14–3 Genetics and Evolutionary Theory

Guide For Reading

- What causes genetic variations? What do these variations have to do with evolution by natural selection?
- How are evolution, fitness, and adaptation described in genetic terms?

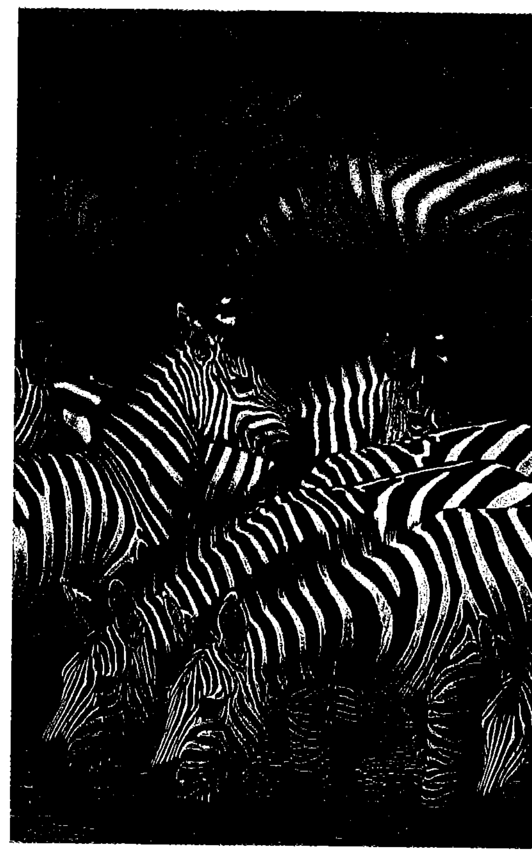
In developing his theory of evolution, Darwin worked under a serious handicap. He had no idea how the inheritable traits so important to his theory were passed from one generation to the next. For although Mendel had formulated his genetic principles during Darwin's lifetime, his work remained unknown to most scientists until the early part of this century. The rediscovery of Mendel's work and the growth of our knowledge of genetics enable us to explain the mechanism of evolution more completely than Darwin could. Genetics and evolutionary theory are inseparable. Today we define fitness, adaptation, species, and the process of evolutionary change in genetic terms.

Genes: Units of Variation

Genes, the carriers of inheritable characteristics, are also the source of the random variation upon which natural selection operates. Mutations cause some variation. Much additional variation arises during meiosis as the parents' chromosomes are copied, shuffled like a deck of playing cards, and dealt out to the gametes.

It is important to remember that genetic variation is not controlled or directed toward a goal. It does not occur because an organism needs or wants to evolve—an idea central to Lamark's theory. Sometimes genetic variation occurs; sometimes it doesn't. When variations do occur, natural selection then goes to work, selecting the successsful ones.

Figure 14–10 ***It is a zebra's genes that determine the exact pattern of the animal's stripes. Notice that there are slight variations in the stripes of each animal.***



Raw Material for Natural Selection

In the evolutionary struggle for existence, entire organisms, not individual genes, either survive and reproduce or do not. How then does natural selection operate? Natural selection can operate only on the phenotypic variation among individuals. As you learned in Chapter 9, an organism's phenotype includes all the physical and behavioral characteristics produced by the interaction of genotype and environment.

You can sample phenotypic variation by measuring the height of all the students in your class. Using mathematics, you can calculate an average height for this group. Many students will be just a little taller or shorter than average. However, a few very tall or very short individuals may be in your class. If you graph the number of individuals of each height, you will get a curve similar to the one shown in Figure 14–11 on page 300. This phenotypic variation is produced by a combination of genetic instructions and environmental influences, such as nutrition and exercise. If your classmates are not malnourished, most (though not all) of the variations in height you observe

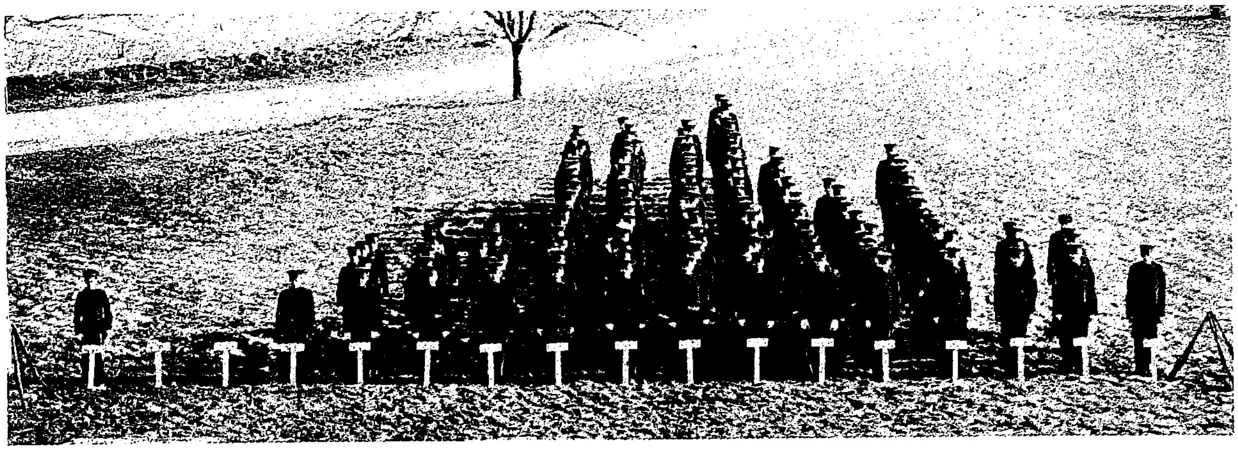


Figure 14–11 This photograph shows height distribution in a population of U.S. Army recruits. As you can see, most of the recruits fall in the range of average heights in the center of the curve. There are relatively few very tall or very short recruits.

can be said to result from differences in genotype. Of course, you can also observe many other kinds of phenotypic variation among your classmates. For example, variations in skin, hair, and eye color, and variations in the shapes of noses, the curves of lips, and the amount of body hair can be observed.

