1.1 The Characteristics of Life

LEARNING OUTCOMES

Upon completion of this section, you should be able to

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.

The science of **biology** is the study of living organisms and the environments they live in. All living organisms (Fig. 1.1) share several basic characteristics. They (1) are organized, (2) acquire materials and energy, (3) are homeostatic, (4) respond to stimuli, (5) reproduce and have the potential for growth, and (6) have an evolutionary history.

Life Is Organized

Life can be organized in a hierarchy of levels (Fig. 1.2). Note that, at the very base of this organization, **atoms** join together to form the **molecules,** which in turn make up a cell. A **cell** is the smallest structural and functional unit of an organism. Some organisms, such as bacteria, are single-celled organisms. Humans are multicellular, because they are composed of many different types of cells. For example, the structure of nerve cells in the human body allows these cells to conduct nerve impulses.

A **tissue** is a group of similar cells that perform a particular function. Nervous tissue is composed of millions of nerve cells that transmit signals to all parts of the body. An **organ** is made up of several types of tissues, and each organ belongs to an **organ system.** The organs of an organ system work together to accomplish a common purpose. The brain works with the spinal cord to send commands to body parts by way of nerves. **Organisms,** such as trees and humans, are a collection of organ systems.

The levels of biological organization extend beyond the individual. All the members of one **species** (a group of interbreeding organisms) in a particular area belong to a **population.** A tropical grassland may have a population of zebras, acacia trees, and humans, for example. The interacting populations of the grasslands make up a **community.** The community of populations interacts with the physical environment to form an **ecosystem.** Finally, all the Earth's ecosystems collectively make up the **biosphere** (Fig. 1.2, *top*).

Figure 1.1 All life shares common characteristics.
From the simplest one-celled organisms to complex plants and animals, all life shares several basic characteristics.
(student group): FatCamera/E+/Getty Images; (mushrooms): IT Stock/age fotostock; (bacteria): Paul Gunning/Science Photo Library/Getty Images; (gorilla): Mike Price/Shutterstock; (sunflower): MedioImages/PunchStock/Getty Images; (*Giardia*): Dr. Stan Erlandsen/CDC

