I. Skeletal System

The skeletal system is the body's framework. It is made of bones, joints, and cartilage. An organism's skeleton stores minerals, makes blood cells, and protects organs.

There are three types of skeletons:

- The hydrostatic skeleton, found in earthworms, is a support system consisting of a body compartment filled with fluid under pressure. There are no bones. Either contractile cells or muscles surround the fluid-filled compartment. When contraction occurs, the compartment elongates and the animal moves forward.
- An exoskeleton is a hard covering on the outside of the body composed of molecules called chitin. Arthropods such as crabs and spiders have exoskeletons. To grow larger, the arthropod must shed its exoskeleton and then replace it with a larger one.
- An endoskeleton, found in vertebrates such as mammals, fishes, and birds, is made of bone and cartilage located inside the body. This hard internal skeleton facilitates movement, provides support, and stores minerals such as calcium. You have 206 bones in your body. Feel the back of your neck. Did you know that nearly all mammals have seven vertebrae in their necks? Necks vary in length, shape, and flexibility because the alignment of bones and cartilage are different in different mammals. These variations enable a giraffe to nibble treetops and a person to look out a window.

II. Muscular System

When muscles work with bones, they move parts of the body including hands, fingers, legs, neck, and head. Muscles in internal organs move substances in the organs.

All muscles can contract to shorten and relax to lengthen. They are in locations where a contraction can cause movement. Movement takes place because muscles are attached to parts of the skeleton. When the attached muscles shorten, they move the corresponding body part. As muscles contract, they use energy to do work and generate heat. Because of this, you may feel warm when you run, stamp your feet, or shiver. Muscle contraction is the main source of heat to maintain body temperature and homeostasis.

- The type of muscles in your legs and other parts of your body are called skeletal muscle. They are sometimes called voluntary muscles because they are under your conscious control. Skeletal muscle is composed of cells that create a striated (striped) pattern when viewed under a microscope.
- Many of your internal organs contain smooth muscles. These are called involuntary muscles because they are not under conscious control. They regulate the width of blood vessels and the contractions of your digestive system. Smooth muscle is not striated.
- Cardiac muscle is found only in your heart. It is striated and is under involuntary control. Cardiac muscle contracts and relaxes throughout your life to pump blood through your vessels.

III. Integumentary System

The integumentary system includes skin, hair, nails, and the glands in the skin. This system forms a waterproof protective barrier separating the body's internal environment from the external environment.

- The epidermis is the skin's outer layer. This skin layer is 10 to 30 cells thick—about as thick as this page. The epidermis is covered with tiny openings called pores. Sweat and oils secreted by the skin leave the body through pores.
- The thickest layer of the skin is the dermis. The cells of the dermis make collagen, a protein that makes skin flexible and strong.
- Collagen forms the ridges on your fingertips that make your fingerprints. It also forms ridges on the palms of your hands. Your toes, and the soles of your feet. The ridges act as nonskid treads for your hands and feet.

Skin cancer is a disease that results from the abnormal growth of skin cells. It is often associated with exposure to the sun and may appear as lumps, sores that do not heal, or unusual moles. Frequent baths or showers help to keep skin healthy and eating a balanced diet is important for maintaining healthy skin.

- Many substances in the skin help maintain the environment from the external environment.

The digestive system obtains food, breaks it down, and absorbs nutrients. Any unused food molecules get eliminated from the body. The digestive system includes the mouth, esophagus, stomach, intestines, liver, gallbladder, and pancreas.

During digestion three activities take place to extract nutrients from foods:

- mechanical digestion, which breaks food into tiny pieces without changing its chemical structure
- chemical digestion, which breaks food down into smaller, simpler molecules—nutrients
- absorption, which occurs when these nutrients are taken into the body's cells.

In the mouth chewing starts mechanical digestion, and saliva begins the breakdown of starches to sugars. As you swallow, a small flap of tissue called the epiglottis closes the trachea and the entrance to your respiratory tract. This ensures that food enters the esophagus and moves towards the stomach where mechanical digestion continues as your food churns and chemical digestion continues with the breakdown of proteins by the enzyme pepsin.

