Introduction:   
Biology Today

**CHAPTER**

1

Why This Chapter Matters

1. We are living in the golden age of biology. Biological discoveries revolutionize medicine, change agriculture, and impact human culture.

2. Science is a way of knowing and exploring our natural world. Most scientists use a   
combination of two main forms of inquiry: discovery science and hypothesis-driven science.

3. Understanding how science is done reveals the power and limits of this form of knowledge.

4. Life is united not by a single trait, but by a common set of characteristics. Appreciating what it means to be living is as complex as life itself.

5. The diversity of life is nested into groups that are united and interrelated by their shared evolutionary histories.

6. Life exists at many levels of biological organization. Understanding how these levels   
interrelate provides insight into the mechanisms of living systems.

Chapter Objectives

Biology and Society

1.1. Describe three examples of how biology is woven into the fabric of society.

The Scientific Study of Life

1.2. Compare discovery science and hypothesis-driven science. Provide examples of each.

1.3. Distinguish science from other styles of inquiry.

1.4. Distinguish between a hypothesis and a theory. Explain why natural selection qualifies as a scientific theory.

The Nature of Life

1.5. Describe seven properties or processes we associate with life.

1.6. Define a species and describe the goals of taxonomy.

1.7. Distinguish between the three domains and four eukaryotic kingdoms of life.

Major Themes in Biology

1.8. Describe the two main points that Darwin made in his book On the Origin of Species by Means of Natural Selection.

1.9. Compareand contrast artificial and natural selection.

1.10. Predict how structure and function are correlated using examples.

1.11. Identify and explain information flow and how it functions to regulate processes within biological systems.

1.12. Contrast the movements of energy and matter through ecosystems.

1.13. List and give an example of each level of biological organization, starting with an ecosystem and ending with atoms.

1.14. Define emergent properties and predict where they occur.

Lecture Outline

I. Biology and Society:An Innate Passion for Life

1. Most of us have an inherent interest in life,an inborn curiosity of the natural world that leads us to explore andstudy animals and plants and their habitats.

2. Life is relevant and important to you, no matter your background or goals.

3. The subject of biology is woven into the fabric of society.

II. The Scientific Study of Life

1. Biology is the scientific study of life. But

a. what is a scientific study, and

b. what does it mean to be alive?

A. The Process of Science

1. How do we tell the difference between science and other ways of trying to make sense of nature?

**2.** Scienceis an approach to understanding the natural world that is based on inquiry:

a. a search for information,

b. explanations, and

c. answers to specific questions.

3. The basic human drive to understand our natural world is manifest in two main scientificapproaches:

a. discovery science, which is mostly about *describing* nature, and

b. hypothesis-driven science, which is mostly about *explaining* nature.

4. Most scientists practice a combination of these two forms of inquiry.

B. Discovery Science

1. Science seeks natural causes for natural phenomena.

2. This limits the scope of science to the study of structures and processes that we can

a. verifiably observe and

b. measure directly or indirectly with the help of tools and technology, such as microscopes.

3. Recorded observations are called data, and data are the items of information on which scientific inquiry is based.

4. This dependence on verifiable data

a. demystifies nature and

b. distinguishes science from supernatural beliefs.

5. Science can neither prove nor disprove that angels, ghosts, deities, or spirits, whether benevolent or evil,cause storms, eclipses, or illnesses, or cure diseases,because such explanations are not measureable andare therefore outside the bounds of science.

6. Verifiable observations and measurements are the data of discovery science.

a. Charles Darwin’s careful description of the diverse plants and animals he observed in South America is an example of discovery science.

b. Jane Goodall spent decades observing and recording the behavior of chimpanzees living in the jungles of Tanzania.

C. Hypothesis-Driven Science

1. The observations of discovery science motivate us to ask questions and seek explanations.

2. As a formal process of inquiry, the scientific methodconsists of a series of steps that provide a loose guideline for scientific investigations.

