Everything in our world is either living or nonliving. However, telling the difference between a living thing and a nonliving thing is not always easy. Why is a tree considered a living thing, while a rock is not?

How are living things similar to and different from nonliving things, and how are living things similar to and different from each other?

**Living Versus Nonliving**

How do you know that something is living? You might say that living things grow. Yes, living things can increase in size, but so do some nonliving things like gases, foams, and the flames in Figure 2.1. So how do you decide whether a thing is living or nonliving?

Over time, biologists have established that all living things share certain characteristics. These characteristics include:

- a cellular organization,
- reproduction that passes hereditary information to offspring,
- growth and development, and
- adjusting to surroundings to maintain internal stability.

An *organism* is anything that possesses all of the characteristics of life. Sometimes, nonliving things have one or more of these characteristics, but to be considered living, something must have all of them.

**Living Things are Organized**

An orderly cellular or organismal structure is one of the characteristics that biologists use to determine if something is living or nonliving.

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**Figure 2.1** Although a flame can increase in size and produce more flames, it cannot adjust if its surroundings change.
All living things are made of one or more cells. All cells contain the information needed to carry on the processes essential for life. All living things maintain this cellular organization. This orderly structure enables the parts of an organism to work together as a living system.

**Living Things Reproduce**
The ability to produce offspring is another characteristic of life. While an individual organism cannot live forever, the hereditary information for that organism can be passed to its offspring by reproduction. The offspring, in turn, pass this information to their offspring, and so on through subsequent generations. Life continues because hereditary information is passed on by reproduction.

**Living Things Grow and Develop**
All organisms begin life as a cell. A unicellular organism remains nearly the same size all of its life but can undergo development. For a multicellular organism, a cell divides into new cells, these cells increase in size and divide, and new structures form. A multicellular organism also goes through many developmental changes during its life.

The amount of time required for growth and development varies greatly among organisms. A bacterium might exist only hours before dividing into two new cells. Some insects complete their lives in a few months. However, a redwood tree might grow for centuries.

**Living Things Adjust to Their Surroundings**
Organisms constantly interact with the nonliving and living things in their surroundings. For example, a sunflower’s “face” turns toward the Sun as it appears to move across the sky throughout the day. You might shiver when stepping outside on a cold winter morning. A bony fish, as shown in Figure 2.2, can sense living and nonliving objects in its surroundings. Anything in an organism’s external or internal environment that causes the organism to react is a **stimulus**. A reaction to a stimulus is a **response**.

All living things have the ability to respond to stimuli in their environments. Even as organisms adjust to changes in their environments, they also must be able to maintain internal conditions in order to carry out life-sustaining processes. For example, in humans, a nearly constant internal temperature and the proper amount of water in cells must be maintained in order to function properly.

**CHECK FOR UNDERSTANDING** Identify the stimulus and the response in the following situation: A dog sees a rabbit and chases it.

Regulation of an organism’s internal environment to maintain conditions suitable for its survival is known as **homeostasis**. Without the ability to regulate its internal environment, an organism would die. Homeostasis occurs in all living things—another characteristic of life.

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**Quick Review**

1. List the four characteristics of life shared by all organisms.

2. Anything that possesses all of life’s characteristics is called a(n)
   (1) stimulus (3) homeostasis
   (2) organism (4) reproduction

3. How do most organisms ensure continuation of life?

4. An organism’s regulation of its internal environment to maintain stability is called
   (1) homeostasis (3) organization
   (2) structure (4) stimulus

5. What is the difference between a living and a nonliving thing?

6. What is a response?
From a Cell to an Organism

Cells are the basic units of all living organisms. They perform functions necessary to sustain life. In multicellular organisms, groups of cells that work together to perform a specific function are called a tissue. Two or more tissues that work together are called an organ. An organ performs specific complex functions within the organism. For example, cells make up cardiac muscle tissue. Cardiac muscle tissue works with other tissues in the heart, which is the organ that pumps blood. Multiple organs that work together form an organ system. The heart, arteries, veins, and capillaries are parts of the circulatory system that carries blood throughout the body.

CHECK FOR UNDERSTANDING Arrange the following from smallest to largest: organ, cell, organ system, tissue.

All organ systems work together for the survival of the organism. An example of cell specialization and organization for a complex organism is shown in Figure 2.3. The digestive system works together with other organ systems to ensure the survival of this panther.