After about three hours the food is reduced to a soft pulp called chyme made of acids, partially digested proteins and carbohydrates, and undigested fats. The stomach valve opens and sends the chyme to the small intestine where the digestion of carbohydrates and proteins is completed, fats are digested, and nutrients are absorbed. Tiny finger-like projections called villi line the internal surface of the small intestine increasing its surface area and making absorption more efficient. In the colon, or large intestine, water and water-soluble vitamins are absorbed from undigested material and redistributed to the rest of your body. When most of the water is removed, a solid waste matter, called feces moves through the rectum and out of the body through the anus.
### V. Excretory System

The excretory system removes wastes from the body. It includes the kidneys and the bladder. The skin, lungs and liver are sometimes considered part of the excretory system.

- The kidneys are located at the bottom of the rib cage near the backside of the body. Blood enters the kidneys from vessels that branch from the aorta, the body's largest blood vessel. The kidneys remove wastes from the blood and process them into a yellow liquid called urine.
- The kidneys control the amount of salts, water, and vitamins in the blood, and regulate the pH and volume of the blood in the body. At any given time, up to 25 percent of the body’s blood may be in the kidneys.
- The functional unit of the kidney is called the **nephron**.
  - **Filtration** causes water, salt, glucose, and amino acids to be filtered out of the blood and into urea to form a filtrate that can exit the body. Proteins and blood cells remain in the blood.
  - **Reabsorption** allows water and nutrients to be reabsorbed into the blood and waste to remain.
  - **Secretion** allows wastes, such as urea toxins, vitamins, and some medications, such as penicillin to be removed from the blood.
- Urine produced by each kidney flows into a long thin tube called a ureter to the bladder. The bladder has a tube, the urethra that opens to outside the body.

### VI. Respiratory System

The respiratory system is made of a network of breathing passages and the lungs. These organs take in oxygen from the air for cellular respiration and release carbon dioxide.

- All animals depend on cellular respiration for energy to survive. In cellular respiration food molecules are broken down to make **ATP**. The most efficient form of cellular respiration is aerobic and requires oxygen and produces carbon dioxide. Animals obtain oxygen from the environment and then expel carbon dioxide. This gas exchange takes place in the respiratory system.
- The respiratory system provides surfaces where oxygen and carbon dioxide diffuse across cell membranes. These tissues are moist because oxygen and carbon dioxide must be dissolved in water before they can efficiently diffuse across cell membranes.
- First, air passes over the mucous membrane of the nasal cavity and is moistened, warmed, and filtered. Next air travels through the pharynx (throat) to the epiglottis, then down to the larynx (voice box), and then to the trachea (windpipe) leading to the lungs. The trachea divides into two tubes called bronchi that branch into bronchioles. At the end of the bronchioles are bunches of alveoli, or air sacs. Most of the gas exchange occurring between the circulatory and respiratory systems takes place at the alveoli.
- Most of the oxygen needed by the body is bound to a protein in red blood cells called hemoglobin. Breathing is regulated by the amount of carbon dioxide in your blood. Carbon dioxide in the blood forms carbonic acid which changes the blood’s pH. As the pH drops it signals your body to breathe more. During inhalation the diaphragm (a sheet of muscle below the lungs) contracts and moves down. During exhalation the diaphragm relaxes and moves up.

### VII. Circulatory System

The circulatory system transports essential substances such as **O₂**, **CO₂**, nutrients, wastes, and hormones throughout the body. This system includes the heart, the network of blood vessels, and blood.

- You have a closed circulatory system through which blood travels.
  - **Arteries** carry oxygenated blood away from the heart.
  - **Veins** return oxygen deficient blood to the heart.
  - **Capillaries** are thin blood vessels where gases, nutrients, and wastes are exchanged by cells via diffusion.
- The circulatory system is divided into two parts based on whether blood is being transported between your heart and the lungs or the heart and the rest of your body. Blood is carried to and from your lungs by the **pulmonary circuit**. The systemic circuit takes blood from the heart to the body’s capillaries and back.
- Smoking increases the risk of lung cancer and cardiovascular disease. Nicotine in tobacco raises the heart rate and narrows arteries. Smoking lowers the efficiency of the respiratory organs. Consequently, the heart must pump faster to deliver oxygen to the body’s cells.

