

Mader: Essentials of Biology, 4e

Instructor's Manual

Chapter 1 Biology: The Science of Life

Learning Outcomes

1.1 The Characteristics of Life

1. Explain the basic characteristics that are common to all living organisms.
2. Distinguish between the levels of biological organization.
3. Summarize how the terms *homeostasis*, *metabolism*, and *adaptation* all relate to living organisms.
4. Contrast chemical cycling and energy flow within an ecosystem.

1.2 Evolution: The Core Concept of Biology

1. Define the term *evolution*.
2. Explain the process of natural selection and its relationship to evolutionary processes.
3. Summarize the general characteristics of the domains and major kingdoms of life.

1.3 Science: A Way of Knowing

1. Identify the steps of the scientific method.
2. Describe the basic requirements for a controlled experiment.
3. Distinguish between a theory and a hypothesis.

1.4 Challenges Facing Science

1. Distinguish between science and technology.
2. Summarize some of the major challenges currently facing science.

Extended Lecture Outline

1.1. The Characteristics of Life

Life Is Organized

Living things are organized by scientists from the cell as the basic unit of life to tissues, organs, organ systems through populations, communities, ecosystems and the biosphere.

Life Requires Materials and Energy

All life needs the input of energy beginning with the capture of solar energy by photosynthesizers. Cells perform metabolic reactions, which depend on homeostasis. Energy is the capacity to do work. Metabolism refers to all of the chemical reactions that occur in a cell, and photosynthesis refers to the transformation of solar energy to chemical energy in photosynthetic organisms such as plants.

Living Organisms Maintain an Internal Environment

Living things need to keep themselves stable in temperature, moisture level, acidity, and other factors that are critical to maintaining life. The maintenance of internal conditions within certain boundaries is called homeostasis.

Living Organisms Respond

All living things respond in some fashion to their environment.

Living Organisms Reproduce and Develop

All living things produce offspring, passing on genes that control how the offspring develops.

This process is called reproduction.

Living Organisms Have Adaptations

Living things adapt to their environment often by natural selection. Species are defined as interbreeding individuals that produce viable and fertile offspring. Over time, as evolution occurs, new species develop and common ancestors occur. Evolution is modification by descent.

1.2 Evolution: The Core Concept of Biology

Evolution is the process in which populations accumulate adaptations over time to become more suited to their environments.

Natural Selection and Evolutionary Processes

Evolution occurs by using natural selection as a means.

Biodiversity includes the total number of species, as well as diversity of genetic material and diversity within ecosystems. Extinction affects biodiversity. Biodiversity is a very dynamic phenomenon. For example, more than 400 species become extinct every day.

Organizing the Diversity of Life

Taxonomy involves identifying and classifying organisms.

Scientists use taxonomy to group organisms using evolutionary relationships.

Classification includes species, genus, family, order, class, phylum, kingdom, and domain from the least inclusive to the most inclusive. Three domains are presented; they are **Bacteria**, **Archaea**, and **Eukarya**. Bacteria and Archaea are prokaryotes. Kingdoms are found in the Eukarya domain; they are protists, fungi, plant, and animal. Organisms are identified using scientifically based binomial names.

1.3 Ecosystems and the Biosphere

Ecosystem

An ecosystem is composed of populations forming a food chain through which energy flows. It includes producers, consumers, and decomposers.

Biosphere

The biosphere is made up of many ecosystems, some endangered by human activity. Healthy ecosystems are important for human life.

Human Influence on Ecosystems

Human population tends to modify ecosystems for its own purposes.

1.4 Science: A Way of Knowing

The scientific method is typically used to study the natural world.

Start with an Observation

Observation is the first step, which includes an individual's observations, as well as observations of other scientists found in the scientific literature. Instrumentation extends a scientist's ability to observe.

Develop a Hypothesis

Hypotheses are often proposed and conclusions are often provided using inductive reasoning.

Make a Prediction and Perform Experiments

Experimental design includes an experimental variable and a control group. Models are often used. Data collected is often mathematical.

Develop a Conclusion

Based on the experimental data, conclusions can be drawn as to whether the hypothesis was supported or not. Experiments must be repeatable.

Scientific Theory

Scientific theories explain how the natural world works.

An Example of a Controlled Study

Experimental design and data is presented for an investigation of pea plants as fertilizer for winter wheat. In experimental systems, there are often Test Groups and Control Groups.