Cellular Organization

Just as organ systems are coordinated and work together for the survival of an organism, the parts of a cell also must be coordinated and work together for the survival of the cell. A cell is covered by the plasma membrane. It is a flexible boundary between a cell and its environment. All cells contain small structures called organelles that perform specific functions. Organelles work together to carry out metabolic processes necessary for a cell’s survival. Membranes surround many organelles. The absence or presence of membrane-bound organelles determines cell type, as shown in Figure 2.4. A cell that does not contain membrane-bound organelles is called a prokaryotic cell. Bacteria are prokaryotic organisms. A cell that has membrane-bound organelles is called a eukaryotic cell. Some unicellular organisms and most multicellular organisms are composed of eukaryotic cells.

The Plasma Membrane

Phospholipids, proteins, and carbohydrates are the primary components of the plasma membrane. The structural model of the plasma membrane is called the fluid mosaic model. Like a fluid, the phospholipids move within the membrane.

Figure 2.4 Cell types are either prokaryotic A or eukaryotic B.
The proteins also move easily among the phospholipids and create a “mosaic,” or a pattern, on the plasma membrane’s surface.

The plasma membrane, shown in Figure 2.5, separates a cell from its environment, controls which molecules enter and leave a cell, and recognizes chemical signals. It maintains homeostasis within a cell by being selectively permeable. **Selective permeability** is a process that allows the passage of some molecules into a cell while keeping others out. As indicated in Figure 2.6, some molecules, such as water molecules, can freely enter and leave a cell. The plasma membrane also allows for the excretion of wastes from a cell and prevents other substances from entering a cell. It also regulates certain amounts of other substances, such as sodium ions, in a cell.

**CHECK FOR UNDERSTANDING** How would a cell be affected if the plasma membrane lost its selective permeability?

Some molecules can pass through the plasma membrane by the processes of diffusion or active transport. **Diffusion** occurs when molecules randomly move from an area of higher concentration to an area of lower concentration without the expenditure of cellular energy. In **active transport**, molecules move from an area of lower concentration to an area of higher concentration. Active transport requires an expenditure of cellular energy.
In a multicellular organism, cells communicate with one another. Embedded within the phospholipid layer of the plasma membrane are proteins that serve as receptor molecules. These receptors identify and bind with specific chemical signals, such as hormones and antibodies, to aid in cellular communication. These signals generally give some kind of instructions to a cell that might modify cell function.

**Transport of Materials Inside a Cell**

You have learned that the plasma membrane regulates the movement of materials into and out of a cell. How does material move inside of a cell?

The **cytoplasm** is the main component inside of a cell. It is a clear, gelatinous fluid. However, unlike dessert gelatin, cytoplasm flows and moves around a cell. In a prokaryotic cell, most of the metabolic processes take place in the cytoplasm. In a eukaryotic cell, organelles suspended in the cytoplasm perform the metabolic processes.

The cytoplasm contains a framework called the **cytoskeleton**. It is composed of microtubules—thin, hollow rods made of protein—and microfilaments—solid protein fibers. This network of rods and filaments helps maintain the shape of a cell and allows for cellular movement. It also provides a system by which materials and organelles move within a cell. Figure 2.7 shows how the cytoskeleton connects organelles.

**Information Storage in a Cell**

Just as a computer needs a hard drive to store the information used to make it operate, a cell needs a storage unit to hold all of its operating information. The **nucleus**, as shown in Figure 2.8A on page 18, is the organelle in a eukaryotic cell that contains DNA—hereditary material. DNA contains the instructions for making proteins. Every part of a cell depends on proteins. Since the nucleus holds the instructions for making proteins, it manages cellular function by controlling the activities of all the organelles.

**Building Proteins in a Cell**

The nucleus contains an organelle called the nucleolus, which makes ribosomes. **Ribosomes** translate the directions from DNA and build proteins. Unlike many other organelles, ribosomes are not membrane-bound. In order to build proteins, ribosomes and copies of the hereditary material must leave the nucleus and enter the cytoplasm of a cell.

In the cytoplasm, ribosomes remain free or attach to the endoplasmic reticulum, an organelle that is the site of cellular chemical reactions. Endoplasmic reticulum (ER) with ribosomes attached is called rough ER, as shown in Figure 2.8B. The proteins made in the rough ER carry out particular functions. They may be released from a cell, bound in the plasma membrane, or move to other organelles. Free-floating ribosomes produce proteins that perform functions in the cytoplasm itself.