3. There is no single formula for successfully discovering something new.

4. Instead, the scientific method suggests a broad outline for how discovery might proceed.

5. Most modern scientific investigations can be described as hypothesis-driven science.

6. A hypothesis is

a. a tentative answer to a question, or

b. a proposed explanation for a set of observations

7. A good hypothesisimmediately leads to predictionsthat can be tested by experiments.

8. Once a hypothesis is formed,an investigator can make predictions about what results are expectedif that hypothesis is correct.

9. We then test the hypothesis by performing an experiment to see whether or not the results are as predicted.

10**.** The scientific method is therefore just a formalization of how you already think and act.

11**.** Having a firm grasp of science as a process of inquiry can therefore help you in many ways in your life outside the classroom.

12.Scientific investigations are not the only way of knowing nature.

a. Science and religion are two very different ways of trying to make sense of nature.

b. Art is yet another way to make sense of the world around us.

13.A broad education should include exposure to all these different ways of viewing the world.

D. Theories of Science

1. Accumulating facts is not the primary goal of science.

2. Facts are

a. verifiable observations and repeatable experimental results, and

b. the prerequisites of science.

3. But what really advances science are new theories that tie together a number of observations that previously seemed unrelated.

4. The cornerstones of science are the explanations that apply to the greatest variety of phenomena.

5. People like Isaac Newton, Charles Darwin, and Albert Einstein stand out in the history of science not because they discovered a great may factsbut because their theories had such broad explanatory power.

6. What is a scientific theory, and how is it different from a hypothesis?

a. A scientific theory is much broader in scope than a hypothesis.

b. A theory is a comprehensive explanation supported by abundant evidence, andis general enough to spin off many new testable hypotheses.

7. For example, these are two hypotheses.

a. “White fur is an adaptation that helps polar bears survive in an Arctic habitat.”

b. “The unusual bone structure in a hummingbird’s wings is an evolutionary adaptation that provides an advantage in gathering nectar from flowers.”

8. In contrast, the following theory ties together those seemingly unrelated hypothesis:

a. “Adaptations to the local environment evolve by natural selection.”

9. Theories only become widely accepted by scientists if they

a. are supported by an accumulation of extensive andvaried evidence, and

b. have not been contradicted by any scientific data.

10. The use of the term theory by scientists contrasts with our everyday usage, which implies untested speculation (“It’s just a theory!”).

11. We use the word theory in our everyday speech the way that a scientist uses the word hypothesis.

III. The Nature of Life

1. What is life?

2. What distinguishes living things from nonliving things?

3. The phenomenon of life seems to defy a simple, one-sentence definition.

4. We recognize life mainly by what living things do.

A. The Properties of Life

1. Figure 1.4highlights seven of the properties and processes associated with life.

2. The Mars rover *Curiosity*

a. has been exploring the surface of the red planet since 2012 and

b. contains several instruments designed to identify biosignatures, substancesthat provide evidence of past of present life.

3. As of yet, no definitive signs of the properties of life have been detected, andthe search continues.

B. Life in Its Diverse Forms

1. The tarsier shown in Figure1.6is just one of about 1.8 million identified species on Earththat displays all of the properties outlined in Figure 1.4.

2. The diversity of known life—all the species that have been identified and named—includes

a. at least 290,000 plants,

b. 52,000 vertebrates (animals with backbones), and

c. 1 million insects (more than half of all known forms of life).

3. Biologists add thousands of newly identified species to the list each year.

4. Estimates of the total number of species range from 10 million to more than 100 million.

5. Grouping Species: The Basic Concept

a. To make sense of nature, people tend to group diverse items according to similarities.

b. A species is generally defined asa group of organismsthat

i. live in the same place and time and

ii. have the potential to interbreed with one another in nature to produce healthy offspring.

c. We may even sort groups into broader categories such as

i. rodents (which include squirrels) and

ii. insects (which include butterflies).

d. Taxonomy, the branch of biology that names and classifies species, is the arrangement of species into a hierarchy of broader and broader groups.

