Teacher Tune-up

Quick Content Refresher for Busy Professionals

How are the trillions of cells in the human body able to cooperate?

In a multicellular organism, the cells all help each other out in a cooperative community. But how? If you pick two cells in your body at random (say, a muscle cell in your shoulder and an epithelial cell in the lining of your stomach), it might be hard to see an obvious connection between them. It's much easier to see how the cells in your body help each other if you look at the steps of the hierarchy through which they cooperate: cell, tissue, organ, system, organism.

Exploring the Hierarchy from Cell to Organism

Cells

A unicellular organism (like a yeast cell, an amoeba, or a paramecium) performs all the basic functions it needs to live. The cells in multicellular organisms, on the other hand, divide up the tasks necessary for the organism to live. The trillions of cells in a human body can be sorted into about 200 kinds. The different types of human cells make different contributions for the benefit of the whole organism. And these highly specialized cells all receive support from each other, to make up for the things they can't do for themselves. They live through a cooperative division of labor.

Tissues

Groups of cells join together to form tissues that perform particular functions. Tissues consist of similar cells and the materials that surround them (their so-called extracellular matrix, generally produced by the cells themselves). There are lots of different tissues in the human body, and they fall into four main categories.

Epithelial tissues form a sheet that covers and protects all of the cells beneath them. Examples of epithelial tissues include the epidermis (the top layer of the skin) and the inner linings of hollow organs, like the bladder, uterus, or air sacs of lungs, as well as blood vessels.

Connective tissues join, support, or protect various parts of the body, and sometimes store resources for later use. Examples of connective tissues include bone (which is made of bone cells and the hard, calcium-rich material those cells produce); ligaments that link bones together; most of the dermis (the layer of skin lying just below the surface epithelial layer); and fat tissue, which protects and insulates various structures and also stores energy for later use.

Muscle tissues move things. For example, skeletal muscle moves bones in relation to each other, as when we walk; or sometimes skeletal muscle moves skin in relation to bone, as when we smile. Smooth muscle tissue moves things inside the body, as when food gets swallowed or moved through the digestive system. Cardiac muscle makes the heart beat, pumping blood throughout the body.

Nerve tissues carry electrical signals from place to place, allowing information processing, communication, and control. Nerve tissues are found in the brain and spinal cord, and in nerves that run like electrical wiring throughout the body.

Organs

Tissues are the building blocks for organs, which are complex structures that each do one or more jobs for the body. Some organs, such as the skeletal muscles or the brain, are mostly solid. Others, such as the stomach or the intestines, are hollow. Most are hidden inside the body, but the largest organ is the skin.

