# 15 Processes of Evolution

## Chapter Outline



Evolution explains the interrelatedness of all of the different species of microbes, plants, and animals. Some commonalities of life include the genetic code, the similarity of developmental genes, and similar biochemical processes (glycolysis) across the phyla. In this chapter, we examine the history of thought on life's mechanisms of change, derived from the analytical observations and ideas of Charles Darwin.

Evolution's factual basis is that organisms have always changed and are still changing today. Evidence of evolutionary change comes from analysis of fossils, biochemistry, homologous structures, and biogeography, and the direct observation of change. Today, as we observe active evolution in the development of antibiotic-resistant bacteria and pesticide-resistant insects, we ask, "How have these changes occurred over long periods of time?" This is the theoretical side of evolutionary study. It is important to remember that a theory is not just a random thought or idea. Rather, a theory is a well-developed idea, repeatedly tested with experiments, and it provides a cohesive framework for analysis.

The basis of evolutionary theory, which explains how populations change over time, was first proposed by Darwin and Alfred Russell Wallace. The success of their ideas hinged on the idea of natural selection. Darwin observed that there is variation among the members of any species and that not all members of each species survive to reproduce. Only those members of a species that are well adapted thrive enough to reproduce and to pass their genes on to the next generation. Thus, some variants of form are passed from generation to generation, resulting in evolution, a change over time.

A primary source of new variation in a population is mutation of DNA, resulting in offspring that have a DNA sequence that is different from that of their parent or parents. In addition, genetic variation results from meiosis, nonrandom mating, gene flow, and genetic drift. These changes can be estimated by counting the frequencies of traits and genes in a population. The Hardy–Weinberg theorem is more about non-evolution than evolution, as it states that in order for a population to "not evolve" over time, five conditions must exist: no mutations, no gene flow, no environmental impact on survival, random mating, and a very large (infinite) population size. The Hardy–Weinberg conditions are not obtained in nature, except in contrived settings set up by humans, so evolution proceeds.

Changes in the phenotype of a population over time can follow distinct patterns, including stabilizing, directional, or disruptive selection. These changes are assessed by observations of phenotypes or observable behaviors. The changes underlying these phenotype changes can be seen in the genes of organisms or genomes. Sequencing DNA or proteins and then looking at mutation rates is used to research the evolution of genomes. These techniques have provided many new insights into evolutionary theory and the interrelationships of different organisms, including the splitting of prokaryotes into two groups and the creation of a new level of classification called the *domain*.

The emphasis in Chapter 15 is primarily on **Big Idea 1**, but some of **Big Idea 4** is addressed, as well.

The specific parts of the AP Biology curriculum covering **Big Idea 1:** The process of evolution drives the diversity and unity of life, recognizes that evolution ties together all parts of biology, include:

- **1.A.1:** Natural selection is a major mechanism of evolution.

- **1.A.2:** Natural selection acts on phenotypic variations in populations.
- **1.A.3:** Evolutionary change is also driven by random processes.
- **1.A.4:** Biological evolution is supported by scientific evidence from many disciplines, including mathematics.
- **1.C.3:** Populations of organisms continue to evolve.

Specifically, the curriculum addressing **Big Idea 4:** Biological systems interact, and these systems and their interactions possess complex properties, includes:

- **4.C.3:** The level of variation in a population affects population dynamics.

## Chapter Review

**Concept 15.1** *introduces evolutionary theory and the ideas of Darwin, Wallace, and others.*

1. Explain in evolutionary terms why a different flu vaccine is developed each year.

2. Explain the meaning of *theory* in the context of atomic theory and evolutionary theory.

3. Charles Darwin noted that the species of South America's temperate regions were more similar to the species of South America's tropical regions than they were to the species of Europe's temperate regions. Explain how this observation guided his evolutionary thinking.

4. In addition to observing biological specimens, Darwin also read a book about geology by Charles Lyell. Discuss how Lyell's concepts of geological time and space influenced Darwin's biological considerations of life on Earth.

5. Describe two ways that the discovery of genes and chromosomes affected evolutionary theory.

**Concept 15.2** *examines the primary mechanisms of evolution, including mutation, gene flow, genetic drift, and nonrandom mating.*

6. Explain the phrase "individuals do not evolve, populations do."

7. Describe the origin of new genetic variation in the genetic code.

8. It has been observed that 10 percent of the Japanese population has blood type AB. Discuss this observation using the terms *allele*, *gene frequency*, and *gene pool*.

