Chapter 1

EXPLORING LIFE AND SCIENCE

# LEARNING OUTCOMES

## 1.1 The Characteristics of Life

1. Explain the basic characteristics common to all living organisms.
2. Describe the levels of organization of life.
3. Explain why the study of evolution is important in understanding life.

## 1.2 Humans Are Related to Other Animals

1. Summarize the place of humans in the overall classification of living organisms.
2. Understand that humans have a cultural heritage.
3. Describe the relationship between humans and the biosphere.

## 1.3 Science as a Process

1. Describe the general process of the scientific method.
2. Distinguish between a control group and an experimental group in a scientific test.
3. Recognize the importance of scientific journals in the reporting of scientific information.
4. Recognize the importance of statistical analysis to the study of science.

## 1.4 Challenges Facing Science

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

# EXTENDED LECTURE OUTLINE

## 1.1 The Characteristics of Life

The science of biology is the study of living organisms and their environments. All living organisms share several basic characteristics.

Life Is Organized

Atoms join together to form molecules that make up cells. A cell is the smallest structural and functional unit of an organism. Some organisms are single-celled, while other more complex living things are multicellular. Cells joined together form tissues, which form organs, which form organsystems, which then form individual organisms. Biological organization extends beyond the individual to populations, communities, ecosystems, and, finally, the biosphere.

Life Requires Materials and Energy

Human beings require an outside source of materials and energy to carry on life’s activities. Humans and other animals get these materials when they eat food. The ultimate source of energy for the majority of life on Earth is the sun.

Living Organisms Maintain an Internal Environment

The ability of a cell or an organism to maintain a constant balance of the internal environment under specific conditions is called homeostasis.

Living Organisms Respond

Living things respond to external stimuli, often by moving toward or away from a stimulus. Organisms use a variety of mechanisms to move.

Living Organisms Reproduce and Develop

When organisms reproduce, they pass on genetic information to the next generation. Following fertilization of the egg by the sperm cell, the zygote that results undergoes growth and development. Growth is an increase in size and number of cells and is a part of development. In humans, development includes all the changes that occur from the time the egg is fertilized until death, as well as repair that takes place following an injury. DNA is genetic information of all life and is contained within genes. Genes enable living organisms to pass on hereditary information from parent to child. Mutation is an alteration in the DNA sequence that results in evolutionary change.

Organisms Have an Evolutionary History

Evolution is the process by which a population changes through time for survival by adapting to the environment. Evolution explains both the unity and the diversity of life.

## 1.2 Humans Are Related to Other Animals

All life is now classified into three domains: Bacteria, Archaea, and Eukarya. Bacteria and Archaea are single-celled organisms that do not have a nucleus. Eukarya have a nucleus, are single-celled or multicelled, and are divided into four kingdoms: Protista, Fungi, Plantae, and Animalia. In addition, there are six subgroups, known as eukaryotic supergroups. Humans are mammals within the vertebrates of the kingdom Animalia (supergroup Opisthokonta) within the domain Eukarya.

Humans Have a Cultural Heritage

Humans’ cultural heritage encompasses human activities and products passed on from one generation to the next outside of direct biological inheritance. This includes beliefs, values, and skills.

Humans Are Members of the Biosphere

All living things on Earth are part of the biosphere, a living network that spans the surface of the Earth into the atmosphere and down into the soil and seas.

## 1.3 Science as a Process

Science is a way of knowing about the natural world and is studied objectively versus subjectively. Objective observations are supported by factual observations while subjective observations involve personal judgment. The process of science involves the scientific method, which includes observations, hypotheses, controlled experiments, conclusions that either support or reject hypotheses, and reformulation of hypotheses.

Start with an Observation

The scientific method begins with observation. Scientists may expand their understanding beyond observation by taking advantage of the knowledge and experiences of other scientists.

Develop a Hypothesis

After making observations and gathering knowledge about a phenomenon, a scientist uses inductive reasoning. A hypothesis is a supposition that is formulated after making an observation. A hypothesis is based on existing knowledge, so it is much more informed than a mere guess. When thinking about how to test a hypothesis, a scientist may make predictions based on the knowledge of the factors involved in the observations. A hypothesis is tested by obtaining more data by experimentation.

**Test the Hypothesis**

A hypothesis is tested by performing experiments. Experiments are a series of procedures and the use of deductive reasoning. An experiment consists of an experimental design, experimental variable, and responding variable. Experiments can take many forms; however, in all experimental designs, the researcher attempts to keep all the conditions constant except for the experimental variable. To ensure that the result of the experiment is meaningful, the experiment should contain test and control groups. One or more test groups are exposed to the experimental variable, but one other group, called the control group, is not. Scientists often use model organisms and model systems to test a hypothesis.

**Collect and Analyze the Data**

The data obtained from scientific experiments may be presented in various formats such as tables and graphs. These formats show the relationship between two quantities and summarize data.

Statistical Data

Statistics help scientists evaluate experimental data. In statistics, the standard error (standard deviation) shows how uncertain a particular value is.