6. The Three Domains of Life

a. The three domains of life are

i. Bacteria,

ii. Archaea, and

iii. Eukarya.

b. Bacteria andArchaea have prokaryotic cells.

c. Eukaryahave eukaryotic cells.

d. The Domain Eukarya in turn includes three smaller divisions called kingdoms:

i. Kingdom Plantae,

ii. Kingdom Fungi, and

iii. Kingdom Animalia.

e. Most members of the three kingdoms are multicellular.

f. These three multicellular kingdoms are distinguished partly by how the organisms obtain food.

i. Plants produce their own sugars and other foods by photosynthesis.

ii. Fungi are mostly decomposers, digesting dead organisms and organic wastes.

iii. Animals obtain food by ingesting (eating) and digesting other organisms.

g. Those eukaryotes that do not fit into any of the three kingdoms fall into a catch-all group called the protists.

i. Most protists are single-celled; they include microscopic organisms such as amoebas.

ii. But protists include certain multicellular forms, such as seaweeds.

iii. Scientists are in the process of organizing protists into multiple kingdoms, although they do not yet agree on exactly how to do this.

IV. Major Themes in Biology

1. Five unifying themes will serve as touchstones throughout our investigation of biology.

A. Evolution

1. Whatdo a tree, a mushroom, and a human have in common?

a. At the cellular level, all life bears striking similarities.

b. Despite the amazing diversity of life, there is also striking unity.

2. What can account for this combination of unity and diversity in life?

3. The scientific explanation is the biological process called evolution.

4. Evolution is

a. the fundamental principle of life and

b. the core theme that unifies all of biology.

5. The theory of evolution by natural selection,first described by Charles Darwin more than 150 years ago, is the one idea that makes sense of everything we know about living organisms.

6. Life evolves.

a. Each species is one twig of a branching tree of life extending back in time through ancestral species more and more remote.

b. Species that are very similar, such as the brown bear and polar bear,share a more recent common ancestorthat represents a relatively recent branch point on the tree of life.

7. Through an ancestor that lived much farther back in time,

a. all bears are also related to squirrels, humans, and all other mammals and

b. all have hair and milk-producing mammary glands.

8. The Darwinian View of Life

a. The evolutionary view of life came into focus in 1859 when Charles Darwin published On the Origin of Species by Means of Natural Selection.

b. Darwin’s book developed two main points:

i. Species living today descended from a succession of ancestral species in what   
Darwin called “descent with modification,” capturing the duality of life’s

1) unity (descent) and

2) diversity (modification).

ii. Natural selection is the mechanism for descent with modification.

c. In the struggle for existence,those individuals with heritable traits best suited to the local environment are more likely to survive and leave the greatest number of healthy offspring.

d. Therefore, these passed-down traitsthat enhance survival and reproductive success will be represented in greater numbers in the next generation.

i. It is this unequal reproductive success that Darwin called **natural selection** because the environment “selects” only certain heritable traits from those already existing.

e. The product of natural selection is adaptation, the accumulation of variations in a population over time.

f. We now recognize many examples of natural selection in action.

g. A classic example involves the finches (a kind of bird) of the Galápagos Islands.

h. Over two decades, researchers measured changes in beak size in a population of a species of ground finch that eats mostly small seeds.

i. In dry years, when the preferred small seeds are in short supply, the birds mush eat large seeds.

1) Birds with larger, stronger beakshave a feeding advantage and greater reproductive success, andthe average beak depth for the population increases.

i. During wet years,small seeds become more abundant.

i. Smaller beaks are more efficient for eating the plentiful small seeds, and thus the average beak depth decreases.

j. Such changes are measureable evidence of natural selection in action.

k. Antibioticresistance in bacteria evolves in response to the overuse of antibiotics when dairy and cattle farmers add antibiotics to feed.

**i.** The members of the bacteria population will, through random chance, vary in their susceptibility to the antibiotic.

**ii.** Once the environment changes by the addition of antibiotics,

1) some bacteria will succumb quickly and die,

2) while others will tend to survive.

**iii.** Those bacteria that survive will multiply, producing offspring that will likely inherit the traits that enhance survival.

**iv.** Over many bacterial generations, feeding antibiotics to cows may promote the evolution of antibiotic-resistant bacteria that, if transferred to the human food supply, could cause infections that are not susceptible to standard drug treatments.