Publish Your Results

Scientific studies are published in scientific journals through a process of rigorous review, this makes them available to the entire scientific community.

1.5 Challenges Facing Science

The importance of scientific knowledge in order for everyone to make informed decisions about the use of technology is presented.

Bioethics

Bioethics is a branch of ethics that revolves around the development of biotechnology.

Human Influence on Ecosystems

Humans modify ecosystems for their own purposes, which may lead to the extinction, or death, of a species or a larger taxonomic group.

Emerging Diseases

Changes in human behavior and use of technology can lead to emerging diseases.

Climate Change

Human activities have affected climate change—changes to the normal cycle of the Earth's climate.

Lecture Enrichment Topics

1.1 The Characteristics of Life

1. Choose an ecosystem, such as the campus or students' backyards, and have the students list some ways living things interact with their physical environment. How do students interact with their physical environment? For example, food chains and food webs unify the diversity of life, also described later.
2. Ask students for some ways that humans maintain homeostasis. For example, how do they maintain homeostasis of fluid or temperature when they are exercising and perspiring or they walk outside in cold weather without wearing a coat.

1.2 Evolution: The Core Concept of Biology

1. To reinforce the need for scientific names, present the following common names for the snake, *Bothrops asper*: Belize – yellow-jaw tomygoff; Guatemala and Honduras – barba amarilla; Mexico – cola blanca, palancaloca, tephocho; Venezuela – macagua, tigua.

1.3 Science: A Way of Knowing

In presenting the scientific method, present the students with different fields of biology. Do scientists in the different fields use the same techniques or different techniques to conduct their investigations?

1. In presenting the parts of the scientific method, give an ongoing example of how people use the scientific method in everyday life. One example may be the use of premium versus regular gasoline. Students can propose conditions that should remain constant, as well as the type of mathematical data that could be collected and analyzed.
2. Propose a "study" as follows: A report on the television states that a 12-year study of a new dog food will allow your dog to live longer if fed to the dog throughout its life. Ask the students what questions they might have about the report in order to discern its validity.
3. Explain the importance of objectivity (one reason mathematical data is so important) in experimental design. Using the example in #2, categorize the following statements about the example into objective statements versus subjective statements. Have the students include reasons why they categorized each statement as objective or subjective.
"The dogs that ate the new dog food seemed to have shinier coats."
"78% of the control dogs did not eat all of their food within the time allotted."
"Most of the experimental dogs needed fewer teeth cleanings."
"Half of the experimental dogs were more playful after 8 years of using the new dog food."
"The new dog food probably tasted better as the experimental dogs ate their food in less time."
4. Present when Charles Darwin proposed the evolution theory (1859), when Schleiden and Schwann proposed the cell theory (1838), and when Mendel (1866), and Watson and Crick (1953) proposed the gene theory. Emphasize the length of time and number of studies that must have occurred during this time that support these theories.
5. Discuss the scientific definition of *theory* versus the everyday use of the word *theory*. Presenting a dictionary's definition should include both aspects. Explain why saying "It's *just* a theory" may not be appropriate with regard to scientific theories (see also #4).

1.4 Challenges Facing Science

1. Ask for a list of biotechnology issues currently in the news (cloning, stem cell research). Students could bring in headlines or articles from newspapers. Point out that at the end of this course, students should be better able to decide their positions on these issues.

Critical Thinking Questions

1. Discuss the difference in meaning between the terms "supported" and "proven." Why is the term "supported" used with regard to hypotheses, as in, a hypothesis is supported by experimental data?

Ans: The term "proven" indicates a greater degree of certainty with no indication suggested for further search of information. The term "supported" indicates that with the current knowledge, the hypothesis appears to be true, but further experimentation may indicate otherwise.

2. Regarding the example of a controlled study in the text using winter wheat and pea plants as fertilizer, what specific aspects of environmental conditions would be included as conditions that were kept constant?

Ans: Answers will vary but may include:

- amount and type of nutrients in soil before addition of nitrogen fertilizer or pea plants

- amount of water the plants received
- amount of sunlight the plants received
- the temperatures throughout the test period
- the size of the pots
- pH of soil

Essay Questions

1. Give an example of how behavior contributes to homeostasis.

Ans: (Students may be able to come up with some of their own examples.) Animals such as lizards need to regulate their body temperature by moving about their environment. If they are cold, they move to a sunny area, if hot, they move to a shaded area. A plant may grow its leaves to follow the position of the sun to maintain a certain rate of photosynthesis.