### VIII. Immune System

The immune system defends the body against infectious agents and mutant cells. This system includes bone marrow and white blood cells, and organs such as lymph nodes.

- The body’s first line of defense against pathogens is nonspecific and includes the skin and mucus membranes. The second line of defense is the inflammatory response. The third defense is a specific response that targets specific pathogens (a virus or organism that causes an infectious disease) and can be either humoral, creating antibodies that target infected cells for death, or cell-mediated, creating cytotoxic T-cells that rupture infected cells.
- While blood cells or leukocytes are cells of the immune system that originate in the bone marrow. Some mature in the bone marrow while others migrate and develop in the thymus. Most white blood cells circulate in the blood, while others are stored in the lymphatic system. When an invasion is detected, leukocytes gather at the infection site.
- Different types of white blood cells are involved in nonspecific and specific responses.
  - **Phagocytes** engulf and digest unwanted cells and pathogens in a nonspecific manner.
  - **Macrophages** are the largest phagocytes; each one can engulf hundreds of bacterial cells.
  - **Lymphocytes** are involved in the body’s specific defense as some secrete antibodies that are specific to different pathogens and others recognize and destroy body cells that have been infected by specific pathogens.
- Autoimmune diseases result when the body’s immune system fails to differentiate between pathogens and its own cells, attacking the body’s own tissues. Allergies occur when your immune system mounts a response to a normally harmless substance such as pollen.
The lymphatic system returns fluid from spaces between cells to the circulatory system. It also filters bacteria and particles out of the fluid. This system is made of a network of vessels and lymph nodes, as well as organs such as the spleen, tonsils, and appendix.

Lymph capillaries entwine with blood capillaries, absorbing intercellular fluid, called lymph, that leaks from blood capillaries. The fluid is then moved into larger lymph vessels and is filtered through densely packed areas called lymph nodes. Eventually lymph is put back into the blood. The lymphatic system plays a critical role in the immune system by producing and circulating white blood cells. White blood cells are stored in lymph nodes and can attack pathogens. Your lymph nodes swell and become sore when you are sick because of the large number of white blood cells your body is producing. The tonsils, located in the back of your mouth, filter and destroy bacteria. The thymus produces hormones that play a role in white blood cell maturation. The spleen removes worn-out red blood cells, platelets, bacteria, and other particles from the blood. The spleen also stores some of the components of red blood cells, such as iron. Finally, the lymphatic system returns fluid to the circulatory system helping keep the cells moist.

The endocrine system secretes chemicals called hormones. Hormones control body processes that take place over longer periods of time such as growth. This system includes the thyroid, the pituitary, and the adrenal glands.

The endocrine system controls the body by means of chemical messengers called hormones. Hormones are typically produced in one part of the body and control activities in another part of the body, including growth, development, metabolism, behavior, and reproduction.

- The hypothalamus makes hormones such as ADH (anti-diuretic hormone) that increases water uptake by the kidneys, and oxytocin which stimulates uterine contractions during labor, and controls the pituitary gland which secretes hormones to other endocrine glands.
- The pineal gland secretes melatonin, which controls the response to daylight and seasonal changes.
- The parathyroid gland regulates blood calcium levels and the thyroid gland secretes thyroxine which speeds up metabolism and helps manage growth and development.
- The thymus secretes thymosin which stimulates the development of T cells.
- The pancreas has patches of tissue called the Islets of Langerhans, which have cells that make the hormones insulin and glucagon. Insulin keeps blood sugar levels from rising too high and glucagon stimulates the release of glycogen from the liver to help keep blood sugar levels from falling too low.
- The adrenal glands make epinephrine and norepinephrine, two hormones which cause the “fight or flight” response. They also secrete aldosterone, which affects the body’s osmotic balance, and cortisol, which promotes glucose synthesis.
- Ovaries produce estrogen and progesterone that help maintain the female reproductive system.
- Testes make testosterone that helps maintain the male reproductive system.