9. Observing Artificial Selection

a. Artificial selection is the purposeful breeding of domesticated plants and animals by humans.

b. Humans have customized crop plants through many generations of artificial selection by selecting different parts of the plant to accentuate as food.

c. All the vegetables shown in Figure 1.13 have a common ancestor in one species of wild mustard (shown in the center of the figure).

d. The power of selective breeding is also apparent in our pets, which have been bred for looks and usefulness.

e. For example, people in different cultures have customized hundreds of dog breeds as different as basset hounds and Saint Bernards, all descended from wolves.

B. Structure/Function: The Relationship of Structure to Function

1. Within biological systems,structure (the shape of something) and function (what it does) are often related, with each providing insight into the other.

2. The correlation of structure and function can be seen at every level of biological organization.

3. Consider your lungs, which function to exchange gases with the environment:

a. oxygen (O2) in,

b. carbon dioxide (CO2) out.

4. The structure of your lungs correlates with this function.

a. Increasingly smaller branches end in millions of tiny sacs in which the gases cross from the air to your blood and vice versa.

b. This structure provides a tremendous surface area over which a very high volume of air may pass.

5. Cells, too, display a correlation of structure and function.

a. As oxygen enters the blood in the lungs, it diffuses into red blood cells.

b. The shape of red blood cells provides a large surface area over which oxygen can diffuse.

C. Information Flow

1. For life’s function to proceed in an orderly manner, information must be

a. stored,

b. transmitted, and

c. used.

2. Every cell in your body was created when a previous cell transmitted information (in the form of DNA) to it.

3. Even your very first cell, the zygote, or fertilized egg, contains information passed on from the previous generation.

4. In this way, information flows from generation to generation, passed down encoded within molecules of DNA.

5. All cells use DNA as the chemical material of genes, the units of inheritance that transmit information from parent to offspring.

6. The language of life has an alphabet of just four letters.

7. The chemical names of DNA’s four molecular building blocks are abbreviated as A, G, C, and T.

8. A gene’s meaning to a cell is encoded in its specific sequence of these letters, just as the message of this sentence is encoded in its arrangement of the 26 letters of the English alphabet.

9. The entire set of genetic information that an organism inherits is called its **ge**nome.

10. The nucleus of each human cell contains a genome that is about 3 million chemical letters long.

11. At any given moment, your genes are producing thousands of different proteins that control your body’s processes.

12. For example, the information in one of your genes translates to “Make insulin.”

13. Insulin

a. is produced by cells within the pancreas and

b. is a chemical that helps regulate your body’s use of sugar as a fuel.

14. Some people with diabetes regulate their sugar levels by injecting themselves with insulin produced by genetically engineered bacteria.

D. Energy Transformations: Pathways That Transform Energy and Matter

1. Various cellular activities of life are work, such as movement, growth, and reproduction, and work requires energy.

2. Life is made possible by

a. the input of energy, primarily from the sun, and

b. the transformation of energy from one form to another.

3. Most ecosystems are solar powered.

4. Plants and other photosynthetic organisms (“producers”)

a. capture the energy that enters an ecosystem as sunlight and

b. convert it, storing it as chemical bonds within sugars and other complex molecules.

5. Chemical energy is then passed through a series of “consumers” that break the bonds,

a. releasing the stored energy and

b. putting it to use.

6. In the process of these energy conversions between and within organisms, some energy is converted to heat, which is then lost from the system.

7. Thus, energy flows through an ecosystem,

a. entering as light and

b. exiting as heat.

8. Every object in the universe, both living and nonliving, is composed of matter.

9. In contrast to energy flowing through an ecosystem, matter is recycled within an ecosystem.

10. Within all living cells, a vast network of interconnected chemical reactions (collectively referred to as metabolism) continually converts energy from one form to another as matter is recycled.

E. Interconnections within Biological Systems

1. The study of life extends

a. from the microscopic scale of the molecules and cells that make up organisms

b. to the global scale of the entire living planet.

2. The biosphereconsists of

a. all the environments on Earth that support life, including soil, oceans, lakes and other bodies of water, and the lower atmosphere.