Proteins are transferred from ribosomes to another organelle called the Golgi apparatus. The Golgi apparatus, as shown in Figure 2.8C, is a system of flattened tubular membranes that sorts and packs the proteins before sending them to their appropriate destinations.

**Storage in a Cell**

**Vacuoles** are membrane-bound spaces in the cytoplasm used for the temporary storage of materials. Vacuoles store materials needed by a cell, such as food and enzymes. Some vacuoles are used for the temporary storage of wastes. Plant cells usually have one large vacuole, while some animal cells contain a few small vacuoles.

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Figure 2.7 The cytoskeleton of a eukaryotic cell acts like a highway for the movement of organelles.
Energy and a Cell

All of the metabolic processes that occur in a cell, such as protein building and transportation, require energy. Two organelles—mitochondrion (plural, mitochondria) and the chloroplast—can transform energy for use within a cell.

Mitochondria are membrane-bound organelles that transform energy stored in food molecules. Each mitochondrion is surrounded by a double membrane that consists of an outer membrane and a highly folded inner membrane, as shown in Figure 2.8D. Molecules that store energy are produced on the inner folds. The energy released by the mitochondria comes from the chemical bonds of other molecules. This released energy fuels all activities of a cell.

**CHECK FOR UNDERSTANDING** What organelles transform energy stored in food to perform metabolic processes?

Chloroplasts are found in some protists and some cells of plants. A chloroplast has a double membrane, consisting of an outer membrane and a folded inner membrane, as shown in Figure 2.9 on page 19. The inner membrane is arranged into stacks called grana. The grana contain the structures called thylakoids that can trap the energy in sunlight. The chloroplasts transform light energy to chemical energy during the process of photosynthesis. This chemical energy is stored in the bonds of sugar molecules produced by some plant cells or protists.

The number of chloroplasts or mitochondria in a cell depends on the function of a cell. A cell that requires a high amount of energy to function can contain many mitochondria. For example, muscle cells require much energy and contain a high number of mitochondria. In contrast, skin cells use little energy and contain few mitochondria.
Waste Disposal in a Cell

How does a cell dispose of any waste products? In an animal cell, the process begins with lysosomes—organelles that contain digestive enzymes. Lysosomes help digest food particles, trapped viruses, or bacteria and excess or worn out organelles. What prevents a lysosome from destroying the cell it is in? The membrane surrounding the lysosome separates the lysosome’s digestive enzymes from the rest of the cell. After materials are broken down by a lysosome, the waste exits a cell through the plasma membrane.

CHECK FOR UNDERSTANDING How does a cell break down waste materials?

Prokaryotic Cells and Eukaryotic Cells

You have learned that most unicellular organisms consist of a prokaryotic cell and multicellular organisms consist of eukaryotic cells. You also know that eukaryotic cells contain membrane-bound organelles that perform cellular metabolic processes. In addition, a complex organism has tissues, organs, and organ systems that work together for the survival of the organism. How does a unicellular organism function despite lacking the levels of organization present in more complex organisms?

As mentioned earlier, many metabolic processes in prokaryotic organisms are performed in the cytoplasm, not in membrane-bound organelles. unicellular eukaryotic organisms have structures that act in a manner similar to the tissues, organs, and organ systems found in multicellular organisms, enabling them to perform all of the life processes needed to maintain homeostasis. To help you understand this concept, Table 2.1 compares prokaryotic cells to eukaryotic cells, their cell parts, and what those parts do.

<table>
<thead>
<tr>
<th>Cell Part</th>
<th>Function</th>
<th>Prokaryotic</th>
<th>Eukaryotic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma membrane</td>
<td>Maintains homeostasis</td>
<td>Present</td>
<td>Present</td>
</tr>
<tr>
<td>Cytoplasm</td>
<td>Transports materials</td>
<td>Present</td>
<td>Present</td>
</tr>
<tr>
<td>Nucleus</td>
<td>Cell control center</td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td>Nucleolus</td>
<td>Makes ribosomes</td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td>Ribosome</td>
<td>Builds proteins</td>
<td>Present</td>
<td>Present</td>
</tr>
<tr>
<td>Endoplasmic reticulum (ER)</td>
<td>Chemical reactions</td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td>Golgi apparatus</td>
<td>Sorts and transports</td>
<td>Absent</td>
<td>Present in some</td>
</tr>
<tr>
<td>Vacuole</td>
<td>Storage</td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td>Chloroplast</td>
<td>Transforms energy</td>
<td>Absent</td>
<td>Present in some</td>
</tr>
<tr>
<td>Mitochondrion</td>
<td>Releases energy</td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td>Lysosome</td>
<td>Digests material</td>
<td>Absent</td>
<td>Present in some</td>
</tr>
</tbody>
</table>
7. Which of the following organelles builds proteins?
   (1) lysosome  (3) nucleus
   (2) ribosome  (4) vacuole