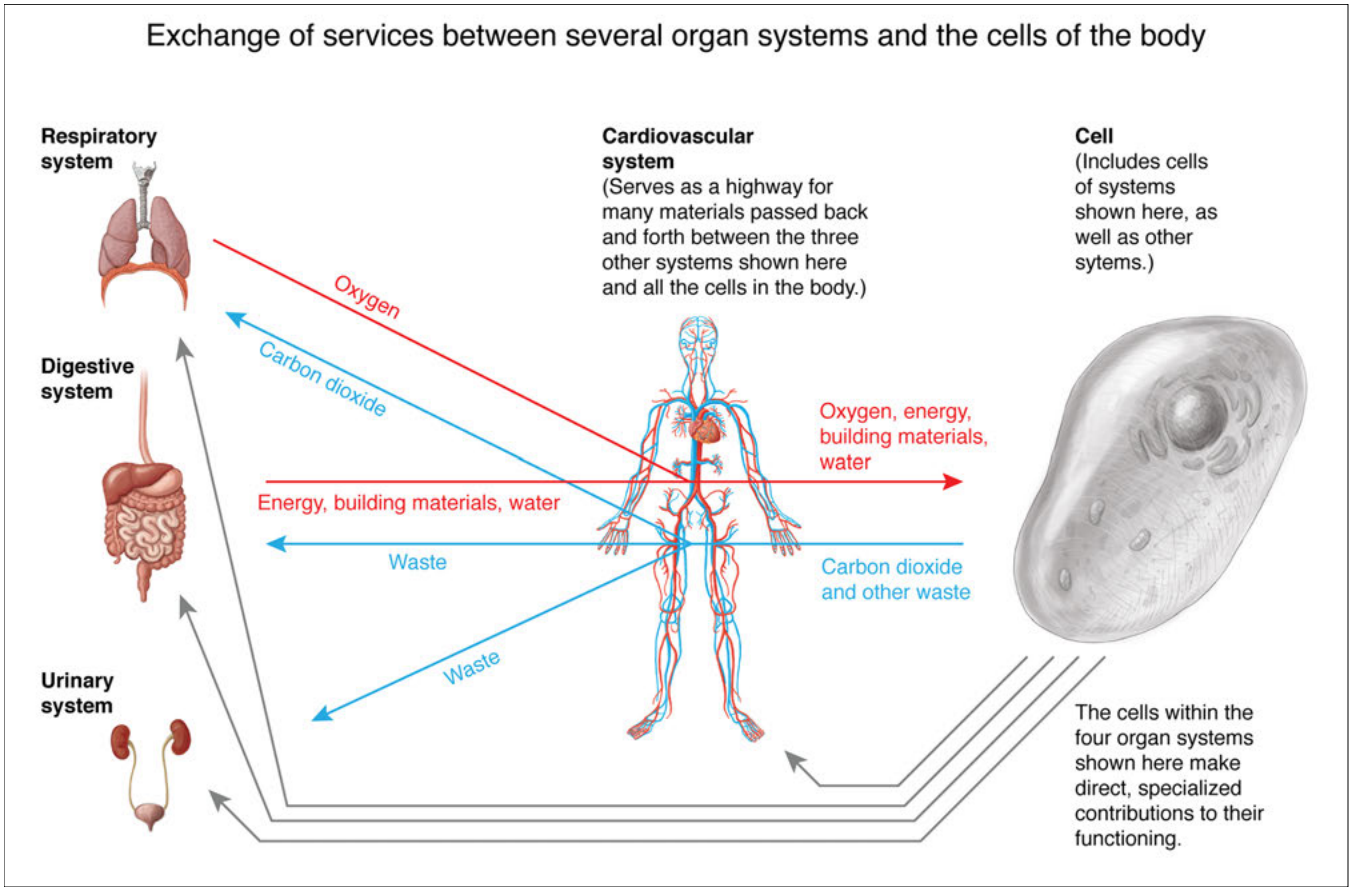
Each organ does specialized work—the skin keeps water in and germs out; the various skeletal muscles move body parts; the brain processes information and sends conscious and unconscious signals to other organs; the stomach breaks down food; the small intestine pulls nutrients out of digested food; the lungs bring in oxygen and get rid of carbon dioxide; and so on.

As an example of how different tissues combine to form an organ, consider the heart. The job of the heart is to pump blood through the blood vessels that go everywhere in the body. The heart has an outer layer of connective tissue that protects it (and stores extra energy for emergency use in the form of fatty tissue). Next comes a thick layer of cardiac muscle, which does the work of making the heart pump blood throughout the body. The inner lining of the heart wall is made of epithelial tissue; it provides a smooth surface to let blood flow freely through the heart. In addition to this three-layered wall, the heart includes nerve tissue that regulates its beating, and epithelial tissue in the blood vessels that serve the heart (because the heart needs oxygen, just like all the other organs in the body).

Systems

Tissues and organs work together in related groups called systems. The specific jobs done by the different organs within a system add up to a more general service that a system performs for an organism.

The following graphic suggests just a few of the ways that cells cooperate through organ systems.



There can be a lot of variation and overlap in the way experts talk about organ systems. You can use the term "muscular system" to mean not only skeletal muscles but also cardiac and smooth muscles. At the same time, you can understand that the heart and the smooth muscle that help control blood vessel diameter are part of the cardiovascular system, and the digestive system includes lots of smooth muscle, and the respiratory system includes the diaphragm. You can also talk separately about the muscular system (which you might think of as including all three kinds of muscle tissue) and the skeletal system, and then combine them into musculoskeletal system—with the qualification that, now that you've combined them, you're no longer including the smooth and cardiac muscle tissue (a taxonomical twist that seems to defy conservation of matter!). All this complexity makes it hard to break things into neat categories, but for working scientists and doctors this is probably one of those places where, as Emerson said, "a foolish consistency is the hobgoblin of little minds."