3. At the other extreme of biological size and complexity are microscopic molecules such as DNA, the chemical responsible for inheritance.

4. At each new level, novel properties emerge that are absent from the preceding one.

a. These emergent properties are due to the specific arrangement and interactions of parts in an increasingly complex system.

b. Such properties are called emergent because they emerge as complexity increases.

5. The global climate

a. is another example of interconnectedness within biological systems and

b. operates on a much larger scale.

6. Throughout our study of life, we will see countless interconnections that operate at and between every level of the biological hierarchy.

7. Biologists are investigating life at its many levels,

a. from the interactions within the biosphere

b. to the molecular machinery within the cells.

Chapter Guide to Teaching Resources

The Scientific Study of Life

Student Misconceptions and Concerns

1. Contrasting the concept of faith with the tentative nature of science can help to define and distinguish science from other ways of knowing. Students sometimes enter science classes expecting absolutes of facts and rigid dogma. Instead, scientific knowledge is tentative, reflecting degrees of confidence closely correlated to the strength of the evidence.

2. The authors’ distinction between natural and supernatural explanations is essential to understanding the power and limits of scientific explanations.

3. Some students think that variables are somehow restricted in a controlled experiment. That is, everything about the experiment is “controlled.” But controlled experiments limit the differences between experimental and control groups, with only one difference in most situations. That way, when a difference between the groups is identified, it can be explained by the single difference between the groups.

4. The common use of the terms law and theory by the public often blurs the stricter definitions of these terms in science. In general, laws describe and theories explain. Both are typically well-established concepts in science. A free online publication by the National Academy of Sciences helps to define these and related terms more carefully. See Chapter 1 of Teaching about Evolution and the Nature of Science at www.nap.edu/openbook.php?record\_id=5787.

Teaching Tips

1. Consider using a laboratory exercise to have your students plan and perhaps conduct investigations using discovery science and a hypothesis-driven approach. Emphasize the processes and not the significance of the questions. Students can conduct descriptive surveys of student behavior (e.g., use of pens, pencils, or electronic devices for taking notes) or test hypotheses using controlled trials. Students may need considerable supervision and advice while planning and conducting their experiments.

Active Lecture Tips

1. Consider presenting your class with several descriptions of scientific investigations. Then ask students to categorize each type of experiment as discovery science or hypothesis-driven science. If students can work in small groups, encourage quick discussions to clarify these two types of scientific investigations.

2. You might also present to your class descriptions of several scientific investigations that you have written. Include in your descriptions numerous examples of improper methodology (small sample size, several variables existing between the control and experimental groups, failure to specifically test the hypothesis, and the like). Let small groups or individuals analyze the experiments in class to identify the flaws. This critical analysis allows students the opportunity to suggest the characteristics of good investigations in class.

3. Have your students turn to a few other students seated nearby to explain why a coordinated conspiracy promoting a specific idea in science is unlikely to succeed. Have your students describe aspects of science that would check fraudulent or erroneous claims and/or political efforts.

4. See the Activity Practicing the Scientific Method: Are Girls Better Than Boys at Some Tasks?on the Instructor Exchange. Visit the Instructor Exchange in the MasteringBiology instructor resource area for a description of this activity.

The Nature of Life

Student Misconceptions and Concerns

1. We live in a world that is largely understood by what we can distinguish and identify with our naked senses. However, the diversity of life and the levels of biological organization extend well beyond the physical scale of our daily lives. For many students, appreciating the diversity of the microscopic world is abstract, nearly on par with an understanding of the workings of atoms and molecules. A laboratory opportunity to examine the microscopic details of objects from our daily lives (the surface of potato chips, the structure of table salt and sugar, the details of a blade of grass) can be an important sensory extension that prepares the mind for greater comprehension of these minute biological details.

Teaching Tips

1. Consider asking students to bring to class a page or two of an article about biology that appeared in the media in the last month. Alternatively, you could have each student email a Web address of a recent biology-related news event to you. You might even have them e-mail relevant articles to you for each of the main topics you address throughout the semester.