8. Compare the number of vacuoles in plant cells and animal cells.

9. Which of the following is a group of cells that works together to perform a specific function?
   (1) organ system  (3) tissue
   (2) organ  (4) organism

10. Brain cells require a large amount of energy to function. Which organelles might be numerous in a brain cell?

11. The digestive enzymes in lysosomes break down food particles and worn out organelles. Why don’t these enzymes digest the cell itself?

12. What is the structural model of the plasma membrane called? Explain.

13. Describe how the plasma membrane uses selective permeability to maintain homeostasis in the cell.

14. Why are chloroplasts known as energy transformers?

15. Which of the following describes the process by which molecules randomly move from an area of high concentration to an area of low concentration without the expenditure of energy?
   (1) active transport
   (2) fluid mosaic model
   (3) diffusion
   (4) selective permeability

16. Which of the following statements is not true about ribosomes?
   (1) Ribosomes build proteins by following the directions of the DNA.
   (2) Ribosomes are made in the cytoplasm of the cell.
   (3) Ribosomes attach to the endoplasmic reticulum when they are in the cytoplasm.
   (4) Ribosomes are not bound by a membrane.
1 The diagram below represents a cell in water. Formulas of molecules that can move freely across the cell membrane are shown. Some molecules are located inside the cell and others are in the water outside the cell.

Based on the distribution of these molecules, what would most likely happen after a period of time?

(1) The concentration of $O_2$ will increase inside the cell.
(2) The concentration of $CO_2$ will remain the same inside the cell.
(3) The concentration of $O_2$ will remain the same outside the cell.
(4) The concentration of $CO_2$ will decrease outside the cell.

2 Which statement describing the cells in a body system is correct?

(1) Each cell in the system is identical to the other cells in the system, and each cell works independently of the other cells.
(2) Some cells in the system may be different from the other cells in the system, but all cells are coordinated and work together.
(3) Each cell in the system is different from the other cells in the system, and each cell works independently of the other cells.
(4) All cells in the system are identical to each other and work together.

3 Every single-celled organism is able to survive because it carries out

(1) metabolic activities
(2) autotrophic nutrition
(3) heterotrophic nutrition
(4) sexual reproduction

4 Which of the following is a structure that performs a specialized function within a cell?

(1) organ system
(2) tissue
(3) organelle
(4) organ

5 Both a deer and a tree react to changes in their external surroundings, helping them to maintain a constant internal environment. This statement describes

(1) predation
(2) homeostasis
(3) antibiotic resistance
(4) autotrophic nutrition

6 While viewing a slide of rapidly moving sperm cells, a student concludes that these cells require a large amount of energy to maintain their activity. The organelles that most directly provide this energy are known as

(1) vacuoles
(2) ribosomes
(3) chloroplasts
(4) mitochondria

7 In a cell, all organelles work together to carry out

(1) diffusion
(2) active transport
(3) information storage
(4) metabolic processes
8 Which statement regarding the functioning of the cell membrane of all organisms is not correct?
(1) The cell membrane forms a boundary that separates the cellular contents from the outside environment.
(2) The cell membrane is capable of receiving and recognizing chemical signals.
(3) The cell membrane forms a barrier that keeps all substances that might harm the cell from entering the cell.
(4) The cell membrane controls the movement of molecules into and out of the cell.

9 An example of a reaction to a stimulus is
(1) a boy smelling a flower
(2) eyes blinking due to smoke in the air
(3) a person tapping on the shoulder of a friend
(4) a loud clap of thunder following lightning

10 Which life process is indicated by the arrows in the diagram of an amoeba shown below?

11 Anything that possesses all of the characteristics of life is called
(1) an organ
(2) an organism
(3) a stimulus
(4) a vector

12 In multicellular organisms, cells must be able to communicate with each other. Structures that enable most cells to communicate with each other are known as
(1) pathogenic agents
(2) chloroplasts
(3) antibiotics
(4) receptor molecules

13 Which of the following statements does not describe a characteristic of life?
(1) All living things maintain a cellular organization.
(2) All living things pass on hereditary information through reproduction.
(3) All living things grow and develop.
(4) All living things move.