All of the body's systems are so interconnected that they often overlap, not just in the examples we're dealing with here, but others as well. Nature does not give a hoot about our system models; they are models for our convenience, and they may serve us best when we don't insist on them too blindly. Textbooks and experts will provide different organ systems taxonomies, depending on context and purpose; but "different" does not necessarily mean "conflicting" in this case.

In SciGen's student materials, we have identified and illustrated eleven systems.

The **integumentary system** includes skin, sweat glands, hair, and fingernails. It protects the body from the outside world and keeps moisture inside. It also helps regulate body temperature, and contains sense receptors for temperature, pain, and touch.

The **skeletal system** includes bones, cartilage, and the ligaments and tendons of the joints. It provides shape, support, and protection to the body, while allowing it to move. Blood cells are also produced in the marrow of bones.

The **muscular system,** for our purpose, includes skeletal muscles, which are attached to bones and move the body around. (We take smooth muscle tissue and cardiac muscle tissue to be parts of other systems.) The muscular system also generates heat (either in the ordinary course of moving around, or, in extreme cases, by shivering).

The **nervous system** includes the brain, spinal chord, and nerves. It controls and coordinates body functions. The nervous system receives signals, processes information, and transmits responses to organs.

The **endocrine system** consists of various glands throughout the body, including the pituitary, adrenal, and thyroid glands; and also ovaries in women and testes in men. It regulates and controls growth, development, and various body functions by releasing chemical signals called hormones into the bloodstream.

The **cardiovascular system** is made up of the heart, blood vessels, and blood. It delivers oxygen and nutrients to cells throughout the body. It also carries waste materials away from all the cells. It serves as the main distribution system for all sorts of chemical signals, and for white blood cells that travel around the body fighting infectious diseases. The cardiovascular system also helps regulate body temperature, by controlling how much blood flows near the body's surface at different times.

The **lymphatic system** includes lymph vessels, lymph nodes, tonsils, thymus, and spleen. It takes fluid that has leaked out of blood vessels and returns it to the cardiovascular system. As this lymph fluid filters through the system, white blood cells also check it for signs of infection, and manage the body's immune response to disease. (Sometimes scientists identify the immune system as a separate system.)

The **respiratory system** includes the nose, larynx, trachea, bronchi, lungs, and diaphragm (the muscle that works the lungs). This system inhales oxygen and allows it to be dissolved into the bloodstream. It also

removes carbon dioxide from the bloodstream and exhales it.

The **digestive system** is made up of the mouth, esophagus, stomach, liver, small intestines, large intestines, rectum, and anus. It breaks down food, absorbs its useful substances, and gets rid of the waste. The useful substances—or nutrients—are used by cells throughout the body for energy and building materials.

The **urinary system** includes the kidneys, ureters, bladder, and urethra. It removes excess fluid and many dissolved waste products from the body.

The **reproductive system** includes the vagina, uterus, and ovaries, or the penis and testes. It brings together specialized sex cells from parents, each with a half complement of chromosomes, to form a single fertilized egg cell, a zygote, a zygote whose daughter cells will differentiate and eventually develop into a whole complex organism with all the cells, tissues, organs, and organ systems that entails.

Look Out! Possible Student Misconceptions

When students hear that cells are specialized for certain tasks, they often forget that individual cells still do many of the things that unicellular organisms do: they carry instructions to function and reproduce; they use energy; they take materials in; and they produce waste. Students sometimes confuse these basic functions of a cell with basic functions of the body. For example, just because some of the cells of the urinary or digestive system are specialized to process waste for the body, students sometimes believe that they are the only cells that make waste. Not true: all cells make waste, some of which gets removed from individual cells, but the urinary system and digestive systems are the systems of cells responsible for removing all the waste out of the body. Cells of the reproductive system are involved with creating new organisms, but individual cells are capable—at some point in their lives—of dividing and reproducing, no matter what system they are a part of. Helping students differentiate between the functions of a cell and of an organism can assist in navigating this potential misconception.