People take steroids to “boost” their development by abusing drugs affect their endocrine system. Anabolic steroids stimulate growth of muscles and increase strength and performance. But they eventually cause liver and heart disease. In males testes shrink and female sex characteristics develop. Females stop menstruating and develop male sex characteristics. All of this can lead to an early death.

The reproductive system enables the body to produce offspring. This system includes some endocrine glands as well as the reproductive organs.

Male reproductive organs include the testes which produce sperm and the hormone testosterone. The testes are inside a protective sac called the scrotum. They are located outside the body to keep the sperm slightly cooler than body temperature. Matured sperm are stored in the epididymis. They travel through the vas deferens to the urethra in the penis. Semen consists of sperm cells, fluids made by the seminal vesicles and the prostate gland, and fructose as an energy source for the rapidly moving sperm cells. Female reproductive organs include the ovary that releases eggs and produces the hormones estrogen and progesterone. The egg will travel from the ovaries through the fallopian tube, where the egg is fertilized by the sperm, and then to the uterus, where the fetus will develop. The cervix, a muscle located at the base of the uterus, connects the uterus to the vagina.

The nervous system detects changes in the environment and signals rapid responses. It is also responsible for higher order functions such as memory and emotions. It includes the brain, the spinal cord, and the nerves that transmit the information throughout the body.

The nervous system is divided into two main parts.

- The central nervous system (CNS) is the body’s main control center and consists of the brain and spinal cord. This part processes information and sends instructions to other parts of the body.
- The peripheral nervous system (PNS) is a network of nerves that extend throughout the body. It gathers information from the environment and delivers it to the CNS and it sends messages from the CNS back out to the body.

The nervous system consists of two types of cells, neurons that carry nerve impulses, and glial cells that protect, support and assist the neurons.

The nervous system performs four functions that enable an animal to respond quickly. First, it uses sensors to gather information from inside and outside the body. Then, the PNS transmits the information over a network of specialized nerve cells to processing areas such as the brain in the CNS. Next, the information is processed into possible responses. Finally, information to direct responses is sent back through the network of nerve cells of the PNS to the appropriate part of the animal to affect the response.
The Nervous System:
Neurons send signals to other cells as electrochemical waves travelling along thin fibers called **axons**, which cause chemicals called **neurotransmitters** to be released at junctions called **synapses**. A cell that receives a synaptic signal may be excited, inhibited, or otherwise modulated. Sensory neurons are activated by physical stimuli impinging on them, and send signals that inform the central nervous system of the state of the body and the external environment. Motor neurons, situated either in the central nervous system or in peripheral ganglia, connect the nervous system to muscles or other effector organs. Central neurons, which in vertebrates greatly outnumber the other types, make all of their input and output connections with other neurons. The interactions of all these types of neurons form neural circuits that generate an organism’s perception of the world and determine its behavior. Along with neurons, the nervous system contains other specialized cells called **glial cells** (or simply glia), which provide structural and metabolic support.

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The immune system, which is made up of special cells, proteins, tissues, and organs, defends people against germs and microorganisms every day. In most cases, the immune system does a great job of keeping people healthy and preventing infections. But sometimes problems with the immune system can lead to illness and infection.