14 Which letter in the diagram below indicates the structure that is most closely associated with protein building?
Part B

Base your answers to questions 15 through 17 on the diagram below, which shows some of the specialized organelles in a single-celled organism, and on your knowledge of biology.

A (contains food)  
B (contains liquid wastes)  
C (contains DNA)  
D (contains receptors)

15 Write the letter of one of the labeled organelles and state the name of that organelle.

16 Explain how the function of the organelle you selected in question 15 assists in the maintenance of homeostasis.

17 Identify a system in the human body that performs a function similar to that of the organelle you selected in question 16.

18 In desert environments, organisms that cannot maintain a constant internal body temperature, such as snakes and lizards, rarely go out during the hot, sunny daylight hours. They stay in the shade, under rocks, or in burrows during the day. Explain how this behavior helps maintain homeostasis in these organisms.

19 Substance X has a unique characteristic in that it fluoresces (glows) when exposed to ultraviolet light. An investigator added substance X to a dish containing a culture of cells. The investigator exposed the cells to ultraviolet light and found that substance X was highly concentrated only within mitochondria (cell organelles). Which assumption could the investigator make regarding the results of this experiment?

1. Substance X could be used to identify mitochondria in living cells.
2. Substance X could be used to stain nuclei of living cells.
3. All fluorescent substances will be absorbed by mitochondria.
4. All mitochondria synthesize fluorescent substances.

20 A student filled a bag of dialysis tubing with a milky-white starch solution and placed the bag in a beaker of iodine-water solution as shown in the diagram below. An hour later, the student observed that the starch solution had turned blue-black (positive test for starch). What is the most probable explanation for the change?
21 Describe the role of the Golgi apparatus in a eukaryotic cell.

Part C

22 All living things carry out a variety of life functions such as coordination, excretion, digestion, circulation, and synthesis. Select two of the life functions listed. Define the two life functions you selected and explain how they interact to keep an organism alive.

23 Just like complex organisms, cells are able to survive by coordinating various activities. Complex organisms have a variety of systems, and cells have a variety of organelles that work together for survival. Describe the roles of two organelles. In your answer be sure to include:
- the names of two organelles and the function of each
- an explanation of how these two organelles work together
- the name of an organelle and the name of a system in the human body that have similar functions

Base your answers to questions 24 through 26 on the graph below and on your knowledge of biology. Use one or more complete sentences to answer each question.

A group of students designed an experiment to study rate of diffusion vs. temperature. The students recorded the time required for fruit drink crystals to dissolve and diffuse evenly throughout four beakers of water at various temperatures.
24 Do the data in the graph justify the students’ conclusions that rising temperatures speed the process of diffusion? Defend your position with supporting data.

25 Write an appropriate title for this graph on your answer sheet.

26 Explain what would be most likely to happen to the diffusion rate of the crystals if the students lowered the temperature in one beaker from 20°C to 0°C.

27 Explain how a one-celled organism is able to function despite lacking the levels of organization present in more complex organisms.

Part D

Answer all questions in this part.

Directions (28–32): Base your answers on the information and diagram below and on your knowledge of biology. The diagram represents some cells on a microscope slide before and after saltwater solution was added to the slide.

28 Describe the process that occurred when a saltwater solution was added to the red onion cells shown on the slide.

29 Why is it desirable to add the saltwater solution to the cell without removing the coverslip?

30 Which structure in the cell controls the movement of molecules in and out of the cell?
   (1) chloroplasts
   (2) endoplasmic reticulum
   (3) Golgi apparatus
   (4) plasma membrane

31 How does homeostasis of a cell depend upon selective permeability of the plasma membrane?
32 Describe what would happen to the onion cell if distilled water were added to the cell.

Directions (33–35): Base your answers on the information and diagram below and on your knowledge of biology. The diagram represents a procedure or technique often used in biology laboratory activities.

33 Explain what is occurring in the procedure shown.

34 Identify a scenario in which this procedure might be used.

35 How does staining aid the investigation of cells when viewing them under a microscope?