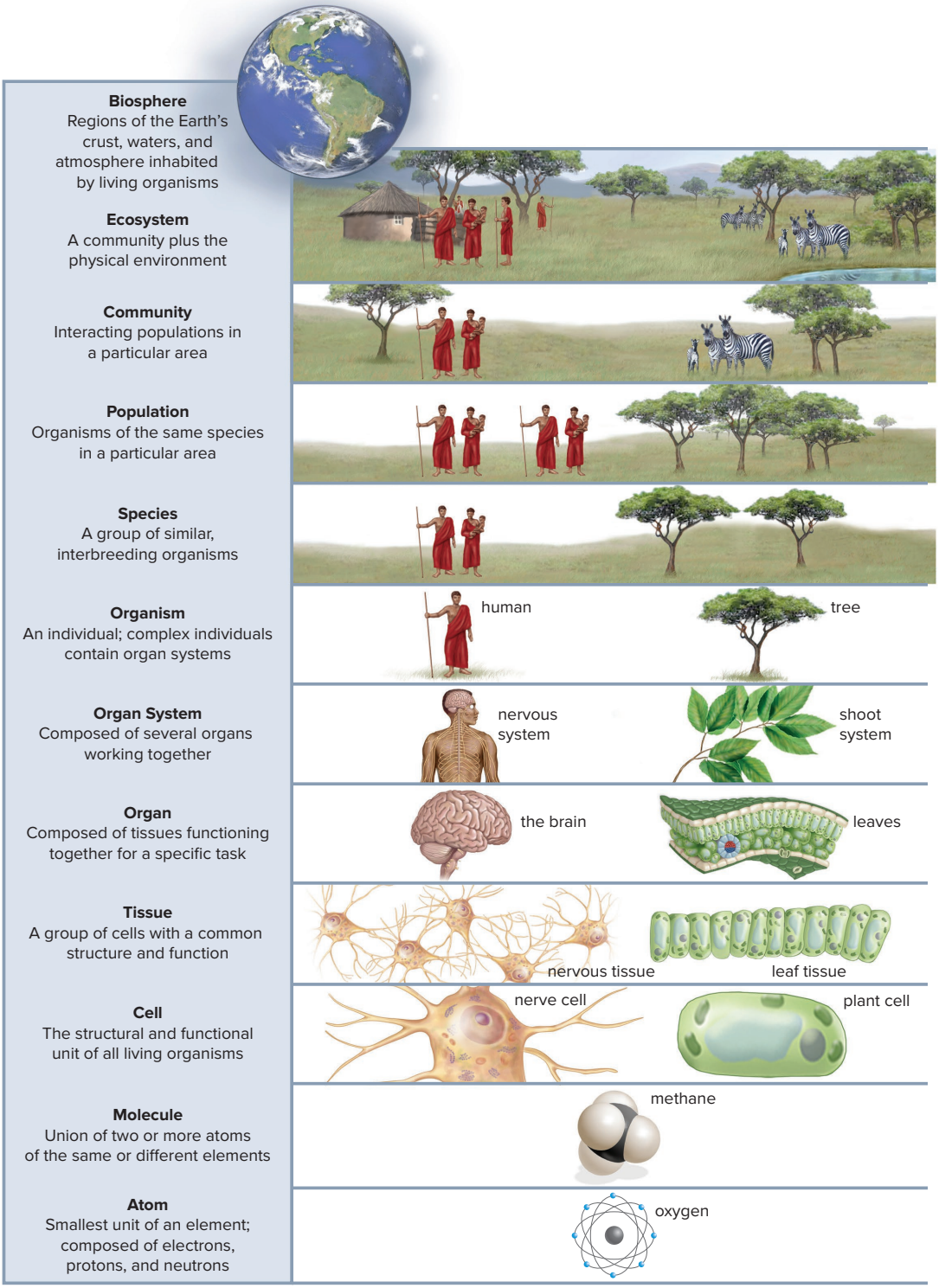

Figure 1.2 Levels of biological organization.
Life is connected from the atomic level to the biosphere. The cell is the basic unit of life, and it comprises molecules and atoms. The sum of all life on the planet is called the biosphere.

BIOLOGY IN YOUR LIFE

How many cells are in your body?

The number of cells in a human body varies depending on the size of the person and whether cells have been damaged or lost. However, most estimates suggest there are well over 30 trillion cells in a human body. To put this into perspective, there are only an estimated 3 trillion trees on Earth.

Life Requires Materials and Energy

Humans, like all living organisms, cannot maintain their organization or carry on life's activities without an outside source of materials and energy. **Energy** is the capacity to do work. Like other animals, humans acquire materials and energy by eating food (Fig. 1.3).

Food provides nutrient molecules, which are used as building blocks or for energy. It takes energy to maintain the organization of the cell and the organism itself. Some nutrient molecules are broken down completely to provide the energy necessary to convert other nutrient molecules into the parts and products of cells. The breakdown of food is a component of our **metabolism,** or the sum of all the chemical reactions that occur within a cell or organism.

a.

b.

Figure 1.3 **Humans and other animals must acquire energy.** All life, including humans (**a**) and other animals, such as this eagle (**b**), must acquire energy to survive. The method by which organisms acquire energy is dependent on the species.

(a): Ariel Skelley/Blend Images/Getty Images; (b): Brian E Kushner/Shutterstock

The ultimate source of energy for the majority of life on Earth is the sun. Plants, algae, and some bacteria are able to harvest the energy of the sun and convert it to chemical energy by a process called **photosynthesis.** Photosynthesis produces organic molecules, such as sugars, that serve as the basis of the food chain for many other organisms, including humans and all other animals.

Living Organisms Maintain an Internal Environment

For the metabolic pathways within a cell to function correctly, the environmental conditions of the cell must be kept within strict operating limits. Many of the metabolic activities of a cell, or organism, function in maintaining **homeostasis**—a constant internal environment.

In humans, many of our organ systems work to maintain homeostasis. For example, human body temperature normally fluctuates slightly between 36.5 and 37.5°C (97.7 and 99.5°F) during the day. In general, the lowest temperature usually occurs between 2 A.M. and 4 A.M., and the highest usually occurs between 6 P.M. and 10 P.M. However, activity can cause the body temperature to rise, and inactivity can cause it to decline. The metabolic activities of our cells, tissues, and organs are dependent on maintaining a relatively constant body temperature. Therefore, a number of body systems, including the cardiovascular system and the nervous system, work together to maintain a constant temperature. The body's ability to maintain a normal temperature is also somewhat dependent on the external temperature. Even though we can shiver when we are cold and perspire when we are hot, we will die if the external temperature becomes overly cold or hot.