2. Here is a simple way to contrast the relative size of prokaryotic and eukaryotic cells. Mitochondria and chloroplasts are thought to have evolved by endosymbiosis. Thus, mitochondria and chloroplasts are about the size of bacteria, contained within a plant cell. A figure of a plant cell therefore provides an immediate comparison of these sizes, not sidebyside, but one inside the other!

3. The scientific organization Sigma Xi offers a free summary of the major science news articles each weekday. The first few paragraphs of each article are included with a hyperlink to the source of the entire article. The topics are diverse and can be an excellent way to be aware of daily scientific announcements and reports. Typically, about 10 articles are cited each weekday. Science in the News is part of the website www.americanscientist.org/, where you can sign up for a free newsletter each weekday.

4. An excellent introduction to the domains and kingdoms of life is presented at www.ucmp.berkeley.edu/exhibits/historyoflife.php.

Active Lecture Tips

1. Ask your students, at the start of the semester, to write down the first type of animal that comes to mind.The most frequent response is a mammal. (In my courses, over a 25-year period, more than 98% of the examples have been mammals.) As the diversity of life is explored, the common heritage of biological organization can be less, and not more, apparent. The diverse forms, habits, and ecological interactions overwhelm our senses with differences. Emphasizing the diversity and unifying aspects of life is necessary for a greater understanding of the evolutionary history of life on Earth.

2. Consider asking students to pair up with someone sitting near them to identify examples of the seven properties of life in some organism from your region (or perhaps a school mascot, if appropriate).

Major Themes in Biology

Student Misconceptions and Concerns

1. Students often believe that Charles Darwin was the first to suggest that life evolves; the early contributions by Greek philosophers and the work of Jean-Baptiste Lamarck may be unappreciated. Consider emphasizing this earlier work in your introduction to Darwin’s contributions.

2. Students often misunderstand the basic process of evolution and instead reflect a Lamarckian point of view. Organisms do not evolve structures deliberately or out of want or need. Individuals do not evolve. Evolution is a passive process in which the environment favors one or more existing variations of a trait already present in a population.

Teaching Tips

1. Many resources related to Charles Darwin are available on the Internet:

a. General evolution resources:

evolution.berkeley.edu

nationalacademies.org/evolution

ncse.com

b. The complete works of Charles Darwin can be found at darwin-online.org.uk/

c. Details of Charles Darwin’s home are located at

williamcalvin.com/bookshelf/down\_hse.htm

2. There are many variations of games that model aspects of natural selection. Here is one that is appropriate for a laboratory exercise. Purchase several bags of dried grocery store beans of diverse sizes and colors. Large lima beans, small white beans, red beans, and black beans are all good options. Consider the beans “food” for the “predatory” students. To begin, randomly distribute (throw) 100 beans of each of four colors onto a green lawn. Allow individual students to collect beans over a set period, perhaps 3 minutes. Then count the total number of each color of bean collected. Assume that the beans remaining undetected (still in the lawn) reproduce by doubling in number. Calculate the number of beans of each color remaining in the field. For the next round, count out the number of each color to add to the lawn so that the new totals on the lawn will double the number of beans that students did not find in the first “generation.” Before each predatory episode, record the total number of each color of beans that have “survived” in the field. Then let your student “predators” out for another round of collection (generation). Repeat the process for at least three or four “generations.” Note what colors of beans are favored by the environment. Ask students to speculate which colors might have been favored during another season or on a parking lot.

3. Many websites devoted to domesticated species can be used to illustrate the variety of forms produced by artificial selection. Those devoted to pigeons, chickens, and dogs have proven to be especially useful.

4. The authors make an analogy between the four bases used to form genes and the 26 letters of the English alphabet used to create words and sentences. One could also make an analogy between the four bases and trains composed of four different types of railroad cars (perhaps an engine, boxcar, tanker, and flatcar). Imagine how many different types of trains one could make using just 100 rail cars of four different types. (The answer is 4100.)

