



Cell Biology

Cells are the basic units of life, the microscopic building blocks from which the human body as well as those of animals, insects, and plants are constructed. All cells share some common features, such as an outer membrane that controls what can enter or leave, but there are also vast differences.

Animal cells

Every adult body contains more than 10 trillion cells, microscopic structures averaging only a hundredth of a millimeter in diameter. No one cell is capable of surviving on its own outside the body unless it is cultured (artificially bred) in special conditions, but when grouped together into tissues, organs, and systems of the body, cells work together in harmony to sustain life.

Body cells vary greatly in shape, size, and detailed structure according to the jobs they have to do. Muscle cells, for example, are long and thin and contain fibers that can contract and relax, thus allowing the body to move. Many nerve cells are also long and thin but are designed to transmit electrical impulses that compose nerve messages. The hexagonal cells of the liver are equipped to carry out a multitude of vital chemical processes. Disk-shaped red blood cells transport oxygen and carbon dioxide around the body, while spherical cells in the pancreas make and replace the hormone insulin.

Structure

Despite these variations, all body cells are constructed according to the same basic pattern. Around the outside of every cell is a boundary wall, or cell membrane, enclosing a jellylike substance, the cytoplasm. Embedded in this is the nucleus, which houses genetic instructions in the form of chromosomes. These chromosomes are essential to the creation and maintenance of human life and personal characteristics.

The cytoplasm, although between 70 and 85 percent water, is far from inactive. Many chemical reactions take place between substances dissolved in this water, and the cytoplasm also contains many tiny structures called organelles, each with an important and specific task.

The cell membrane also has a definite structure, that of a lipid bilayer. Lipid molecules have an ionic head and a hydrocarbon tail. In the bilayer the molecules are tail-to-tail so that the ionic heads are in contact with water on both sides. Protein molecules are embedded at different locations in the bilayer. Some act as channels through which ions and small molecules can flow. Others bind chemical messenger molecules to initiate action within the cell. Some cells have

hairlike projections called cilia on their membranes that move in unison to waft substances along in a particular direction.

The cytoplasm of all cells contains micro-scopic sausage-shaped organs called mitochondria, which convert oxygen and nutrients into the energy needed for all the other actions of the cells. These "powerhouses" work through the action of enzymes—complex proteins that speed up chemical reactions in the cell and are most numerous in the muscle cells, which need an enormous amount of energy to carry out their work.

Lysosomes—another type of microscopic organ in the cytoplasm—are tiny sacs filled with enzymes that make it possible for the cell to use the nutrients with which it is supplied. The liver cells contain the greatest number. Substances made by a cell that are needed in other parts of the body, such as hormones, are first packaged and then stored in further minute organs called the Golgi apparatus.

Many cells possess a whole network of tiny tubes that are thought to act as a kind of internal cell "skeleton," but all cells contain a system of channels called the endoplasmic reticulum. Dotted along the reticulum are tiny spherical structures called ribosomes, responsible for controlling the construction of essential proteins needed by all cells. The proteins are required for structural repairs and, in the form of enzymes, for cell chemistry and the manufacture of molecules such as hormones, to regulate bodily functions.

Plant cells

Plant cells are very similar to animal cells but contain an extra number of specialized components. Unlike animals, plants do not have a hard skeleton to support them, so their cell walls are tougher than animal cells to help give them rigidity. This strengthening is achieved by regular arrangements of cellulose fibers laid in a matrix of polysaccharides.

Inside the cell, much of the space is filled with vacuoles. Vacuoles are very large single-membrane vesicles that can occupy as much as 90 percent of the cell volume. Some are filled with sap and exert pressure on the cell wall to keep it rigid. Others are the location for intracellular digestion, and contain a variety of hydrolytic enzymes to breakdown macromolecules in the sap. Storage of nutrients and waste materials also occurs in vacuoles. Proteins are often stored in the vacuoles of seeds as a food supply during germination. Rubber is another substance stored in vacuoles, as are pigments in petals, scents to attract insects, and noxious chemicals to deter predators.