This text emphasizes how all the systems of the human body help maintain homeostasis. For example, the digestive system takes in nutrients, and the respiratory system exchanges gas with the environment. The cardiovascular system distributes nutrients and oxygen to the cells and picks up their wastes. The metabolic waste products of cells are excreted by the urinary system. The work of the nervous and endocrine systems is critical, because these systems coordinate the functions of the other systems.

Living Organisms Respond

It would be impossible to maintain homeostasis without the body's ability to respond to stimuli, both from the internal and external environments. Response to external stimuli is more apparent to us, because it involves movement, as when we quickly remove a hand from a hot stove. Certain sensory receptors also detect a change in the internal environment, and then the central nervous system brings about an appropriate response. When you are startled by a loud noise, your heartbeat increases, which causes your blood pressure to increase. If blood pressure rises too high, the brain directs blood vessels to dilate, helping restore normal blood pressure.

All life responds to external stimuli, often by moving toward or away from a stimulus, such as the sight of food. Organisms may use a variety of mechanisms to move, but movement in humans and other animals is dependent on their nervous and musculoskeletal systems. The leaves of plants track the passage of the sun during the day; when a houseplant is placed near a window, its stems bend to face the sun. The movement of an animal, whether self-directed

Figure 1.4 Growth and development define life.

a. A small acorn becomes a tree, and (**b**) following fertilization an embryo becomes a fetus by the process of growth and development.

(a) (seedling): bogdan ionescu/Shutterstock; (a) (tree): Frank Krahmer/Photographer's Choice/Getty Images; (b) (sperm/egg): David M. Phillips/Science Source; (b) (fetus): Steve Allen/Brand X Pictures/Getty Images

or in response to a stimulus, constitutes a large part of its *behavior*. Some behaviors help us acquire food and reproduce.

Living Organisms Reproduce and Develop

Reproduction is a fundamental characteristic of life. Cells come into being only from preexisting cells, and all living organisms have parents. When organisms **reproduce,** they pass on their genetic information to the next generation. Following the fertilization of an egg by a sperm cell, the resulting zygote undergoes a rapid period of growth and development. This is common in most forms of life. Figure 1.4*a* illustrates that an acorn progresses to a seedling before it becomes an adult oak tree. In humans, growth occurs as the fertilized egg develops into a fetus (Fig. 1.4*b*). **Growth,** recognized by an increase in size and often in the number of cells, is a part of development. In multicellular organisms, such as humans, the term **development** is used to indicate all the changes that occur from the time the egg is fertilized until death. Therefore, it includes all the changes that occur during childhood, adolescence, and adulthood. Development also includes the repair that takes place following an injury.

The genetic information of all life is **DNA (deoxyribonucleic acid).** DNA contains the hereditary information that directs not only the structure of each cell but also its function. The information in DNA is contained within **genes,** short sequences of hereditary material that specify the instructions for a specific trait. Before reproduction occurs, DNA is replicated so an exact copy of each gene may be passed on to the offspring. When humans reproduce, a sperm carries genes contributed by a male into the egg, which contains genes contributed by a female. The genes direct both growth and development so that the organism will eventually resemble the parents. Sometimes **mutations,** minor variations in these genes, can cause an organism to be better suited for its environment. These mutations are the basis of evolutionary change.

Organisms Have an Evolutionary History

Evolution is the process by which a population changes over time. The mechanism by which evolution occurs is **natural selection** (see Section 23.2). When a new variation arises that allows certain members of a population to capture more resources, these members tend to survive and have more offspring than the other, unchanged members. Therefore, each successive generation will include more members with the new variation, which represents an **adaptation** to the environment. Consider, for example, populations of humans who live at high altitudes, such as the cultures living at elevations of over 4,000 meters (m) (14,000 ft) in the Tibetan Plateau. This environment is very low in oxygen. As the Science feature "Adapting to Life at High Elevations" investigates, these populations have evolved an adaptation that reduces the amount of hemoglobin, the oxygen-carrying pigment in the blood. As the feature explains, this adaptation makes life at these altitudes possible.

Evolution, which has been going on since the origin of life and will continue as long as life exists, explains both the unity and diversity of life. All organisms share the same characteristics of life because their ancestry can be traced to the first cell or cells. Organisms are diverse because they are adapted to different ways of life.