2. Explain why scientific binomial names are important.

Ans: People often have many different common names for living things, varying between geographical areas or languages. Scientists need a name for each species that does not change no matter what language is spoken or what geographical area is being considered. Each known species has an assigned scientific binomial name that is accepted by all scientists.

3. Describe the importance of using models in experimental design.

Ans: Models, or modeling, can be used instead of the actual subject. This can be important in forecasting the impact of human activity on ecosystems. Also, animals can be used as models when testing chemicals or processes being developed for humans.

4. Which model organism are best for:

- a) Field investigations?
- b) Lab investigations?

Consider the size, reproductive habit, and the life cycle of the organisms.

Chapter 2 The Chemical Basis of Life

Learning Outcomes

2.1 Atoms and Atomic Bonds

1. Distinguish among the types, location, and charge of subatomic particles.
2. Relate how the arrangement of electrons determines an element's reactivity.
3. Explain how isotopes are useful in the study of biology.
4. Contrast ionic and covalent bonds.
5. Identify the reactants and products in a chemical equation.

2.2 Water's Importance to Life

1. Describe the general structure of a water molecule.
2. List the properties of water that are important to life.
3. Understand the importance of hydrogen bonds to the properties of water.

2.3 Acids and Bases

1. Distinguish between an acid and a base.
2. Interpret the pH scale.
3. Explain the purpose of a buffer.

Extended Lecture Outline

2.1 The Nature of Matter

Matter is anything that takes up space and has mass.

Atomic Structure

Atoms are made up of protons, neutrons, and electrons in an organized fashion. The atomic mass of an element depends on the number of protons and neutrons in the nucleus; the atomic number indicates the number of protons of an element.

The Periodic Table

Chemists have organized all known elements in the periodic table, grouping them by shared characteristics. Isotopes are atoms of the same element with extra neutrons in their nucleus that are unstable and emit radiation. Radioactive isotopes are used in many medical procedures.

Arrangement of Electrons in an Atom

Electrons are arranged by their energy levels, illustrated by shells in modeling atoms. The octet rule states that an atom is stable if it has 8 electrons in its valence shell.

Types of Chemical Bonds

When two or more atoms bond covalently, they are a molecule. If the molecule contains more than one element, it is a compound. Two common types of bonds are ionic bonds and covalent bonds.

Chemical Formulas and Reactions

Chemical reactions can be represented by equations showing reactants and products.

2.2 Water's Importance to Life

The Structure of Water

Because of the electronegativity of hydrogen and oxygen, these atoms form polar covalent bonds, giving water a consistent shape and important properties.

Properties of Water

Because of the polar covalent bonds and the ability to form hydrogen bonds, water has the following properties important to life: it is a solvent; it is cohesive and adhesive; it has high surface tension; it maintains a temperature compatible with life; as a solid, it is less dense than as a liquid.

2.3 Acids and Bases

Acidic Solutions (High H^+ Concentration)

Acidic solutions have a high hydrogen ion (H^+) concentration. An example of a strong acid is hydrochloric acid (HCl) which dissociates in water:



Basic Solutions (Low H^+ Concentration)

Basic solutions have a low hydrogen ion (H^+) concentration. An example of a strong base is sodium hydroxide, which dissociates in water:



pH and the pH Scale

The pH scale was created to indicate the hydrogen ion concentration of a solution. The lower the pH, the more acidic the solution, and the higher the pH, the more alkaline the solution. The pH scale is on a scale of 0-14. A pH of 7 is considered neutral.

Buffers and pH

Buffers are important substances found in living organisms that help maintain a certain range of pH.