Chloroplasts are double-membrane organelles found in all higher plants. They are similar to mitochondria but are much bigger and have three separate internal compartments. It is in these organelles that the energy from sunlight is converted for use in driving metabolic reactions within the cell. This process is called photosynthesis and is unique to plant cells. Chloroplasts contain a pigment called chlorophyll, which gives plants their typical green color.

Chromosomes

Each cell nucleus is packed with information coded in the form of molecules of deoxyribonucleic acid (DNA) and organized into groups called genes, which are arranged on threadlike structures, the chromosomes. Every chromosome contains thousands of genes, each with enough

information for the production of one protein. This protein may have a small effect within the cell and on the appearance of a plant or animal, but equally it may make all the difference between a person having brown or blue eyes, straight or curly hair, or normal or albino skin. Genes are responsible for every physical characteristic.

In humans, apart from mature red blood cells, which lose their chromosomes in the final stages of their formation, and the eggs and sperm (the sex cells), which contain half the usual number of chromosomes, every body cell contains 46 chromosomes arranged in 23 pairs. One of each pair comes from the mother and one from the father. The eggs and sperm have only half that number so that, when an egg is fertilized by a sperm, the new individual is assured of having the correct number.

At the moment of fertilization, the genes start issuing instructions for the molding of a new human being. The father's chromosomes are responsible for sex determination. The chromosomes are called X or Y, depending on their shape. In women, both the chromosomes in the pair are X, but in men, there is one X and one Y. If an X-containing sperm fertilizes the X egg, the baby will be a girl, but if a Y sperm fertilizes the egg, then the baby will be a boy.

Cell division

As well as being packed with information, the DNA of the chromosomes also has the ability to reproduce itself. Without this ability, the cells could not duplicate themselves, nor could they pass on information from one generation to another.

The process of cell division in which the cell duplicates itself is called mitosis. This type of division takes place when a fertilized egg grows first into a baby and then into an adult and when worn out cells are replaced.

When the cell is not dividing, the chromosomes are not visible in the nucleus. When the cell is about to divide the chromosomes become shorter and thicker and can be seen to split in half along their length. These double chromosomes then pull apart and their members move to opposite ends of the cell. Finally, the cytoplasm is halved and new walls form around the two new cells, each of which has the normal number of 46 chromosomes.

Cell communication

Multicellular organisms are made up of many different kinds of cells working together. In order to achieve this the cells must be able to communicate. In animals, cells communicate by releasing chemical messengers, including hormones that travel through the bloodstream to distant targets and neurotransmitters, which nerve cells use to signal adjacent cells. When these messenger molecules reach a target cell, they usually attach to a receptor, a protein that is part of the cell membrane.

This receptor extends through the membrane. The part exposed on the outside has a structure that exactly fits the shape of one particular messenger molecule; inside the cell, it has a structure that is able to interact with chemicals called effectors. Some receptors cross the membrane only once and are described as single transmembrane domain receptors. Others

have as many as seven transmembrane domains. When a messenger molecule binds to the outer part of the receptor, it can change the shape of the entire receptor, including the inner structure. The inner structure then reacts with an effector, often an enzyme, that converts another molecule into a second messenger, which diffuses through the interior of the cell, triggering further reactions. Other receptors transmit their message across the membrane by transporting the messenger molecule itself through the membrane and releasing it inside.

Still other receptors form a channel that can be opened and closed when a messenger binds to the receptor, allowing other molecules to flow into the cell. These receptors are called ion channels and are found in nearly all cells. Ion channels are responsible for generating the electrical currents that carry signals along nerve fibers. These channels open in response to a neurotransmitter molecule released by an adjacent neuron, or nerve cell, allowing sodium and potassium to pass through the channel, generating an electrical signal. In sensory organs, ion channels translate physical or chemical stimuli into electrical signals for the nervous system.

Biological roles of nitric oxide

Most of the body's functions are regulated by large, complex proteins and compounds. However, nitric oxide, a simple gas that is noxious, has been discovered to be an extremely important messenger molecule.