In nature, organisms show as many variations as humans, although most humans are not aware of this. For example, to the casual observer, one zebra looks much like any other zebra. But when researchers study the characteristics of many individuals of a species, they find the same sort of distribution for each characteristic that you saw in human height. It is this sort of variation in organisms that provides the raw material for natural selection.

Evolution as Genetic Change

In order to describe the evolution of plants and animals, modern evolutionary biologists study groups of organisms called **populations.** A population is a collection of individuals of the same species in a given area whose members can breed with one another. For example, all the fishes of a certain species in a single pond could be considered one population. Individuals in another, separate pond would belong to a different population, even if that pond was close by.

Because all members of a population can interbreed, they and their offspring share a common group of genes, called a **gene pool.** Each gene pool contains a number of alleles—or forms of a certain gene at a given point on a chromosome—for each inheritable trait, including alleles for recessive traits. The number of times an allele occurs in a gene pool compared with the number of times other alleles for the same gene occur is called the **relative frequency** of the allele.

Sexual reproduction alone does not change the relative frequency of alleles in a population. To understand why, you can compare the combinations of alleles produced by sexual reproduction to the different hands you get when you shuffle and deal a deck of playing cards. Shuffling and reshuffling produce an enormous variety of different hands. But shuffling alone will not change the relative numbers of aces, kings, fours, or jokers in the deck.

With this in mind, we can view evolution in another way. **Evolutionary change involves a change in the relative frequencies of alleles in the gene pool of a population.** And, as you can see in Figure 14–13, when the relative frequencies of alleles in a population change, the curves that describe the distribution of traits controlled by those alleles also change. In the case of the peppered moths, as the alleles for dark color increased, more dark-colored moths appeared in the population. This is the visible result of evolutionary change.

Figure 14–12 These flamingoes represent a tiny part of a much larger group of interbreeding individuals of the same species, or population. Because all members of a population can interbreed, they share a common group of genes, or gene pool.

Genes, Fitness, and Adaptation

Each time an organism reproduces, it passes copies of its genes to its offspring. Thus we can define evolutionary fitness as the success an organism has in passing on its genes to the next generation. And we can define an adaptation as any genetically controlled characteristic of an organism that increases its fitness.

Let's return to our discussion of human weight lifters for a moment. Muscles acquired as a result of exercise are not passed on to offspring. Thus they cannot be considered an evolutionary adaptation and cannot contribute to evolutionary fitness. A gene that somehow allowed an individual to develop stronger muscles by doing less work or by eating less food, on the other hand, might be a useful adaptation under certain circumstances. This gene could be passed on to offspring.

A Genetic Definition for Species

In the past, biologists defined a species as a group of organisms that looked alike. Species were defined according to precise physical descriptions, and differences among individuals were seen as imperfections or mistakes. This definition, however, did not recognize that variation in a population is the rule rather than the exception.

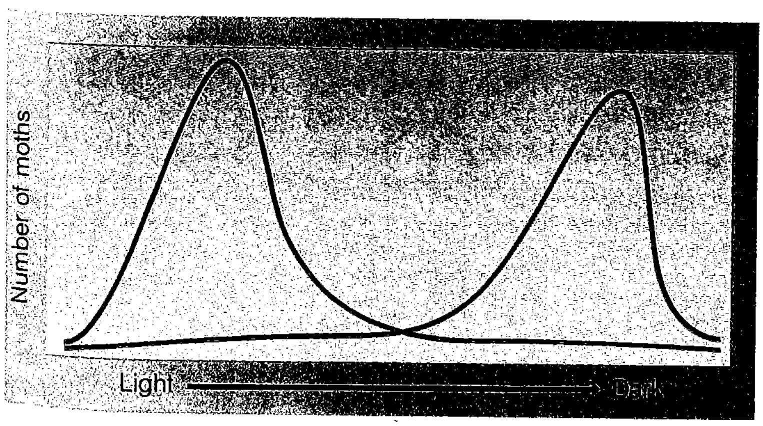


Figure 14–13 Sometimes the frequency of an allele changes in a population. The light-colored moths occurred with greater frequency before the Industrial Revolution. After the Industrial Revolution, the frequency of dark-colored moths became greater. How do you explain these changes?

Figure 14–14 *A species is a population of organisms that breed with one another and share a common gene pool. If this baby hippopotamus survives, it can pass on its genes to another generation.*

We now define a species as a group of similar-looking (though not identical) organisms that breed with one another and produce fertile offspring in the natural environment. This definition is important because it allows us to determine what it means to belong to the same or different species.

Because members of a species can breed with one another, they share a common gene pool. Because of that shared gene pool, a genetic change that occurs in one individual can spread through the population as that individual and its offspring mate with other individuals. If the genetic change increases fitness, that gene will eventually be found in many individuals in the population. Members of a species can thus evolve together and interact with their environment in similar ways.

14–3 SECTION REVIEW

1. What causes phenotypic variation? How is phenotypic variation related to natural selection?
2. Define evolution in genetic terms.
3. What are the genetic definitions of fitness and adaptation?
4. **Critical Thinking—Applying Concepts** Scientists notice that the individuals in a certain plant species are growing taller with each successive generation. Explain what is happening to the gene pool of this population.