About the Immune System The immune system is the body’s defense against infectious organisms and other invaders. Through a series of steps called the immune response, the immune system attacks organisms and substances that invade body systems and cause disease. The immune system is made up of a network of cells, tissues, and organs that work together to protect the body. The cells involved are white blood cells, or leukocytes, which come in two basic types that combine to seek out and destroy disease-causing organisms or substances. Leukocytes are produced or stored in many locations in the body, including the thymus, spleen, and bone marrow. For this reason, they’re called the lymphoid organs. There are also clumps of lymphoid tissue throughout the body, primarily as lymph nodes, that house the leukocytes. The leukocytes circulate through the body between the organs and nodes via lymphatic vessels and blood vessels. In this way, the immune system works in a coordinated manner to monitor the body for germs or substances that might cause problems. The two basic types of leukocytes are: **phagocytes**, cells that chew up invading organisms AND **lymphocytes**, cells that allow the body to remember and recognize previous invaders and help the body destroy them. A number of different cells are considered phagocytes. The most common type is the **neutrophil**, which primarily fights bacteria. If doctors are worried about a bacterial infection, they might order a blood test to see if a patient has an increased number of neutrophils triggered by the infection. Other types of phagocytes have their own jobs to make sure that the body responds appropriately to a specific type of invader. The two kinds of lymphocytes are **B lymphocytes** and **T lymphocytes**. Lymphocytes start out in the bone marrow and either stay there and mature into B cells, or they leave for the thymus gland, where they mature into T cells. B lymphocytes and T lymphocytes have separate functions: B lymphocytes are like the body’s military intelligence system, seeking out their targets and sending defenses to lock onto them. T cells are like the soldiers, destroying the invaders that the intelligence system has identified. Here’s how it works: When antigens (foreign substances that invade the body) are detected, several types of cells work together to recognize them and respond. These cells trigger the B lymphocytes to produce antibodies, specialized proteins that lock onto specific antigens. Once produced, these antibodies continue to exist in a person’s body, so that if the same antigen is presented to the immune system again, the antibodies are already there to do their job. So if someone gets sick with a certain disease, like chickenpox, that person typically doesn’t get sick from it again. This is also how immunizations prevent certain diseases. An immunization introduces the body to an antigen in a way that doesn’t make someone sick, but does allow the body to produce antibodies that will then protect the person from future attack by the germ or substance that produces that particular disease. Although antibodies can recognize an antigen and lock onto it, they are not capable...
of destroying it without help. That's the job of the T cells, which are part of the system that destroys antigens that have been tagged by antibodies or cells that have been infected or somehow changed. (Some T cells are actually called "killer cells.") T cells also are involved in helping signal other cells (like phagocytes) to do their jobs. Antibodies also can neutralize toxins (poisonous or damaging substances) produced by different organisms. Lastly, antibodies can activate a group of proteins called complement that are also part of the immune system. Complement assists in killing bacteria, viruses, or infected cells. All of these specialized cells and parts of the immune system offer the body protection against disease. This protection is called immunity.

**Immunity** Humans have three types of immunity — innate, adaptive, and passive: 

**Innate Immunity:** Everyone is born with innate (or natural) immunity, a type of general protection. Many of the germs that affect other species don't harm us. For example, the viruses that cause leukemia in cats or distemper in dogs don't affect humans. Innate immunity works both ways because some viruses that make humans ill — such as the virus that causes HIV/AIDS — don't make cats or dogs sick. Innate immunity also includes the external barriers of the body, like the skin and mucous membranes (like those that line the nose, throat, and gastrointestinal tract), which are the first line of defense in preventing diseases from entering the body. If this outer defensive wall is broken (as through a cut), the skin attempts to heal the break quickly and special immune cells on the skin attack invading germ. **Adaptive Immunity** The second kind of protection is adaptive (or active) immunity, which develops throughout our lives. Adaptive immunity involves the lymphocytes and develops as people are exposed to diseases or immunized against diseases through vaccination. **Passive Immunity** Passive immunity is "borrowed" from another source and it lasts for a short time. For example, antibodies in a mother's breast milk provide a baby with temporary immunity to diseases the mother has been exposed to. This can help protect the baby against infection during the early years of childhood. Everyone's immune system is different. Some people never seem to get infections, whereas others seem to be sick all the time. As people get older, they usually become immune to more germs as the immune system comes into contact with more and more of them. That's why adults and teens tend to get fewer colds than kids — their bodies have learned to recognize and immediately attack many of the viruses that cause colds.

