28.1 Levels of Organization

VOCABULARY

determination
differentiation
tissue
organ
organ system

KEY CONCEPT **The human body has five levels of organization.**

MAIN IDEAS

- Specialized cells develop from a single zygote.
- Specialized cells function together in tissues, organs, organ systems, and the whole organism.

Connect to Your World

Climbing a wall of ice requires careful interaction among all parts of the body. You probably know that the brain and muscles work together to coordinate the climber's movements. The heart and lungs also have to work together to help provide energy for the climb. Yet every human body starts out as a single cell, a fertilized zygote. How does a single cell give rise to all the different types of cells, tissues, and organs in the human body? Further, how do such different parts coordinate their activities to keep the body functioning?

MAIN IDEA

Specialized cells develop from a single zygote.

If you were to watch an emergency medical team in action, you would quickly notice that each person has a special job. One keeps in radio contact with the main hospital. Another monitors the patient's vital signs. Still others perform life-saving procedures. All emergency teams are made up of people, but each person within the group has a different job.

Likewise, multicellular organisms are made up of cells, but different cells in the organism have different functions. Take a moment to study the images of the blood cells and nerve cells, or neurons, in **FIGURE 1.1.** You will notice that the red blood cells are round with a concave center. This structure gives them more surface area to help deliver oxygen to all parts of the body. In contrast, neurons develop extensions that transmit and receive messages from other neurons.

FIGURE 1.1 The disk-shaped red blood cells (top) carry oxygen to all parts of the body. The neuron (bottom), through its extensions, receives and transmits messages from and to other neurons. (colored SEMs; magnifications: blood cells 2800×; neuron about 1600×)

Humans, like almost all multicellular organisms, are collections of specialized cells that work together. These cells arise from a single cell, the zygote, which is formed by the union of an egg and sperm. The zygote divides and differentiates into more than 200 different types of human cells. These cells allow you to do everything from lifting a glass, to learning people's names, to maintaining your body temperature on a cold day. Cell specialization involves two main steps: determination and differentiation.

Determination

The cells produced during the first few divisions of the zygote are known as embryonic stem cells. These cells have the potential to become any type of specialized cell in the body. Within a few weeks, however, a process called **determination** occurs in which most stem cells become committed to develop

into only one type of cell. For instance, a stem cell might become a cardiac muscle cell or a spinal neuron. These committed cells still retain all of the genetic information needed to build an entire organism. However, during determination, they lose their ability to express some of this information.

Once a cell is committed to becoming a specialized cell, it will develop into only that type of cell. For instance, a cell that will become a neuron can only be a neuron, even if it is transplanted into another part of the body. During normal development, determination cannot be reversed.

Differentiation

Differentiation is the process by which committed cells acquire the structures and functions of highly specialized cells. Differentiation occurs because specific genes in each cell are turned on and off in a complex, regulated pattern. The different structures of these specialized cells, such as those shown in **FIGURE 1.2**, allow them to perform specific functions within the body.

The function of muscle cells, for example, is to produce movement by contracting and relaxing. However, skeletal muscle and smooth muscle cells have different structures. Skeletal muscle cells align in bands of orderly rows and contain many nuclei. They are responsible for nearly all voluntary muscle movements, such as lifting your foot to kick a ball. In contrast, smooth muscle cells are shorter and have only one nucleus. They perform involuntary movements, such as raising the hairs on your arms and legs.

Other cells have even more specialized structures and functions. Sperm cells, for instance, develop whiplike tails that enable them to swim. Cells lining the gut are elongated and tightly packed to provide more surface area for the absorption of nutrients.

Not all cells continue to develop into specialized cells. The process of programmed cell death, called apoptosis (AP-uhp-TOH-sihs), is also a normal part of development. For example, when your hands first formed, your fingers resembled a mitten. The death of cells between the fingers allowed individual fingers to develop.

Analyze **What are some of the reasons that multicellular organisms need specialized cells?**

READING TOOLBOX

TAKING NOTES

Use a supporting main ideas strategy to take notes about processes such as cell specialization.