9. Describe one difference and one similarity between artificial selection and natural selection, and explain how each influenced Darwin's writings on evolution.

10. Darwin made the two key observations presented below. Explain how each supports his concept of natural selection.

a. Populations have a large amount of variation within them. ________________

b. Most individuals that are born do not survive to reproduce. ________________

11. In northern Canada, there are two large herds of caribou that seldom encounter each other. Speculate on the amount of gene flow between these populations.

12. Explain how the bottleneck principle relates to conservation problems for endangered species.

13. While observing wild birds, a fellow student asks, "Why are male cardinals such a brilliant red? Doesn't that make them more visible to predators?" Use your knowledge of sexual selection to answer how the predation risk of high visibility might be offset.

**Concept 15.3** *describes how we can measure evolutionary change with the Hardy–Weinberg equilibrium principle.*

14. Identify the five principles of the Hardy–Weinberg theorem that must be true for a population to be in genetic equilibrium.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

15. Assume that a local population of birds experiences immigration of additional birds of the same species from another country each winter, and that there is a limited amount of breeding during those winters. For each of the five principles of the Hardy–Weinberg theorem, explain why it would be impossible for the local population *not* to evolve.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

16. Discuss the challenge to evolutionary theory based on the fact that many populations of organisms appear to be stable and unchanging from year to year and many of their genotypes are not significantly changing from Hardy–Weinberg expectations.

**Concept 15.4** *considers the interaction of genes with each other and with the environment to create shifts in the phenotoypes of a population based on selection.*

17. A biologist finds a population of small arthropods on a Pacific island with white sand beaches between black lava flows. Most of the arthropods are either dark gray or very light gray, but less than 10 percent of the population is an intermediate gray color. Identify this pattern of selection, and discuss how it might operate in this manner.

18. In lizards, it has been shown that there is an optimum size egg for survival: eggs that are too big or too small are not adaptive. Identify this pattern of selection and discuss this example.

**Concept 15.5** *describes specific processes that operate at the level of genes and genomes. One of the most important examples in this section is called the* heterozygote advantage.

19. Discuss the claim that a heterozygote advantage promotes genetic diversity within a population.

20. Explain whether or not a neutral mutation affects the phenotype of an individual.

21. Much of the DNA in eukaryotes is noncoding, in that proteins are not produced using it as a template. For many years, the noncoding DNA was called "junk" DNA, but recent work shows that it has several important functions. Identify two possible functions of noncoding DNA.

**Concept 15.6** *discusses how new genes with novel functions can form in a population.*

22. Sexual reproduction generates diverse combinations of genes within a population. However, not all species reproduce sexually, revealing some of the drawbacks of sexual reproduction. Discuss three of these drawbacks.

23. Two "endosymbiotic" organelles in eukaryotes appear to have resulted from lateral gene transfer from prokaryotes. What new benefits did these organelles confer on the recipients?

24. Give an example of gene duplication in an organism, and discuss how the duplication appears to be the basis for evolutionary change.

**Concept 15.7** *examines how knowledge of evolutionary theory is used to combat disease, benefit agriculture, and study protein function.*

25. Explain the evolutionary thinking behind the advice to farmers to use different herbicides in consecutive years.

26. Discuss how genomic databases allow for better detection and treatment of diseases.

## Science Practices & Inquiry

In the AP Biology Curriculum Framework, there are seven **Science Practices**. In this chapter, we focus on **Science Practice 2:** The student can use mathematics appropriately. More specifically, we focus on **Science Practice 2.2:** The student can apply mathematical routines to quantities that describe natural phenomena.

Question 27 asks you to apply mathematical methods to data and predict what will happen to the human population in the future (**Learning Objective 1.3**). Most of the Science Practice questions up to this point have been free-response questions. The redesigned AP Biology exam has a multiple-choice portion and a set of grid-in items that require you to apply mathematics to biological concepts. An equation sheet, similar to the one inside the back cover of this workbook, will give you the commonly used equations, such as the Hardy–Weinberg principle that is used in the question below.

27. Cystic fibrosis is an autosomal recessive genetic disorder. This disease occurs in 0.4 out of 1,000 children born in the United Kingdom. Calculate the percent of carriers in the UK, and record your answer in the grid provided. Express your answer to the hundreth of a percent.