Statistical Significance

Statistical significance allows researchers to quantify how likely it is that the results of an experiment resulted from chance alone.

Scientific Publications

Scientists share their work through publication in peer-reviewed journals through a standardized process that promotes responsibility and reliability within the scientific community. People should be careful about scientific information found on the Internet.

Develop a Conclusion

Scientists must analyze the data to conclude whether a hypothesis is supported or not. In science, the conclusion of one experiment can lead to a hypothesis for another experiment that can be used for different subjects. This is one of the reasons that scientist share their findings in scientific journals, so that methodology and data are available to other scientists.

Scientific Theory

The ultimate goal of science is to understand the natural world in terms of scientific theories, which are accepted explanations for how the world works. Examples of these theories are the cell theory, the gene theory, and the theory of evolution. The theory of evolution is the unifying concept of biology because it generates new testable hypotheses, has been supported by many observations and experiments, and enables scientists to understand the history and nature of life.

An Example of a Controlled Study

Controlled laboratory studies involve two groups of subjects, a control group not given the test medication or treatment and a test group given the medication or treatment. It is important to reduce the number of possible differences between the two groups.

Experimental Design

Independent test groups are randomly assigned to be recipients of the variable being tested. The larger the sample size, the greater the chance of reducing the influence of external variables. The data from this group are compared to those from a control group.

The Results and Conclusion

A double-blind study is when the examiner is not aware of which group the subject is in, which prevents subjective influences.

## 1.4 Science and the Challenges Facing Society

Science is a systematic way of acquiring knowledge about the natural world. It can examine only those things that can be observed objectively, not supernatural or religious beliefs. Science differs from technology. Technology is the application of scientific knowledge to the interests of humans. Science and technology are not risk-free.

Climate Change

Climate change is primarily due to an imbalance in the chemical cycling of the element carbon. Due to human activities, more carbon dioxide is being released into the atmosphere than is being removed. This phenomenon is causing a rise in temperature called global warming.

Biodiversity and Habitat Loss

Biodiversity is the total number and relative abundance of species, the variability of their genes, and the different ecosystems in which they live. Due to human activities, biodiversity is threatened with hundreds of species becoming extinct each year.

Emerging and Reemerging Diseases

New diseases have generated a lot of publicity. These emerging diseases may result from human behavior and the use of technology. Reemerging diseases are known to cause disease but generally have not been considered a health risk due to the low level of incidence in human populations. Conversely, reemerging diseases can cause problems.

# STUDENT ACTIVITIES

Is It Alive?

1. Bring to class a collection of living things and inanimate objects. Plastic models of living organisms are particularly useful. Have students gather around the specimens and identify the features that distinguish the living specimens from the inanimate ones. List the distinguishing features on the board or overhead as students suggest them.

Humans Are Related to Other Animals

2. Give students a list of organisms that includes members of the four kingdoms within Eukarya (animals, plants, fungi, and protists). Ask them to divide the organisms into the various groups based on what they already know about these organisms. Then ask them to describe the common characteristics of each group.

Exploring the Scientific Method

3. Propose a simple hypothetical experiment in class, such as how salt affects the hatching of brine shrimp. Suggest the use of water, weak salt solution, and strong salt solution as the three “habitats.” Have students formulate a hypothesis and discuss the steps needed to carry out their plan. Have some brine shrimp or photographs of brine shrimp available for observation.

Animals in the Lab

4. Arrange to take your students to a laboratory on campus or a nearby research facility to tour the animal housing facilities. Have the laboratory technician in charge of the lab explain what methods are used to ensure the animals receive good care and adequate housing. Explain the nature of the research involving animals in the research lab. Allow time for the students to ask questions.

One Application of the Scientific Method

5. Invite a fellow faculty member engaged in research on your campus to tell the class how they use the scientific method to address a specific question. Ask them to include a description of the control group(s) used in their research.

# CLASSROOM DISCUSSION TOPICS

1. Viruses are not considered to be living organisms. Have students determine which of the characteristics of life viruses do not possess. Why would another parasitic organism, such as a disease-causing bacterium, be considered a living organism?

2. How does evolution explain both the unity and the diversity of life? Have students discuss what living things have in common and why these commonalities suggest a common ancestor. Have students discuss how living things are diverse and how this came about.

3. If humans are members of the biosphere, what gives them the right to modify and/or destroy the habitats of other organisms? Are humans “above” other organisms? Are they in some way “special” or “different”? What responsibilities do humans have to take care of the other organisms of the biosphere?

4. Read BIOLOGY TODAY-Science “Adapting to Life at High Elevations” in the text. Have students answer the following questions: What is the function of hemoglobin? How is the hemoglobin of people who live at high elevations different from that of people who live at low elevations? How is the gene *EPSA1* and the transcription factor it encodes involved with hemoglobin production? Define the term *adaptation* using the example of Tibetans who reside at high altitudes.

5. Read BIOLOGY TODAY-Science “Discovering the Cause of Ulcers” in the text. Have students explain how Marshall’s approach was similar to and different from the scientific method.