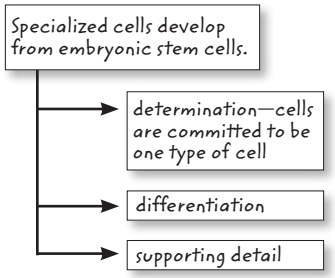
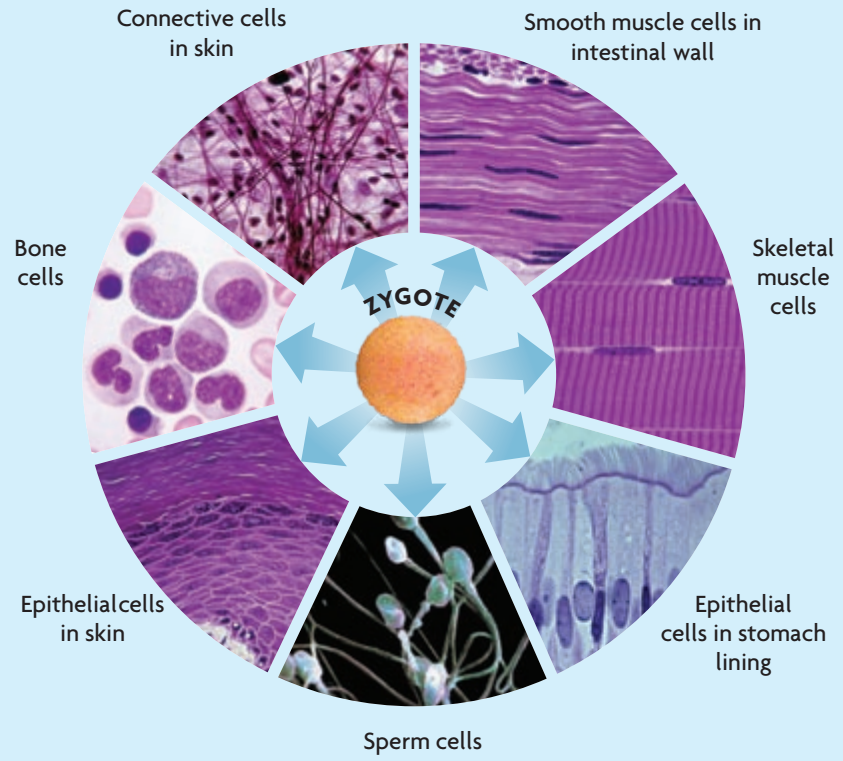


FIGURE 1.2 Cell Differentiation

Cells develop specialized structures and functions during differentiation.



Contrast **How do the structures of sperm cells and epithelial cells in the stomach differ?**

MAIN IDEA

Specialized cells function together in tissues, organs, organ systems, and the whole organism.

Specialized, or differentiated, cells are only the first level of organization in a multicellular organism. Scientists organize multicellular structures into five basic levels, beginning with cells and moving to increasingly complex levels—tissues, organs, organ systems, and the whole organism. These five levels in the human body are shown in **FIGURE 1.3**.

1. **Cells** Each type of specialized cell has a particular structure and a chemical makeup that enable it to perform a specific task. Some cells in the lungs, for instance, are involved in the exchange of gases. Others secrete mucus that helps to trap foreign particles and to protect the lungs from pathogens, such as bacteria and viruses.
2. **Tissues** Groups of similar cells that work together to perform a specialized function are known as **tissues.** The human body is made up of four general types of tissues.
   - Epithelial tissue consists of protective sheets of tightly packed cells connected by special junctions. The skin and the membranes that line the stomach, the lungs, and other organs are epithelial tissues.
   - Connective tissue serves to support, bind together, and protect other tissues and organs. Tendons, ligaments, bone, and cartilage are all connective tissues.
   - Muscle tissue is capable of contracting to produce movement. The human body contains skeletal, cardiac, and smooth muscle tissues.
   - Nervous tissue transmits and receives impulses in response to stimuli, processes information, and regulates the body's response to its environment.
3. **Organs** Different types of tissue that function together form an **organ.** For example, the lungs are organs composed of all four types of tissues. Muscle and connective tissues expand and contract the lungs. Nervous tissue sends and receives messages that help regulate gas exchange in the lungs and the rate at which a person breathes. Epithelial tissue forms the inner lining of the lungs.
4. **Organ systems** Two or more organs working in a coordinated way form an **organ system.** The organ system that allows you to breathe includes not only the lungs but also the sinuses, the nasal passages, the pharynx, and the larynx (the voice box). Organ systems perform the most complex activities in the body.
5. **Organism** Together, the organ systems make up the entire organism. For you or any other organism to stay alive, all of the systems must interact and work together. As a result, anything that harms one organ or organ system will affect the health of the entire body.