5. For a chance to add a little math to the biological levels of organization, consider calculating the general scale differences between each level of biological organization. For example, are cells generally 5, 10, 50, or 100 times more massive than organelles? Are organelles generally 5, 10, 50, or 100 times more massive than macromolecules? For some levels of organization, such as ecosystems, communities, and populations, size or scale differences are perhaps less relevant and more problematic to consider. However, at the smaller levels, the sense of scale might enhance an appreciation for levels of biological organization.

6. The U.S. Census Bureau maintains updated population clocks that estimate the U.S. and world populations (www.census.gov/popclock/). If students have a general idea of the human population of the United States, statistics about the number of people affected with a disease or disaster become more significant. For example, the current population of the United States is about 320,000,000 (in 2014). It is currently estimated that at least 1 million people in the United States are infected with HIV. The number of people infected with HIV is impressive and concerning, but not perhaps as meaningful as the realization that this represents about one of every 320 people in the United States. Although the infected people are not evenly distributed among geographic and ethnic groups, if you apply this generality to the enrollments in your classes, the students might better understand the tremendous impact of HIV infection.

Active Lecture Tips

1. Help the class think through the diverse interactions between an organism and its environment. In class, select an organism and have students work in small groups to develop a list of environmental components that interact with the organism. This list should include living and nonliving categories.

Key Terms

biology

biosphere

data

discovery science

genes

genome

hypothesis

life

natural selection

science

scientific method

species

taxonomy

theory

Word Roots

bio = life, sphere = ball (biosphere: the global ecosystem)

eco = house (ecosystem: all the organisms in a given area, together with the nonliving factors with which they interact)

hypo = below (hypothesis: a tentative explanation)

RelevantSongs to Play in Class

“She Blinded Me with Science,” Thomas Dolby

“Weird Science,” OingoBoingo

“The Scientist,” Coldplay

“Applied Science,” 311

“Science Is Real,” They Might Be Giants

“Put It to the Test,” They Might Be Giants

“The Sounds of Science,” Beastie Boys

“(What a) Wonderful World” (“Don’t Know Much Biology. . .”), Sam Cooke

“Biology,” Joe Jackson

“Alive,” P.O.D.

Answers to End-of-Chapter Questions

The Process of Science

10. Suggested answer: The antibiotic-resistance gene confers a reproductive advantage to those bacteria that carry it only in the presence of the antibiotic. In its absence, this gene is of no advantage—in fact, its inheritance and the production of the protein that it encodes are likely to put the bacteria at a disadvantage by wasting energy and nutrients. Thus, after the withdrawal of the antibiotic, the bacteria lacking the resistance gene are at a reproductive advantage, and they will outcompete the bacteria carrying the resistance gene. Over multiple generations, the resistant bacteria may become eliminated from the population.

11. Heart attack patients had an average of 1.77g of trans fat in 100g of their adipose tissue, which is higher than the 1.48g of trans fat found in non-heart attack patients.

The data could also be summarized by simply saying that heart attack patients had more trans fat in their adipose tissue than patients without a heart attack.

Biology and Society

12. Students may pick over-the-counter or prescribed medicine, cleaning products, and/or cosmetic products and toiletries. In order to generate a hypothesis-driven process of flowchart, they should initially come up with an observation or a hypothesis and then a strategy as to how to test this hypothesis experimentally.

13. The prefix ‘bio’ is often used to evoke positive associations, whereas the scientific definition of biology is of course free from either positive or negative connotations. Some issues and questions to consider for students: Why is a product marketed as ‘bio’ or ‘biological’? How reliable and comprehensible is the science behind the sales claims that are possibly made up by companies selling food and cleaning products? Is a ‘bio’ product necessarily better and/or healthier than a comparable non-bio product?

Additional Critical Thinking Questions

The Process of Science

1. Tobacco is the leading cause of preventable cancers today. In fact, there are very few known cancers for which smoking is not considered a risk factor. The relationship between cigarette smoking and disease has been studied for years. How can this problem be studied at many different levels of biological organization? Give some examples.

Suggested answer: A scientist may try to identify the molecules in tobacco that cause cancer and study how they affect cells (or DNA replication). At the organ level, a scientist may ask how the smoke and the chemicals in the smoke damage the lungs and other organs in the body. The statistical relationship between tobacco smoke and the incidents of lung cancer can be studied at the population level. Finally, if a study on how smoke might affect organisms other than humans were considered, then this would be at the community level.