Regulation of blood pressure is a balance between dilation (opening) and constriction (tightening) of blood vessels. Blood vessels are dilated by neurotransmitters such as acetylcholine that cause the muscle layer of the vessels to relax. Other neurotransmitters, such as norepinephrine, contract the muscle and constrict blood vessels. Because norepinephrine receptors are present on muscle cells, most scientists assumed the cells would also bear receptors for acetylcholine. It was found that acetylcholine acts not on muscle cells but on receptors located on the adjacent endothelial cells that line the blood vessel, releasing a small molecule that diffuses to the muscle layer to relax it. This small molecule was known as endothelium-derived relaxing factor, or EDRF until, in 1987, Salvador Moncada, a scientist at Wellcome Research Labs in England, demonstrated that EDRF is identical to nitric oxide. Nitric oxide is now believed to be the principal regulator of blood pressure.

Nitric oxide appears to play another major role in the brain. Glutamate, a neurotransmitter that is active at more sites in the brain than any other, is now believed to excite cells by a process that uses nitric oxide. The next dramatic observation was that nitric oxide synthase, an enzyme that generates nitric oxide from the amino acid arginine, is found mainly in neurons—specifically in diaphorase neurons, which make up about 2 percent of the cerebral cortex. The reason this distribution is so interesting is that these neurons alone resist the degeneration associated with several diseases. In Huntington's disease, up to 95 percent of neurons in an area called the caudate nucleus degenerate, but virtually no diaphorase neurons are lost. In vascular strokes and in some brain regions involved in Alzheimer's disease, diaphorase neurons are similarly resistant. Knowing how diaphorase neurons resist degeneration might provide treatments for these diseases.

It is believed that the neurons that make nitric oxide release it, and because of its toxicity, it is capable of killing adjacent neurons. However, the cells producing the nitric oxide may have intrinsic defense mechanisms protecting themselves against damage. Bernard Scatton and his colleagues at Synthelabo in Paris found that by injecting small doses of a nitric oxide synthase

inhibitor into mice immediately after initiating a stroke, stroke damage was reduced by 73 percent.

Another unrelated activity of nitric oxide is as one of the major weapons of the white blood cells of the immune system, which use its toxic nature to kill bacteria, fungi, and tumor cells. It is also capable of inhibiting blood clotting by preventing the clumping of platelets.

For an apparently noxious compound, nitric oxide is involved in an impressive array of activities. Carbon monoxide, familiar as a toxic gas in car exhaust, is also thought to have some signaling role in a number of brain regions.

Growing new cells

Perhaps the most excitement in the field of cell research in the late 1990s has been the cultivation of embryonic stem cells in the laboratory. Stem cells are the parent cells of all body tissues, and this discovery may one day lead to replacement materials such as heart muscle, bone marrow, and brain tissue being grown to treat a wide range of human diseases.

The technique has been developed by two teams of researchers at Johns Hopkins University and the University of Wisconsin-Madison. The cells were taken from fetal material and human blastocysts left over from in-vitro fertilization and grown over a "feeder" layer of mouse cells. The cells were able to differentiate into the primary germ lines that make up body-tissue types—endoderm, ectoderm, and mesoderm—which then go on to develop into bone, muscle, neural, cartilage, and gut cells. As yet, this further development into specific types of cell is difficult to achieve in the laboratory.

Being able to grow different types of cells would open up a number of possibilities for medical treatment. Illnesses such as Parkinson's disease or juvenile diabetes that occur because of defects in a particular type of cell could be treated by replacing faulty cells with healthy ones. Another application could be in developing drugs. Being able to measure the response time of specific cells would improve the testing of new drugs by allowing the rapid screening of thousands of chemicals. Scientists also hope to make discoveries about the early stages of development of human embryos, discoveries that could be significant in preventing infertility, miscarriages, and birth defects.

See also: [BLOOD](#); [BOTANY](#); [EMBRYOLOGY](#); [GENETIC ENGINEERING](#); [GENETICS](#); [HORMONE](#); [LIFE](#); [MOLECULAR BIOLOGY](#).

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