Preface

Goals of the Eleventh Edition

The mission of Dr. Sylvia Mader's text, *Biology*, has always been to give students an understanding of biological concepts and a working knowledge of the scientific process. The concepts of biology and the methodology of science can be used to understand the particulars of new ideas or of a system, on any scale, from the cell to the biosphere.

In the twenty-first century, students are being exposed, almost on a daily basis, to exciting new discoveries and insights that, in many cases, were beyond our predictions even a few short years ago. It is our task, as instructors, not only to make these findings available to our students, but to enlighten students as to why these discoveries are important to their lives and society. At the same time, we must provide students with a firm foundation in those core principles on which biology is founded, and in doing so, provide them with the background to keep up with the many discoveries still to come. In this text, we integrate a tested, traditional learning system with modern digital and pedagogical approaches designed to stimulate and engage today's student.

The authors of the text identified several goals that guided them through the revision of *Biology*, Eleventh Edition:

1. build upon the strengths of the previous editions of the text,
2. introduce themes that connect the content of the text across multiple chapters,
3. deploy new pedagogical elements, including multimedia assets, to increase student interaction with the text,
4. develop a new series of digital assets designed to engage the modern student and provide assessment of learning outcomes.

Unit Themes

We recognize that scientific literacy is not based upon the memorization of a series of facts. Instead, learning is based on establishing associations and links between what, at first glance, appear to be diverse topics. The main themes we have chosen to emphasize include

- Evolution
- Nature of Science
- Biological Systems

The cover of this textbook, a gray wolf over a caribou skeleton with the Colorado mountain range in the background, was selected to reflect the importance of these three themes to the life sciences. By studying the historical evolutionary relationship of these species in their natural environment, biologists have been able to better understand the interdependence of the occupants of this ecosystem.

These themes are integrated into all aspects of the textbook, from the unit learning outcomes to the theme-based feature readings in the text. At the start of each chapter, "Following the Themes" introduces the relationship of the chapter's content to each of the themes. At the end of each chapter, "Connecting the Concepts with the Themes" not only reminds the student of the relationships between chapter content and the three core themes, but also acts as a prelude to topics in the next few chapters of the text. In essence, the themes act as the threads that unite the concepts throughout the text, enabling the student to see relationships from the molecular to ecosystem levels of biology.

UNIT LEARNING OUTCOMES

The learning outcomes for this unit focus on three major themes in the life sciences.

Evolution	Support, with examples, the statement that "Darwin's theory of evolution by natural selection is a unifying theory of biology."
Nature of Science	Examine the methods by which scientists obtain evidence in support of evolutionary change.
Biological Systems	Analyze how evolution occurs at the molecular, organismal, and population levels of biology.

FOLLOWING *the* THEMES

CHAPTER 15 DARWIN AND EVOLUTION

UNIT 3 EVOLUTION

Evolution	Darwin's theory of natural selection proposes that all life on Earth descends from a common ancestor.
Nature of Science	A scientific theory, such as Darwin's theory of evolution by natural selection, is supported by abundant evidence.
Biological Systems	Evolution by natural selection comes about from interaction between the organism and its environment.

CONNECTING *the* CONCEPTS *with the* THEMES

Evolution

- All life on Earth has the same building blocks of inheritance, namely DNA, and shares in common many proteins essential to life.
- Vertebrate embryos develop the same set of features early in development, even though these features develop into very different structures in the adult.
- All animals have genes in common that control the development of the body plan. *Hox* genes orchestrate the development of the body plan in all animals.
- The Tree of Life project has collected information on hundreds of organisms. Anatomy, DNA, and behavior are used to trace all of life back to a single common ancestor.

Nature of Science

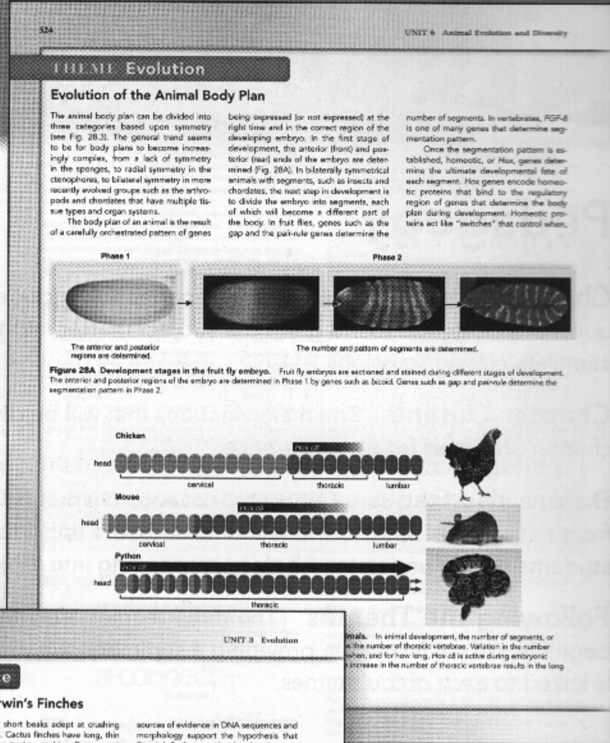
- Fossils provide us with a glimpse of life in the past. Transitional fossils have been discovered that support the theory of evolution via gradual changes to preexisting forms, such as alteration of hindlimbs in whale ancestors.
- At the level of the gene, small changes in the DNA sequence of switches that turn genes "on" and "off" can produce new features, such as the black spot on the wings of *Drosophila biarmipes* males that play a role in mating rituals.
- Evolution does not always occur over millions of years; it can be witnessed over a short period of time. On the Galápagos Islands, a shift in the average beak depth of ground finches can be observed as the weather changes.