2. A newspaper headline reads “Scientific Study Shows That Coffee Can Cut Risk of Suicide.” The article states that in a 10-year study of 86,626 female nurses, there were 10 suicides among individuals who drank 2–3 cups of caffeinated coffee per day, compared with 21 suicides among individuals who almost never drank coffee. The researcher notes that these results were consistent with those of a previous study of 128,934 men and women done virtually the same way. The article also includes the following: (a) mention of a previous study indicating that the amount of caffeine in 2–3 cups of coffee tends to increase the drinker’s general energy level, sense of well-being, and motivation to work;   
(b) criticism by another scientist, who found the study flawed because it failed to address how many nurses used antidepressant drugs; and (c) mention that the researcher recorded the use of alcohol and tobacco by the nurses but did not record the number of nurses who were depressed and told by their physicians not to drink coffee. Do you think the conclusion in the headline is justified? Why or why not? How would you reword the headline to reflect more accurately the study as described? What key elements of the scientific process did the researcher use? Which ones were not used?

Suggested answer: The headline’s conclusion is not supported by the information in the article. Although there were about half as many suicides among caffeinated-coffee-drinking nurses, the study did not rule out the effects of other factors that could affect suicide rates, such as antidepressant drugs and a physician’s advice. Also, the amount of caffeine in a cup of coffee may vary; did the researcher take this into account (that is, determine if the amount of caffeine intake was significantly different between the two groups of nurses)? A headline such as “Preliminary Results May Point to Beneficial Effects of Caffeine” would be more appropriate. The researcher used observations (results of a previous study), then posed a question, a hypothesis (2–3 cups of coffee per day reduces the rate of suicide among nurses), a prediction of a test outcome, and a test (comparing the number of suicides in two groups of nurses). However, the study was flawed, and the scientific process compromised, by a failure to consider all possible factors influencing suicides. In addition to the concerns above, we cannot know about cause and effect. What if depression typically causes a person to avoid coffee? Correlations do not always lead to causes and effects.

3. Consider the following observation: A group of 10 overweight patients has high levels of LDL (low-density lipoprotein) cholesterol. Based on this limited information and using the scientific method, develop a question followed by a hypothesis. Design an experiment to test your hypothesis (make sure to indicate a control) and indicate predicted results.

Suggested answer: A possible question that could be asked is “Is weight a factor in developing high LDL cholesterol levels?” A possible hypothesis might be “Individuals who are overweight will develop high levels of LDL cholesterol.” In this experiment, it would be necessary to recruit overweight individuals for LDL cholesterol screening. The participants should be screened so that their diets and exercise levels are similar. Individuals in the control group should be matched to those in the experimental group (exercise habits, diet habits) except that they are not overweight. Their LDL levels will also be monitored. The predicted results might be that factors other than weight contribute to elevated levels of LDL cholesterol. It should also be noted that this experiment does not test whether or not high LDL levels cause people to be overweight!

Biology and Society

1. Intelligent design theory is an argument used by some people to challenge the teaching of evolution in public schools. One of the supporters of this idea argues that certain biological structures, such as the bacterial flagellum, require so many complex parts working together in perfect synchronization that it is not possible that they could have evolved from simpler structures. This argument, which has arisen in various forms for more than 200 years, states that a simpler structure could not perform the same function, which is evidence of “irreducible complexity.” This is cited as evidence for an intelligent designer. Do you consider this theory scientific? Why or why not? Would you support the inclusion of this theory in the science classroom? If so, would you also support contrasting this theory to the theory of evolution?

Some issues and questions to consider: Explain why intelligent design is not within the boundaries of science. What experiments could we perform to test for a designer? If flaws are discovered in evolutionary theory and other explanations are required, does that automatically support intelligent design theory (a false dichotomy)? Can structures have adaptive advantages that change as new parts are added or modified in the system? For example, can the bones in bird wings have served another function before they became adapted for flight?