CONNECT TO

DIGESTION AND ELIMINATION

In addition to serving as a protective layer, epithelial tissue can absorb materials and secrete special types of fluids. Your ability to digest food and eliminate waste depends in part on the specialized functions of epithelial tissue, as you will learn in **Digestive and Excretory Systems**.

FIGURE 1.3 Five Levels of Organization

All levels of organization interact and work together to maintain the body's health.

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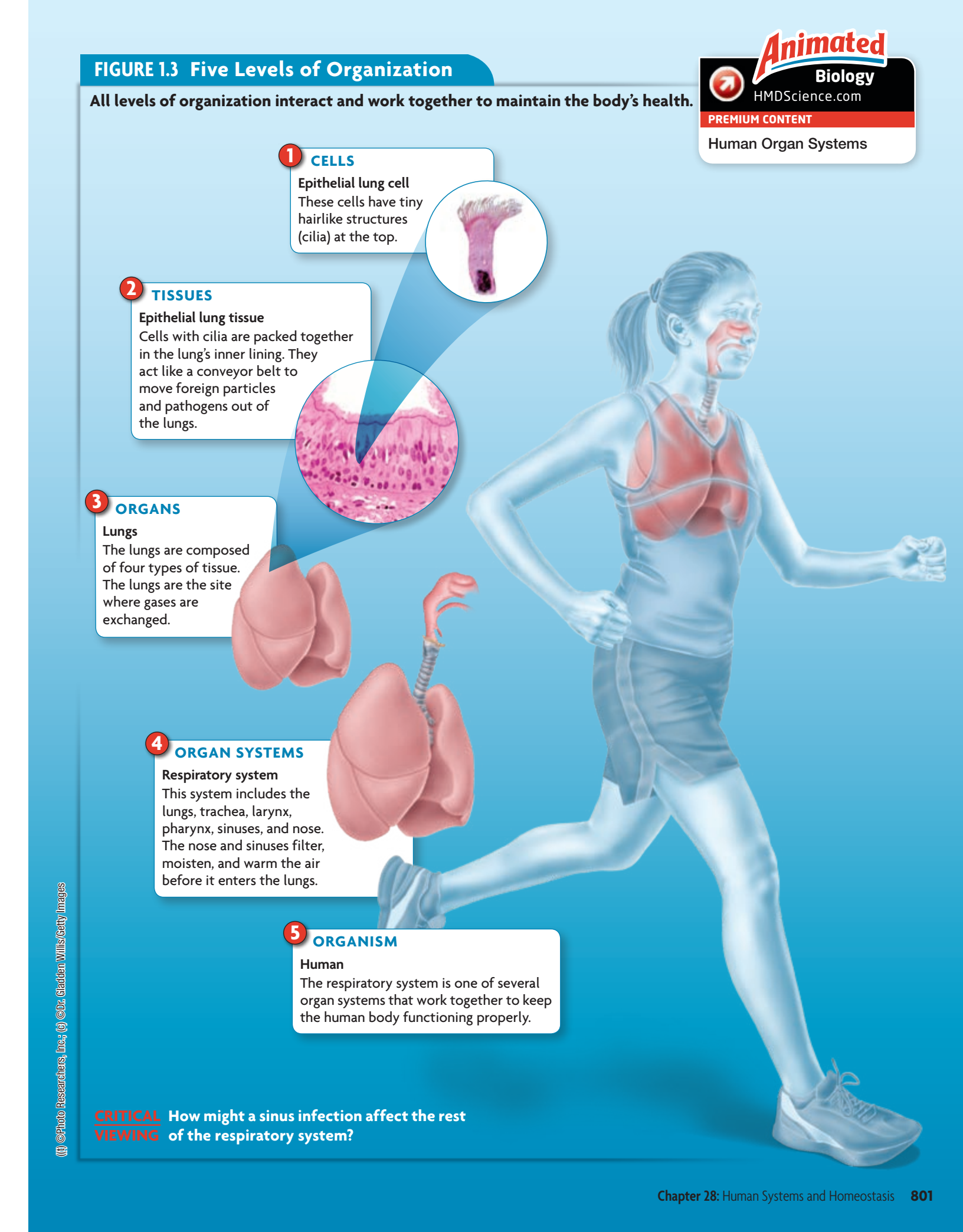
PREMIUM CONTENT
Human Organ Systems



1 CELLS

Epithelial lung cell
These cells have tiny hairlike structures (cilia) at the top.