**Problems of the Immune System** Disorders of the immune system fall into into four main categories: 1. immunodeficiency disorders (primary or acquired) 2. autoimmune disorders (in which the body's own immune system attacks its own tissue as foreign matter) 3. allergic disorders (in which the immune system overreacts in response to an antigen) 4. cancers of the immune system **Immunodeficiency Disorders** Immunodeficiencies occur when a part of the immune system is not present or is not working properly. Sometimes a person is born with an immunodeficiency (known as primary immunodeficiencies), although symptoms of the disorder might not appear until later in life. Immunodeficiencies also can be acquired through infection or produced by drugs (these are sometimes called secondary immunodeficiencies). Immunodeficiencies can affect B lymphocytes, T lymphocytes, or phagocytes. Examples of primary immunodeficiencies that can affect kids and teens are: IgA deficiency is the most common immunodeficiency disorder. IgA is an immunoglobulin that is found primarily in the saliva and other body fluids that help guard the entrances to the body. IgA deficiency is a disorder in which the body doesn't produce enough of the antibody IgA. People with IgA deficiency tend to have allergies or get more colds and other respiratory infections, but the condition is usually not severe. **Severe combined immunodeficiency (SCID)** is also known as the "bubble boy disease" after a Texas boy with SCID who lived in a germ-free plastic bubble. SCID is a serious immune system disorder that occurs because of a lack of both B and T lymphocytes, which makes it almost impossible to fight infections. Acquired (or secondary) immunodeficiencies usually develop after someone has a disease, although they can also be the result of malnutrition, burns, or other medical problems. Certain medicines also can cause problems with the functioning of the immune system. Acquired (secondary) immunodeficiencies include: HIV (human immunodeficiency virus) infection/AIDS (acquired immunodeficiency syndrome) is a disease that slowly and steadily destroys the immune system. It is caused by HIV, a virus that wipes out certain types of lymphocytes called T-helper cells. Without T-helper cells, the immune system is unable to defend the body against normally harmless organisms, which can cause life-threatening infections in people who have AIDS. Newborns can get HIV infection from their mothers while in the uterus, during the birth process, or during breastfeeding. People can get HIV infection by having unprotected sexual intercourse with an infected person or from sharing contaminated needles for drugs, steroids, or tattoos. **Immunodeficiencies caused by medications.** Some medicines suppress the immune system. One of the drawbacks of chemotherapy treatment for cancer, for example, is that it not only attacks cancer cells, but other fast-growing, healthy cells, including those found in the bone marrow and other parts of the immune system. In addition, people with autoimmune disorders or who have had organ transplants may need to take immunosuppressant medications, which also can reduce the immune system's ability to fight infections and can cause secondary immunodeficiency. **Autoimmune Disorders** In autoimmune disorders, the immune system mistakenly attacks the body's healthy organs and tissues as though they were foreign invaders. Autoimmune diseases include: **Lupus,** a chronic disease marked by muscle and joint pain and inflammation (the abnormal immune response also may involve attacks on the kidneys and other organs) **Juvenile rheumatoid arthritis,** a disease in which the body's immune system acts as though certain body parts (such as the joints of the knee, hand, and foot) are foreign tissue and attacks them **Allergic Disorders** Allergic disorders occur when the immune system overreacts to exposure to antigens in the environment. The substances that provoke such attacks are called allergens. The immune response can cause symptoms such as swelling, watery eyes, and sneezing, and even a life-threatening reaction called anaphylaxis. Medications called antihistamines can relieve most symptoms. Allergic disorders include: **Asthma,** a respiratory disorder that can cause breathing problems, frequently involves an allergic response by the lungs. If the lungs are oversensitive to certain allergens (like pollen, molds, animal dander, or dust mites), it can trigger breathing tubes in the lungs to become narrowed, leading to reduced airflow and making it hard for a person to breathe. **Eczema** is an itchy rash also known as atopic dermatitis. Although atopic dermatitis is not necessarily caused by an allergic reaction, it more often occurs in kids and teens who have allergies, hay fever, or asthma or who have a family history of these conditions. Allergies of several types can occur in kids and teens. Environmental allergies (to dust mites, for example), seasonal allergies (such as hay fever), drug allergies (reactions to specific medications or drugs), food allergies (such as to nuts), and allergies to toxins (bee stings, for example) are the common conditions people usually refer to as allergies. **Cancers of the Immune System** Cancer occurs when cells grow out of control. This also can happen with the cells of the immune system. Lymphoma involves the lymphoid tissues and is one of the more common childhood cancers. Leukemia, which involves abnormal overgrowth of leukocytes, is the most common childhood cancer. With current medications most cases of both types of cancer in kids and teens are curable. Although immune system disorders usually can't be prevented, you can help your child's immune system stay stronger and fight illnesses by staying informed about your child's condition and working closely with your doctor.