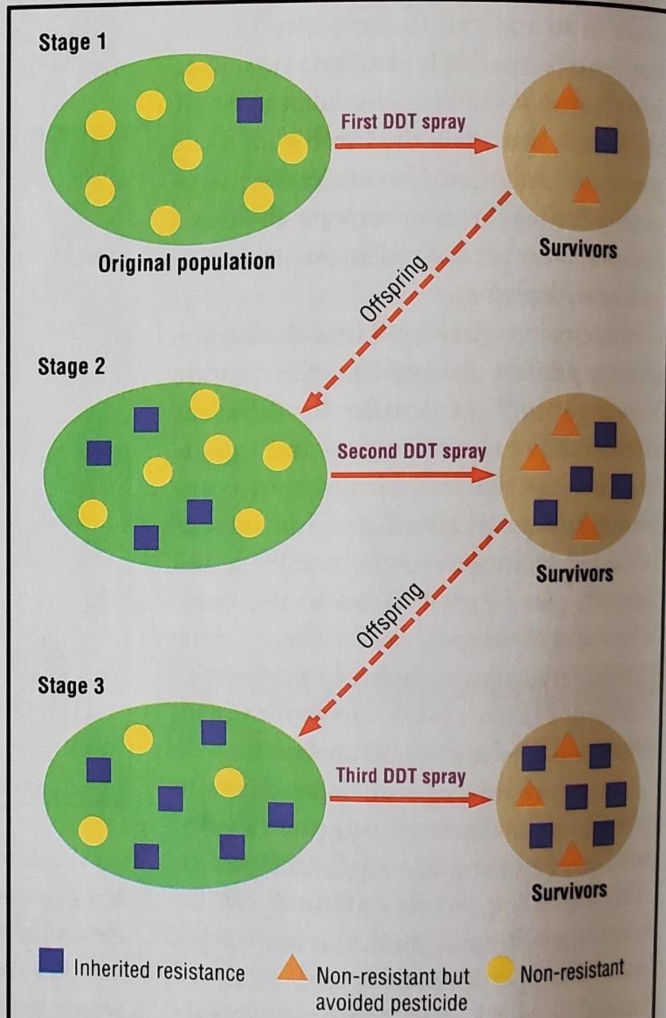
The application of pesticides to target populations favors strains that are resistant to the pesticides. Normally, such strains are uncommon in a population; however, once the environment is changed, the resistant forms have the better chance of survival. The resistant forms will then be reproduced in larger numbers in succeeding generations. Thus, they are spread rapidly throughout the population. As resistance develops, the frequency of application and/or the dosage is increased to maintain levels of control. Increased application and dosages of chemicals further increase the size of the resistant populations. Thus, chemicals that once controlled a pest population are no longer effective.

The Case Study

DDT is a chemical pesticide that has had enormous success in the battle against insect pests. Since it was first used in World War II, to get rid of head lice, it has been effective in the fight against controlling mosquito and other insect populations known to cause diseases such as malaria and yellow fever. Because of its potentially harmful accumulation in the food chain and the possible danger to humans, regulations banning or restricting the use of DDT were implemented by a number of countries in the early 1970s. However, DDT continued to be used in many less developed countries.

Some scientists believe that the resistance displayed by the pests did as much to spell the demise of DDT as did regulations directed at curtailing its use. After 1950, when pesticides came into widespread use, the number of pest species, including insects, that have developed resistant strains has increased dramatically.

Examine the following illustration to determine the effect of repeated sprayings or applications of DDT on a hypothetical population.



a) Where did the resistant trait come from in the original population?

b) What happens to the nonresistant trait over the three stages of the population? Why?

c) What happens to the resistant trait over the course of evolution in this hypothetical situation? Why?

d) Explain the difference in the selection pressure (the trait natural selection is favoring) in stages 1 and 3.

e) Is this a case of "evolution in action"? Explain.

A complicating factor in the use of pesticides such as DDT is that some pests develop multiple resistance and cross-resistance. In cross-resistance, the organism develops a resistance to one compound and then achieves resistance to others, usually in the same chemical group. For example, DDT-resistant houseflies tolerate higher levels of a closely related chemical that is also used to control this common household pest. Multiple resistance is much more serious and has wide-ranging consequences. In this type of resistance, pests develop a tolerance for many classes of different compounds. This effect is common in pests that have a strong resistance to DDT. Insects with this factor, called *kdr* (knock-down resistance), are preadapted to synthetic chemicals that are chemically quite different from DDT.

An understanding of the effects of multiple resistance can be illustrated by the World Health Organization's (WHO) 1955 global education program to control the anopheles mosquito (carriers of the malarial parasite). The WHO strategy included a two-stage offensive: (1) spraying DDT and other pesticides inside dwellings where anopheles mosquitoes frequently obtain blood meals from humans, and (2) treating infected individuals with anti-plasmodium drugs to destroy the blood parasites that cause malaria.

For about 15 years, the program showed remarkable success. For example, within a 10-year period in India the annual incidence of malaria was reduced from 100 million cases to 50 000, with a corresponding reduction from three million to 25 in Sri Lanka. By 1970, efforts to control the mosquitoes that carried plasmodia were failing. By 1980, 51 of the known 60 species of anopheles mosquitoes were capable of transmitting the malarial parasite. During the same time as the WHO mosquito spray programs, many countries had implemented extensive agricultural programs. Crops such as cotton, rice, and tobacco were sprayed with pesticides, including many of the same ones used in the malaria-eradication program.

f) What explanation can be given for the early success of the malarial spray program and its eventual failure in later years?

g) What combination of factors most likely contributed to a strong selective force for developing resistant strains in the mosquito population?

h) Because the anopheles mosquito has developed resistance to DDT, what might be the long-term effectiveness of other known synthetic chemicals in controlling malaria? Explain.

Case-Study Application Questions

1 The resistance of mosquitoes to DDT is a good example of natural selection. Explain how this case study supports Darwin's observation that

a) hereditary variations exist among species

b) natural selection acts on organisms with these variations.

2 Discuss the following statement: "Natural selection as the cause of evolution has been neither proved nor disproved." ■