2 TISSUES

Epithelial lung tissue
Cells with cilia are packed together in the lung's inner lining. They act like a conveyor belt to move foreign particles and pathogens out of the lungs.

3 ORGANS

Lungs
The lungs are composed of four types of tissue. The lungs are the site where gases are exchanged.

4 ORGAN SYSTEMS

Respiratory system
This system includes the lungs, trachea, larynx, pharynx, sinuses, and nose. The nose and sinuses filter, moisten, and warm the air before it enters the lungs.

5 ORGANISM

Human
The respiratory system is one of several organ systems that work together to keep the human body functioning properly.

CRITICAL VIEWING **How might a sinus infection affect the rest of the respiratory system?**

FIGURE 1.4 Major Organ Systems

SYSTEM	MAJOR TISSUES AND ORGANS	PRIMARY FUNCTION
Circulatory	heart, blood vessels, blood, lymph nodes, lymphatic vessels	transports oxygen, nutrients, wastes; helps regulate body temperature; collects fluid lost from blood vessels and returns it to circulatory system
Digestive	mouth, pharynx, esophagus, stomach, small/large intestines, pancreas, gallbladder, liver	breaks down and absorbs nutrients, salts, and water; eliminates some wastes
Endocrine	hypothalamus, pituitary, thyroid, parathyroid, adrenals, pancreas, ovaries, testes	influences growth, development, metabolism; helps maintain homeostasis
Excretory	skin, lungs, kidneys, bladder	eliminates waste products; helps maintain homeostasis
Immune	white blood cells, thymus, spleen	protects against disease; stores and generates white blood cells
Integumentary	skin, hair, nails, sweat and oil glands	acts as a barrier against infection, injury, UV radiation; helps regulate body temperature
Muscular	skeletal, smooth, and cardiac muscles	produces voluntary and involuntary movements; helps to circulate blood and move food through digestive system
Nervous	brain, spinal cord, peripheral nerves	regulates body's response to changes in internal and external environment; processes information
Reproductive	*male:* testes, penis, associated ducts and glands *female:* ovaries, fallopian tubes, uterus, vagina	produces reproductive cells; in females, provides environment for embryo
Respiratory	nose, sinuses, pharynx, larynx, trachea, lungs	brings in O_2 for cells; expels CO_2 and water vapor
Skeletal	bones, cartilage, ligaments, tendons	supports and protects vital organs; allows movement; stores minerals; serves as the site for red blood cell production

The major organ systems in the human body, including their main parts and primary functions, are listed in **FIGURE 1.4.** Keep in mind that all of the organs in these systems developed from specialized cells and tissues that arose from a single cell, the zygote. The major parts and functions of each organ system are examined in greater detail in the following chapters on human body systems.

How do these complex organs and organ systems keep functioning and working together properly? As you will read in Section 2, the body has sophisticated mechanisms for maintaining a stable internal environment.

Compare and Contrast **How do tissues differ from organs and organ systems?**

28.1 Formative Assessment

REVIEWING ▶ MAIN IDEAS

1. How does the process of cell **determination** differ from the process of cell **differentiation**?
2. Briefly define and give an example of each of the five levels of organization in multicellular organisms.

CRITICAL THINKING

3. **Apply** What **organ systems** must work together to bring oxygen to the body's cells?
4. **Predict** A cell has undergone determination to become an endocrine gland cell. If it is transplanted to a leg muscle, what do you think will happen to this cell?

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PREMIUM CONTENT

CONNECT TO

CELL CYCLE

5. In the spring, tadpoles lose their tails as part of their life cycle. At a certain stage in development, the human fetus acquires individual fingers and toes. What occurs in some cells of both species to explain these changes?