Biological Systems

- Darwin proposed that natural selection is, in essence, a struggle for existence.
- Organisms tend to produce more offspring than can be supported by the environment.
- All living things require resources such as food, water, and mates in order to survive and reproduce—the intensity of competition is determined by the availability of resources in the environment.
- Natural selection operates on variation in populations. Change in the environment, both long and short term, can cause populations to evolve.

Evolution Theme

Evolutionary change, along with the mechanism of natural selection, represents the unifying concept of the biological sciences. In essence, biological evolution is the thread that links all life together. Throughout this textbook, feature readings on this theme both demonstrate the process of evolution and illustrate how scientists study and measure evolutionary change. By following this theme through the book, students develop a better understanding of why evolution is a dynamic process, and one that has shaped, and will continue to influence, life on this planet.


524 UNIT 6 Animal Evolution and Diversity

THEME Evolution

Evolution of the Animal Body Plan

The animal body plan can be divided into three categories based upon symmetry (see Fig. 28.3). The general trend seems to be for body plans to become increasingly complex, from a lack of symmetry in the sponges, to radial symmetry in the ctenophores, to bilateral symmetry in more recently evolved groups such as the arthropods and chordates that have multiple tissue types and organ systems.

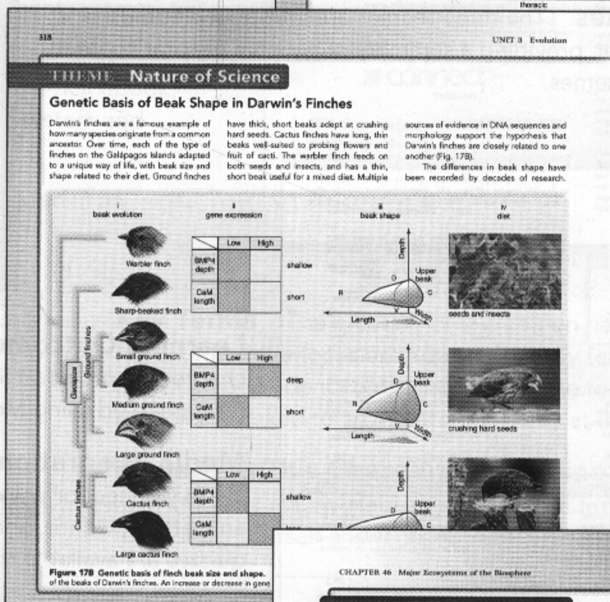
The body plan of an animal is the result of a carefully orchestrated pattern of genes being expressed (or not expressed) at the right time and in the correct region of the developing embryo. In the first stage of development, the anterior (front) and posterior (rear) ends of the embryo are determined (Fig. 28A). In bilaterally symmetrical animals with segments, such as insects and chordates, the next step in development is to divide the embryo into segments, each of which will become a different part of the body. In fruit flies, genes such as the gap and the pair-rule genes determine the number of segments. In vertebrates, FGF-8 is one of many genes that determine segmentation pattern.

Once the segmentation pattern is established, homeotic, or Hox, genes determine the ultimate developmental fate of each segment. Hox genes encode homeotic proteins that bind to the regulatory region of genes that determine the body plan during development. Homeotic proteins act like "switches" that control when,

Figure 28A Development stages in the fruit fly embryo. Fruit fly embryos are sectioned and stained during different stages of development. The anterior and posterior regions of the embryo are determined in Phase 1 by genes such as bicoid. Genes such as gap and pair-rule determine the segmentation pattern in Phase 2.

Nature of Science Theme

Through the processes of observation, the application of the scientific method, and the use of both inductive and deductive reasoning, scientists study life. To develop a deeper understanding of the biological sciences, students must appreciate that the study of life is a process, and that this process has application in their everyday lives. This theme focuses not only on how biologists do science, but also on the influences scientific inquiry has on our understanding of our world.