Lecture Enrichment Topics

2.1 Atoms and Atomic Bonds

1. Present Mendeleev's story. Dmitry Mendeleev was a professor of chemistry and author of *The Principles of Chemistry* in the mid-1800s. Throughout the 1800s, scientists were discovering the elements and their properties and trying to find patterns of similarity. Mendeleev worked on the puzzle of how to organize the elements for nearly 20 years. He wrote each element and its properties on a card and would arrange and rearrange these cards, looking for patterns. Finally, he realized a logical pattern in a dream. "I saw in a dream a table where all the elements fell into place as required. Awakening, I immediately wrote it down on a piece of paper." Mendeleev published the periodic table in 1869 in a paper titled, "A Suggested System for the Elements."
2. Book recommendation for instructor and student: Oliver Sacks, *Uncle Tungsten: Memories of a Chemical Boyhood*. Vintage Books, 2001.
3. In order to reinforce their understanding of the organization in the periodic table, quiz the students by asking for the element which, for example, has 4 electrons in its valence shell and has 2 shells [carbon]. Repeat with other elements; create a contest between groups.
4. More information on radioactivity: Ionizing radiation, the radiation given off by isotopes, has enough energy to remove electrons from atoms. There are three types of ionizing radiation –

alpha particles, beta particles, and gamma rays. Some of the sources of ionizing radiation are the rocks and soil, which may contain radioactive isotopes of uranium or radon; cosmic radiation; and human-produced radiation from weapons, reactors used to produce energy, and medical technology. Household products such as smoke detectors use radioactive isotopes enclosed in a protective housing.

2.2 Water's Importance to Life

1. Ask the students why water beads on a freshly washed or freshly waxed car. What characteristics of water and the car's finish or wax cause this? [Cohesion of water molecules along with the hydrophobic nature of the car's waxy finish repel water.]
2. Demonstrate water uptake in a plant. Leave two large celery stalks with some leaves remaining out at room temperature overnight. They should be limp and bendable in the morning. Make a fresh cut and place one stalk in a container of water. After one to two hours, the stalk should be firmer, showing uptake of water through the stem. Compare it to the other stalk which was not placed in water. Additionally, food coloring could be added to the water which should show as the fluid is taken up into the celery stalk. This is the process florists use to color white daisies.
3. Animals other than insects can use the surface tension of water to walk across the surface. The green basilisk lizard, *Basiliscus plumifrons*, a type of iguana that is about two and a half feet from head to tip of tail and found in Central America, can run across the surface of the water to escape predators. (This lizard is sometimes referred to as the Jesus lizard.) Its feet are webbed but it must run fast in order to stay on top of the water.

Critical Thinking Questions

1. Define radioactivity, including a description of the structure of an atom that is radioactive. Explain why irradiating something does not make it radioactive.

Ans: Radioactivity involves the instability of an atom's nucleus, which has excess neutrons. High energy radioactive particles are given off – this is called radiation. The property of radioactivity originates within the radioactive atom. Exposure to radiation may cause damage to living things or sterilize food, but it does not create radioactive atoms with excess neutrons.

2. Why is water critical for metabolic processes?

Ans: Cells are composed mostly of water. One property of water is that it is a solvent that dissolves many substances, including those that participate in metabolic reactions in cells. When dissolved in water, these substances can move about and interact.

3. The cohesive and adhesive abilities of water are critical in moving water up the conducting vessels of a plant. Since adhesion is important for this process, what must be true of the conducting vessels of a plant?

Ans: Molecules in the walls of plant-conducting vessels must also be polar (hydrophilic) so that water molecules can adhere to them.

Essay Questions

1. An oxygen atom has 8 protons, 8 neutrons, and 8 electrons. Its atomic mass is 16. Do electrons have mass?

Ans: Yes, electrons are composed of matter and do have mass; however, it is so slight that it is not included in an atomic mass number.

2. Explain why is it important for our blood to be buffered?

Ans: Digestion of different types of food can create H^+ and OH^- ions that are absorbed into the blood stream. These ions, which cause acidic or basic conditions, can harm other molecules in our body if in excess, so the blood is buffered to maintain pH within a range that is not harmful.

3. Describe the 2 ways water maintains temperatures appropriate for living organisms.

Ans: Water is a polar molecule that links to other water molecules through hydrogen bonding. Because of these hydrogen bonds, water can absorb some heat (energy) without greatly changing temperature because the hydrogen bonds hold the water molecules together. This is called a high heat capacity. The resistance to temperature change protects living organisms.

Also, due to the nature of hydrogen bonding, a great deal of energy is needed to break these bonds, separating water molecules and creating gaseous water in evaporation. This is called high heat of vaporization, which provides a way for organisms to get rid of excess heat (energy).