318 UNIT 3 Evolution

THEME Nature of Science

Genetic Basis of Beak Shape in Darwin's Finches

Darwin's finches are a famous example of how many species originate from a common ancestor. Over time, each of the type of finches on the Galápagos Islands adapted to a unique way of life, with beak size and shape related to their diet. Ground finches have thick, short beaks adept at crushing hard seeds. Cactus finches have long, thin beaks well-suited to probing flowers and fruit of cacti. The warbler finch feeds on both seeds and insects, and has a thin, short beak useful for a mixed diet. Multiple sources of evidence in DNA sequences and morphology support the hypothesis that Darwin's finches are closely related to one another (Fig. 17B).

The differences in beak shape have been recorded by decades of research.

Figure 17B Genetic basis of finch beak size and shape. of the beaks of Darwin's finches. An increase or decrease in gene

Biological Systems Theme

From cells to ecosystems, all life is interconnected. Increasingly, scientists are becoming aware that small changes in the chemical composition of an ecosystem can have a tremendous influence on the life in that ecosystem. This theme was chosen to provide a holistic approach to the study of the life sciences, by demonstrating not only that all life is interconnected, but also that the principles regulating life at the cellular level play a role in physiology and ecosystem biology as well.


CHAPTER 46 Major Ecosystems of the Biosphere 903

THEME Biological Systems

Biomagnification of Mercury

Scientists have known since the 1950s that the emissions of mercury into the environment can lead to serious health effects for human beings. Studies show that fish and wildlife exposed to mercury emissions are negatively impacted. Humans are impacted if they come into contact with affected fish and wildlife. Recent fish studies have shown a widespread contamination of mercury in streams, wetlands, reservoirs and lakes throughout the majority of the U.S.

Mercury becomes a serious environmental risk when it undergoes bioaccumulation in an organism's body. Bioaccumulation occurs when an organism accumulates a contaminant faster than it can eliminate it. Most organisms can eliminate about half of the mercury in their bodies every 70 days if they can avoid ingesting any additional mercury during this time. Problems arise when organisms cannot eliminate the mercury before they ingest more.

Mercury tends to enter ecosystems at the base of the food chain and increase in concentration as it moves up each successive trophic level. Top-level predators and organisms that are long lived are the most susceptible to high levels of mercury accumulation in their body tissues.

Mercury exposure for humans generally occurs due to eating contaminated fish or breathing mercury vapor. Methylmercury is the form that leads to health problems such as sterility in men, damage to the central nervous system, and in severe cases, birth defects in infants. Developing fetuses and children can have health consequences from intake levels 5–10 times lower than adults.

Studies have shown such elevated levels of mercury in sharks, tuna (Fig. 46Ba), and swordfish that the EPA has advisories against eating these fish for women who may become pregnant, are pregnant, or are nursing mothers, and for young children. Every state in the U.S., in conjunction with federal agencies, has developed fish advisories for certain bodies of water within that state. Currently, 45 states warn pregnant women to limit their fish consumption from their waters.

Mercury poisoning isn't limited to just aquatic species. Research conducted in the northeastern United States and Canada showed the presence of mercury in a variety of birds ranging from thrushes to loons to bald eagles. It is no surprise that loons and bald eagles can have high levels of mercury accumulation due to their consumption of contaminated fish. It was the presence of mercury in the songbirds that raised serious concerns among ecologists. Some speculate that songbirds in the northeast are ingesting mercury when they feed upon insects that have picked up the toxin from eating smaller insects that ingested it from vegetation. This raises concerns about mercury's ability to enter food webs and bioaccumulate in previously unknown ways.

Ultimately the blame for mercury pollution falls squarely on the shoulders of human beings. Every ecosystem on the planet has some degree of exposure to this pollutant, and with this exposure comes the risk of mercury contamination. Studies on species ranging from polar bears and bald eagles to whales and sharks show us that there are no limits to where mercury can be found. With coal-burning power plants being the largest human-caused source of mercury emissions (Fig. 46Bb), it will be up to us to find a solution to this global problem.

Questions to Consider

1. Would you support higher regulations on coal-fired power plants to reduce their mercury emissions even if it meant an increase in energy costs?
2. What is the easiest way to prevent the bioaccumulation of mercury in an organism?
3. Are there any species in an ecosystem that are not impacted by exposure to mercury?
4. Is there a way to limit the movement of mercury from one ecosystem to the next?

a. b.

Figure 46B Biomagnification of mercury. a. Tuna may contain high levels of mercury due to biomagnification. b. Eating tuna or other fish that contain high levels of mercury can lead to problems with fetal development.